Morphometric Analysis Related to the Transcondylar Approach in Dry Skulls and Computed Tomography

Análisis Morfométrico del Acesso Transcondilar en Cráneos Secos y en Tomografia Computarizada

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SUMMARY: The transcondylar approach (TA) has been used in surgeries to access lesions in areas close to the foramen magnum (FM) and is performed directly through the occipital condyle (OC) or through the atlanto-occipital joint and adjacent portions of the same. The objective of this study is to examine anatomical variations related to the TA by morphometric parameters of the FM, OC and of the hypoglossal canal (HC) in dry skulls and in computed tomography (CT). In 111 skulls, characteristics of the HC, and measures related to the FM, the HC and to the OC were examined. In CT, the measurements obtained bilaterally in 10 patients who underwent examination of the skull base in 1 mm-thick axial helical cuts were the distances from the outer half of the clivus to the opening of the HC; from the lower portion of the OC to the middle of HC; from the inner half of the clivus to the intracranial opening of the HC and to the midpoint of the HC; from the HC extracranial opening to the lower portion of the OC and to the outer half of the clivus. The results of CT measurements are consistent to previous studies of morphometric variations related to the TA, with no significant difference between the measurements obtained in the right and in the left sides, or related to gender. The data obtained by three-dimensional CT images are important in assessing the morphometric variations of pre-surgical patientsof TA.

KEY WORDS: Transcondylar Approach; Computed Tomography; Hypoglossal Canal; Foramen Magnum; Occipital Condyle; Dry Skulls.

INTRODUCTION

The transcondylar approach (TA) has been used in surgeries to access lesions in areas close to the foramen magnum (FM) and it is performed directly through the occipital condyle (OC) or through the atlanto-occipital joint and adjacent portions of the same. The topographic relationship between a lesion and neurovascular structures is the most important characteristic when selecting the appropriate surgical procedure, and the identification of anatomical variations is crucial in the prior planning of neurosurgery (George *et al.*, 1988; Kratimenos & Crocard, 1993; Babu *et al.*, 1994; Wen *et al.*, 1997; Dowd *et al.*, 1999; Rothon, 2000,; Nanda *et al.*, 2002; Muthukumar *et al.,* 2005; Barut *et al.*, 2009).

Some approaches stemmed from the extreme lateral transcondylar approach, such as the transcondylar, the supracondylar, and the paracondilar approach, have been successfully performed to reduce the depth of the surgical area and improve the angle of exposure in these surgical procedures related to these approaches, reducing the amount of nerve tissue retraction required (Babu *et al.*; Dowd *et al.*).

The most common lesions found in the areas reached by these approaches are intra (Ammirati *et al.*, 1993) and extradural tumors, vascular lesions of the vertebral artery and congenital lesions (Babu *et al.*; al-Mefty *et al.*, 1996), aneurysms (Rohde *et al.*, 1994) and meningiomas (Tange *et al.*, 2001; Suhardja *et al.*, 2003).

In the TA, the area of the lesion prior to the bone marrow and low-clivus can be reached by piercing the OC above the occipital junction, below the HC through the direct path of the OC. This type of approach decreases the depth of the surgical area and provides better visibility without brain retraction. Nevertheless, it is important to plan and calculate the bone extent to be resected (Barut *et al.*). Direct visualization of the spinal cord, the previous brain stem and the surface of the tumor can be achieved by the OC resection,

which can be either wholly or partly (George *et al.*; Kratimenos & Crocard; al-Mefty *et al.*). According to Spektor *et al.* (2000), resection of the OC above the HC can improve the visual angle from 21 to 28% for the petroclival area, as well as provide an exposure increase from 28 to 71% by resecting the jugular tubercle.

The aim of this study was to analyze the anatomical variations of the bone structures related to the TA, showing important morphometric parameters of the FM, OC and the hypoglossal canal (HC) by studies of skulls and computed tomography (CT).

