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Review

Posterior condylar canal: Anatomy and medical insights

Gabriele Maria de Oliveira Lucena[1], Gabriela Jardim de Paula Lemos[1], Luanna Simonetti Meira Pires de Araújo[1], Marília Soares Alencar[1], Antonio Cavalcanti de Albuquerque Martins[1], Carolina Martins[1,2]

[1]Medical School of Pernambuco, Recife, Pernambuco, Brazil
[2]Federal University of Pernambuco, Recife, Pernambuco, Brazil

Introduction
The importance of the posterior condylar canal lies in its role as a pathway for venous drainage of the brain and its relevance for surgical approaches in the region.

Objective
To describe the posterior condylar canal in the context of the skull's emissary foramina, its development, frequency, morphological/morphometric aspects of clinical/ surgical importance.

Methods
A human anatomical specimen displaying significant morphological variations of the posterior condylar canal is presented. A review is undertaken and further illustrated using anatomical dissections of injected cadaveric heads and dry skulls.

Results
The posterior condylar canal and its emissary vein form a connection between jugular and vertebral venous plexus systems. They can be activated during positional changes and reversible/permanent blocks in drainage through the jugular system - therefore its neurosurgical importance. These structures should be dealt with during lateral approaches to the posterior cranial fossa, requiring understanding of its path, size and variations. Considered a developmental selection induced by bipedalism and a characteristic of the human species, this anatomical feature should be understood within the context of emissary foramina and other structures involved in venous drainage of the head.

Conclusion
Awareness of role and variations of the posterior condylar canal are important when analysing the pattern of venous drainage to plan postero-lateral approaches to the posterior fossa. This knowledge is required to safely customize surgical approaches to a patient's specific needs. Lack of uniform methodology may explain differences in frequency/morphology of PCC in the literature and justify gathering new data into this subject.

Keywords: Cranial venous system, Neuroanatomy, Neurosurgery, Posterior cranial fossa

Edited by:
Marcelo Moraes Valença

Carolina Martins
cmrecife@hotmail.com

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Introduction

The condylar canals are the largest (1,2), most common emissary foramina of the human skull (2). The posterior condylar canal (PCC) transmits a venous connection between the jugular venous system and the suboccipital venous plexus (3,4). The posterior or extracranial opening of this canal is located at the condylar fossa, immediately above the occipital condyle, but its anterior or intracranial opening is variable, ranging from the jugular fossa of the occipital bone to the distal groove for the sigmoid sinus. Therefore, any study of this canal requires careful examination of the area comprised between the endo and exocranial surfaces of the posterior skull base.

This study reviews the anatomy and role of the PCC, while presenting the findings in an adult, human cadaveric specimen, bearing distinct variants of the PCC (and other venous foramina) on each side.

Recognizing the PCC, its role in brain venous circulation, and its potential anatomical variants are important in understanding cerebrovascular pathologies and to safely perform surgical approaches in the posterior cranial region.

Methods

A dry skull, donated for educational purposes to the Medical School of Pernambuco, Recife and harboring on each side a different pattern for the anterior opening of the PCC was registered using photographs (12MP, Apple iPhone camera) and measurements taken using a Vernier caliper (± 0.002 mm, Lufkin, Switzerland) and compass (McCoy, Germany). Measurements were taken three times and averages are presented. The other emissary foramina present were similarly characterized. This study was enrolled at the IRB and approved by the Ethics Committee (CAAE 79006224.8.0000.5569).

A review of the literature on this subject included papers that dealt with the PCC and the posterior condylar emissary vein (PCEV) and reported on 1) gross anatomy using (a) dry skulls, (b) non-injected and (c) injected specimens); 2) radiological aspects using (a) X-rays, (b) CTs, (c) venograms and 3) imagiological anatomy using (a) magnetic resonance imaging (MRI), and (b) MRI venograms; and included reports in (i) children and (ii) adults, (iii) variations of these structures, (iv) their developmental aspects as well as (v) clinical and (vi) surgical implications.

Case Example

The findings related to the anatomical specimen are summarized in Figure 1. The complete set (Figure 1 A-O) presents the emissary network in this specimen, while Figure 1 G-M presents the variations found at the posterior condylar canal (PCC).

The PCC is part of a group of structures involved in the venous drainage of the head (Table 1). Because the term "emissary foramina" may have a restrictive meaning to include just a few structures (2), a comprehensive approach has been adopted, to include bony structures transmitting elements involved in venous drainage.

The posterior, extracranial opening of the PCC can be readily seen at the dorsal aspect of the skull and just above the occipital condyle, at the depression formed by the condylar fossae (Figure 2A) on either side of the foramen magnum. These fossae accommodate the postero-superior part of the lateral mass of the atlas when the head is bent backward (4) and are the extracranial landmarks that help plot the position of the jugular tubercles - a significant bony obstacle to the lower clivus (6) (Figure 2B). The PCC and particularly its posterior end, has attracted anthropological attention, for being the most common and largest of all emissary foramina in the modern human skull (2).