MATERIAL AND METHOD

Dry Skulls. 111 skulls, 88 male and 23 female, from the Laboratory of Human Anatomy of the Universidade Luterana do Brasil, Canoas, RS, were selected. 222 HCs, 222 OCs and 111 FMs were analyzed. The parameters studied bilaterally were the presence of septa in the HC, the presence and number of septa in each HC, the size of the HC cavities formed by the septa, the FM anteroposterior and transverse diameters (Fig. 1), the OC transverse and anterolateral length (Fig. 1), the distance from the intracranial end of the HC to the anterior, posterior and inferior edge of the OC, the intra and extracranial diameter of the HC, and the incidence of condylar foramina (CFs). Measurements were taken with Mitutoyo calipers and direct observation of structures.

Computed Tomography. The assessment related to the TA was performed in ten patients, three men and seven women, selected randomly, with no lesions involving the HC. The patients underwent 3D CT imaging of the cranial base using 1 mm axial helical slices and reconstruction interval on a Siemens Spirit Dual Slice equipment.

Measurements were taken bilaterally from each patient, completing 20 sides examined. The following distances were measured: from the lower portion of the OC to the extracranial opening of the HC (Fig. 2), from the outer half of the clivus to the opening of the HC (Fig. 3), from the lower portion of the OC to the midpoint of the HC (Fig.4), from the outer half of the clivus to the extracranial opening of the HC (Fig. 5), from the inner half of the clivus to the intracranial opening of the HC (Fig. 6), and from the inner half of the clivus to the midpoint of the HC (Fig. 7).
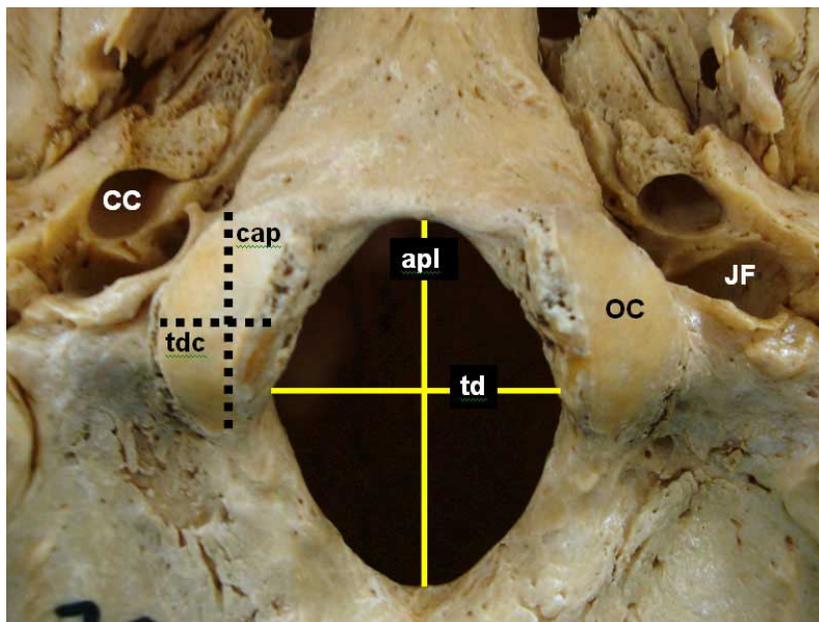

Fig. 1. Measures in dry skulls; apl (dashed line), anteroposterior length of the OC; tdc, transverse diameter of the OC; apl (solid line), anteroposterior length of the FM; td, transverse diameter of the FM; CC, carotid canal; JF, jugular foramen.
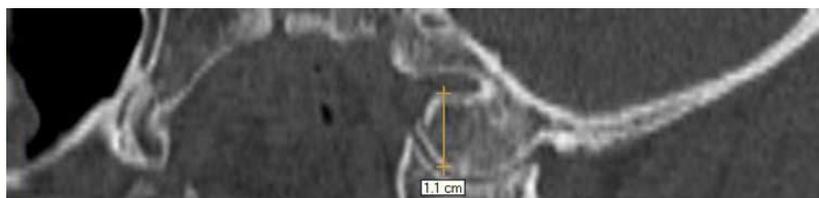

Fig. 2. Measurement in CT; B1-distance from the inferior portion of the OC to the extracranial opening of the HC; right side.
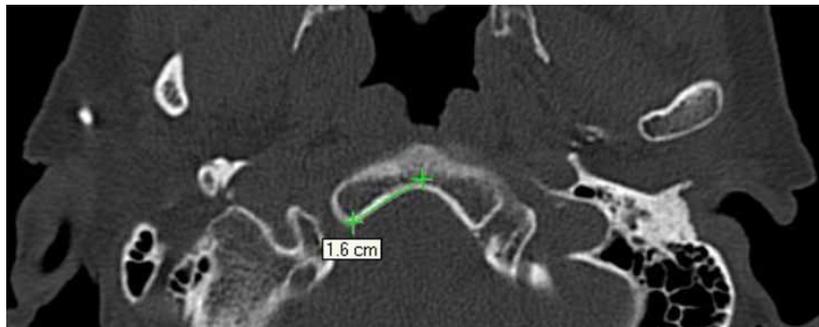

Fig. 3. Measurement in CT, B2 - distance from the outer half of the clivus to the opening of the HC; right side.
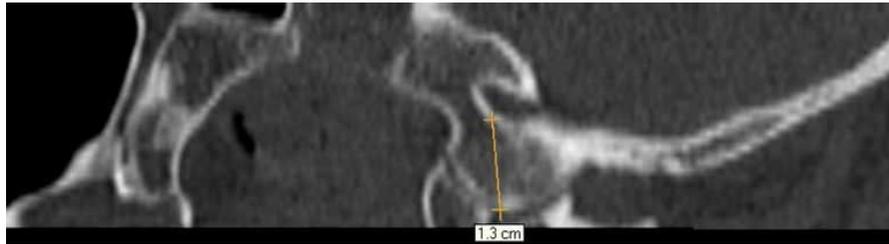
Fig. 4. Measurement in CT, B3 - distance from the inferior portion of the OC to the middle of the HC; left side.
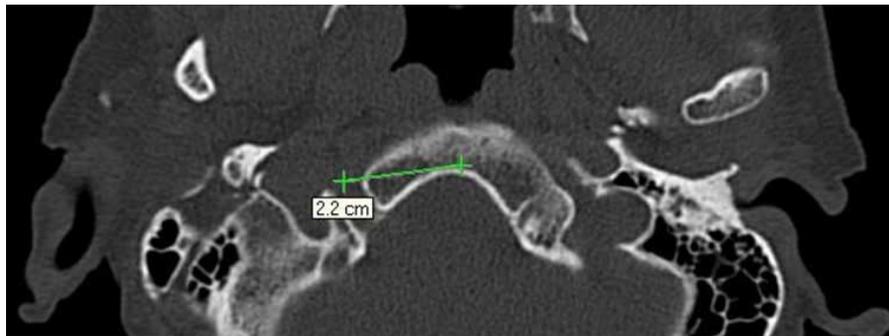

Fig. 5. Measurement in CT, B4 - distance from the outer half of the clivus to the extracranial opening of the HC; right side.
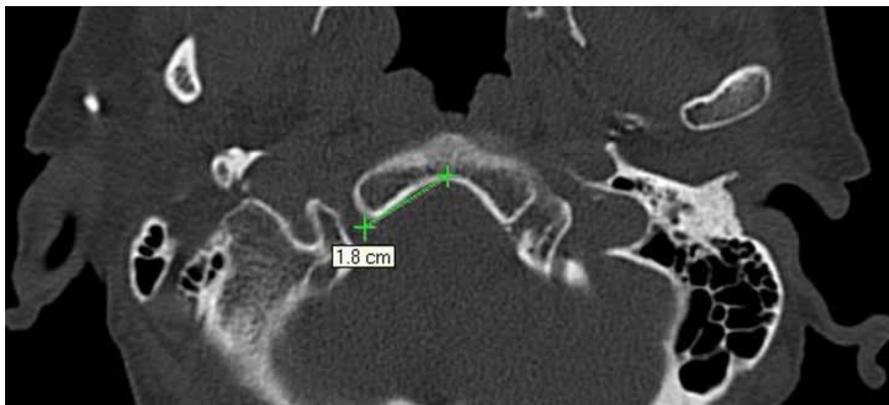