On the other hand, the anterior or extracranial opening of the PCC is not frequently described, despite its surgical importance. Possibly because it frequently opens into the jugular incisura of the jugular foramen (Figure 2C), a tricky site to explore, picture and measure in the complete skull (Figure 1G&J). It can also open at the posterior edge of the sigmoid sinus sulcus (Figure 1H) in a ridge located between this sulcus and the jugular incisura and better evaluated with access to the endocranial side of the skull base (Figure 1A, C, D, G-I). Its emissary vein can also join the occipital sinus, running on the dura along the margin of the foramen magnum (15) or open directly into veins outside the skull (16). It has also been proved to occasionally open along the anterior condylar (hypoglossal) canal. This end of the canal may be exposed during postero-lateral craniectomies that extend to the base of the cerebellar fossae.

The PCC, therefore, is an angled channel (2) (Figure 1N and Figure 2A-C) which forms the communication between the jugular incisura/distal sigmoid sinus and the condylar fossae and is responsible for the anastomosis of the jugular bulb or distal aspect of the sigmoid sinus with the suboccipital venous plexus through the posterior condylar emissary vein (PCEV) (1,3,4). The PCC and PCEV have been studied using dry skulls (2,9,12), corrosion casts (8), injected cadaveric specimens (17), araldite CY 221 injections, tomograms (CT) and magnetic resonance imaging (MRI) angiograms, but even within one method of study, the variations in observations are so that require careful appraisal of generalizations made.

The PCC and its sinuous course can be seen on neuroimaging but will vary in consequence of the position, choice of imaging examination and specific cut or window (1). When in cross-section, only a round hole similar to a foramen may be seen, if analyzed tangentially, a longer canal-like structure is observed (16,18–20). During the venous phase of cerebral arteriography, the PCEV can be analyzed. Nowadays, venous MRI and CT are common and less invasive ways to visualize the PCEV. Tridimensional reconstructions using these data have been fundamental in distinguishing PCEV from neuromas, neoplasms, or abnormal lymph nodes within these same exams, a common diagnostic dilemma in the past (19,21,22).