Fig. 6. Measurement in CT, B5 - distance from the inner half of the clivus to the intracranial opening of the HC; right side.
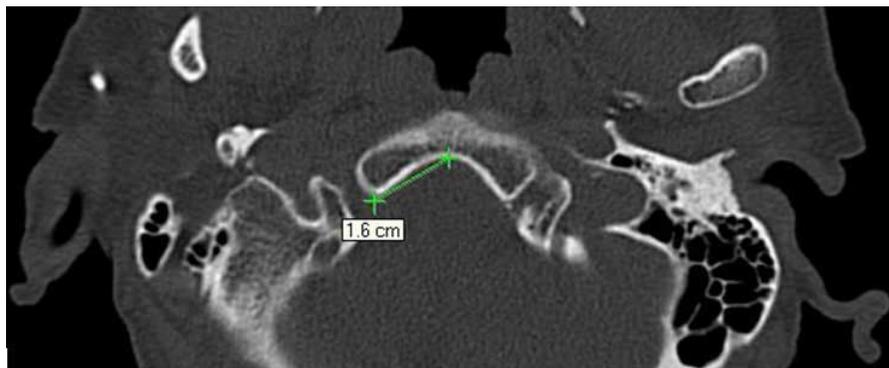

Fig. 7. Measurement in CT, B6 - distance from the inner half of the clivus to the midpoint of the HC; right side.

RESULTS AND DISCUSSION

Dry skulls. Regarding the septa of the HC, 43.2% of skulls showed simple septum and 56.8% double septa, with the highest prevalence of septa in the right side (65.8%). When the septa occur, the HC can be divided equally or unequally; inequitable forms reached 93.7% of skulls. There were no triple septa.

The FM mean index was 1.2 (standard deviation: 0.1), where the anteroposterior mean length was 36.0 mm (28.9 mm - 43.1 mm) and the mean width (transverse diameter) 30.5 mm (25.3 mm - 36.1 mm). In 58.5% of the skulls, there were CFs on the right side, and in 65.9%, on the left side. The results of other measurements related to the OC and the HC are shown in Table I.

Sen & Sekhar (1991) consider that the handling of nervous tissue decreases as the amount of resection of OC increases. Wen *et al.* report that the distance between the posterior edge of the OC and the HC is approximately 8.4 mm and that a resection of the OC of that same amount would be sufficient for surgical exposure. Nanda *et al.* (2002) report that the total resection of the OC does not provide a significant increase in exposure and only allows greater freedom in the surgical procedure.

The measurements of the transverse diameter (Table I, A1) and the anteroposterior length of the OC (Table II, A2) are according to Barut *et al.*, and differ from Nanda *et al.*, who reported 9 mm for the transverse diameter.

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Table I. Descriptive statistics of variables in dry skulls (mm, n, min., max., mean, standard deviation).

| | | | Right Side | | | | | Left Side | | |
Measure	n	Minimum	Maximum	Media	SD	n	Minimum	Maximum	Media	SD
A1	111	11.0	16.9	13.4	1.4	111	11.3	13.4	16.4	1.6
A2	111	11.4	31.0	24.0	3.6	111	18.5	28.3	23.3	2.6
A3	111	0.9	18.8	10.3	2.5	111	8.0	20.0	11.3	2.1
A4	111	5.3	14.0	11.0	1.8	111	5.3	14.4	10.7	1.8
A5	111	6.0	14.7	10.6	1.7	111	6.0	13.6	10.5	1.7
A6	111	3.0	9.8	4.6	1.3	111	2.2	9.0	4.6	1.4
A7	111	2.4	10.3	5.5	1.7	111	3.4	9.7	5.7	1.6

A1, transverse diameter of the OC, A2, anteroposterior length of the OC, A3, distance from the intracranial ending of the HC to the posterior edge of the OC, A4, distance from the intracranial ending of HC to the anterior edge of the OC, A5, distance from the intracranial ending of the HC to the inferior edge of the OC, A6, intracranial diameter of the HC, A7, extracranial diameter of the HC.

Table II. Morphometric measurements (mm, mean ± standard deviation) of the transcondylar approach in CT images.

	Right Side	Left Side
B1	0.94 ± 0.04	0.94 ± 0.04
B2	1.80 ± 0.05	1.72 ± 0.05
B3	1.14 ± 0.06	1.06 ± 0.04
B4	2.22 ±0.04	2.08 ± 0.05
B5	1.68 ± 0.04	1.60 ± 0.05
B6	1.63 ± 0.03	1.57 ± 0.06

B1, distance from the inferior portion of the OC to the extracranial opening of the HC, B2, distance from the outer half of the clivus to the opening of the HC; B3, distance from the inferior half of the OC to the midpoint of the HC; B4, distance from the outer half of the clivus to the extracranial opening of the HC; B5, distance from the inner half of the clivus to the intracranial opening of the HC; B6, distance from the inner half of the clivus to the midpoint of the HC.

between the HC and the OC is crucial in the TA (Bozbuga *et al.,* 1998), and the OC maximum pierceable amount without opening the posterior edge of the HC is 1 / 3 or 1⁄2 posterior of the long axis of the OC (Rhoton; Marin Sanabria *et al.* 2002; Tatagiba *et al.*, 2006). The values of 10.3 mm on the right side, and of 11.3 mm on the left side for the mean distance between the HC and the posterior edge of the OC, found in this study (Table I, A3), are close to the values reported by Muthukumar *et al.* and Barut *et al.*, and different from Wen *et al.*, who reported 8.4 mm. The values of 11.0 mm (right side) and 10.7 mm (left side) for the mean distance between the HC and the anterior edge of the OC (Table I, A4) are also in accordance to the values reported by Muthukumar *et al.* and Barut *et al.*. The structure of the septum of the HC must also be examined, because if two or three parts of the canal are not identified prior to surgery, the nerve of the HC can be injured (Katsuta *et al.*,

2000). 43.2% of the skulls examined had simple septum and 56.8% had double septa. The prevalence of septa in the HC was higher on the right side (65.8%). 25 and 30% of the HCs with a single septum were reported by Barut *et al.* and Muthukumar *et al.*, respectively. Triple septa were not found in any of the studies mentioned. The single septa divided the HC in unequal parts in 93.7% of the skulls, results consistent to those of Barut *et al.* and Muthukumar *et al*. The FM index is calculated by dividing the anteroposterior diameter by the transverse diameter. When the index value is equal to or greater than 1.2, the shape of the foramen is considered oval. In lesions in the anterior portions of the brain stem, if the FM is oval, a wider resection is required, as compared to a circular shape (Muthukumar *et al.*). The mean index of the FM was 1.2 (standard deviation: 0.1), where the mean anteroposterior length was 36.0 mm (28.9 mm-43,1 mm), and the mean width (transverse diameter) was 30.5 mm (25.3-36 mm, 1 mm), results that are similar to those found by Barut *et al*. The CF is located in the condylar fossa, posterior to the OC, and is one of the broadest emissary foramina, which can be seen in pre-surgical image (Ginsberg, 1994). The posterior condylar vein leaves the skull through the posterior condylar canal and it is an alternative source in a dysfunction of the venous drainage of the sigmoid-jugular complex. When obliterated during surgery, it can lead to fatal results (Thompson *et al.*, 1995). The present study indicated the presence of CFs in 58.5% of the skulls on the right side, and in 65.9% on the left side, as the results of Barut *et al*., and unlike Muthukumar *et al*., who reported prevalence of CFs on the right side. Ginsberg identified CFs unilaterally in 50% of the cases and bilaterally in 30%.

Computed Tomography. Results are shown in Table II and Figures 1 to 7, with no significant differences in regard to sex. The laterality was significantly different between the right and left sides only in the measurement shown in

B1 (Table II). Pre-surgical evaluation has been supported by radiological CT images, which are used extensively in the recognition, evaluation and study of morphometric parameters related to the TA (Matsushima *et al.* 2001; Day, 2004; Huynh-Le *et al.*, 2004; Liu & Coudwell, 2005; Bulsara *et al.* 2008; Menezes, 2008; Sen *et al.*, 2010). Likewise, the evaluation and post-surgical follow-up need this resource. In addition, cadaver studies are also conducted to record the anatomical variations of the areas accessed in these procedures (Matsushima *et al.*, 2010; Wu *et al.*, 2010).

The results of measurements in CT (Table II) are consistent to the data obtained by Bulsara *et al.*, who performed the same measurements related to the clivus, HC and OC. These authors found no significant differences in laterality in any of the measurements. Like the results of these authors, there was no significant difference in any of the measurements taken in relation to gender in this study.

Most of the data obtained in dry skulls and CT corroborate previous studies and are important parameters in the evaluation of morphometric variations of pre-surgical patients in regard to the transcondylar approach, thus helping to reduce the risk of neurovascular injury during the procedure, and also, it highlights the importance of three-dimensional CT image and contributes to the data survey of the population of southern Brazil.

PEREIRA, G. A. M.; LOPES, P. T. C.; SANTOS, A. M. P. V.; DUARTE, R. D.; PIVA, L.; POZZOBON, A. Análisis morfométrico del acesso transcondilar en cráneos secos y en tomografia computarizada. *Int. J. Morphol., 30(2)*:399-404, 2012.

RESUMEN: El acceso transcondilar (AT) ha sido utilizado como un procedimiento quirúrgico para lesiones cercanas al foramen magnum (FM) y se realiza directamente a través del cóndilo occipital (CO) o por medio de las porciones atlanto-occipital conjunta y adyacentes de la misma. El objetivo del presente estudio fue examinar las variaciones anatómicas relacionadas con el AT mediante los parámetros morfométricos del FM, CO y el canal del hipogloso (CH) en cráneos secos y tomografía computadorizada (CT). En 111 cráneos fueron examinadas las características del CH y tomadas medidas relacionadas con el FM, CO y CH. En la CT, las mediciones se obtuvieron de forma bilateral en 10 pacientes que se sometieron a exámen de la base del cráneo en corte axial helicoidal de 1 mm de espesor. Las medidas tomadas fueron las distancias: de la mitad exterior del clivus a la apertura del CH; de la parte inferior de las emisiones de CO a la mitad del CH; de la mitad interna del clivus a la apertura intracraneal del CH y hasta el punto medio del CH; de la apertura extracraneal del CH a la parte inferior de las emisiones de CO y hasta la mitad exterior del clivus. Los resultados de las mediciones de CT son consistentes con estudios prévios de los cambios morfométricos en relación con AT, sin diferencia significativa entre las mediciones obtenidas en el lado derecho e izquierdo y ni en relación con el sexo. Los datos obtenidos a través de imágenes en tres dimensiones de CT son importantes para evaluar las variaciones morfométricas de pre-quirúrgicos en el AT.

PALABRAS CLAVE: Acceso transcondilar; Tomografía computadorizada; Canal del hipogloso; Foramen magnum; Cóndilo occipital; Cráneos secos.

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