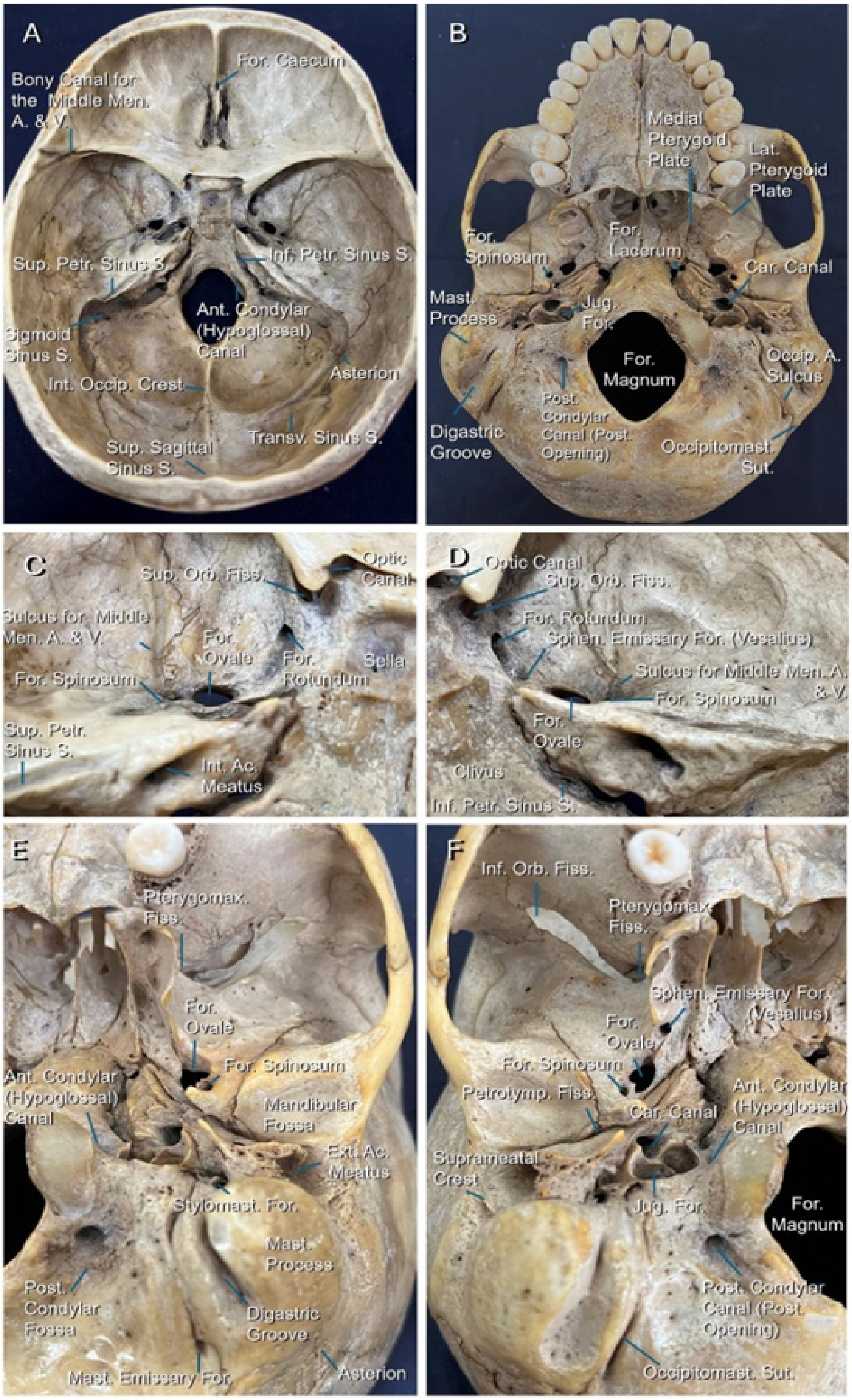
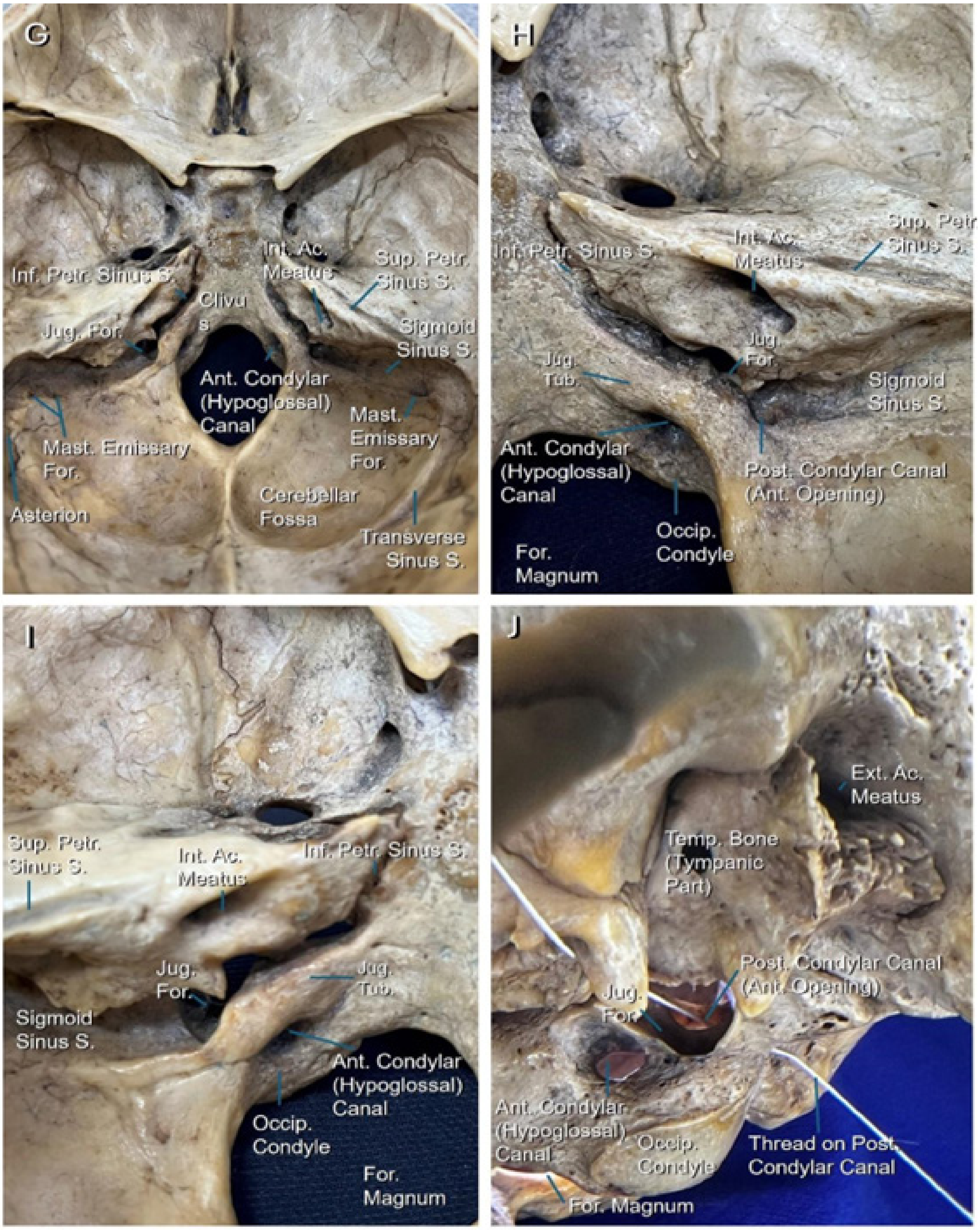
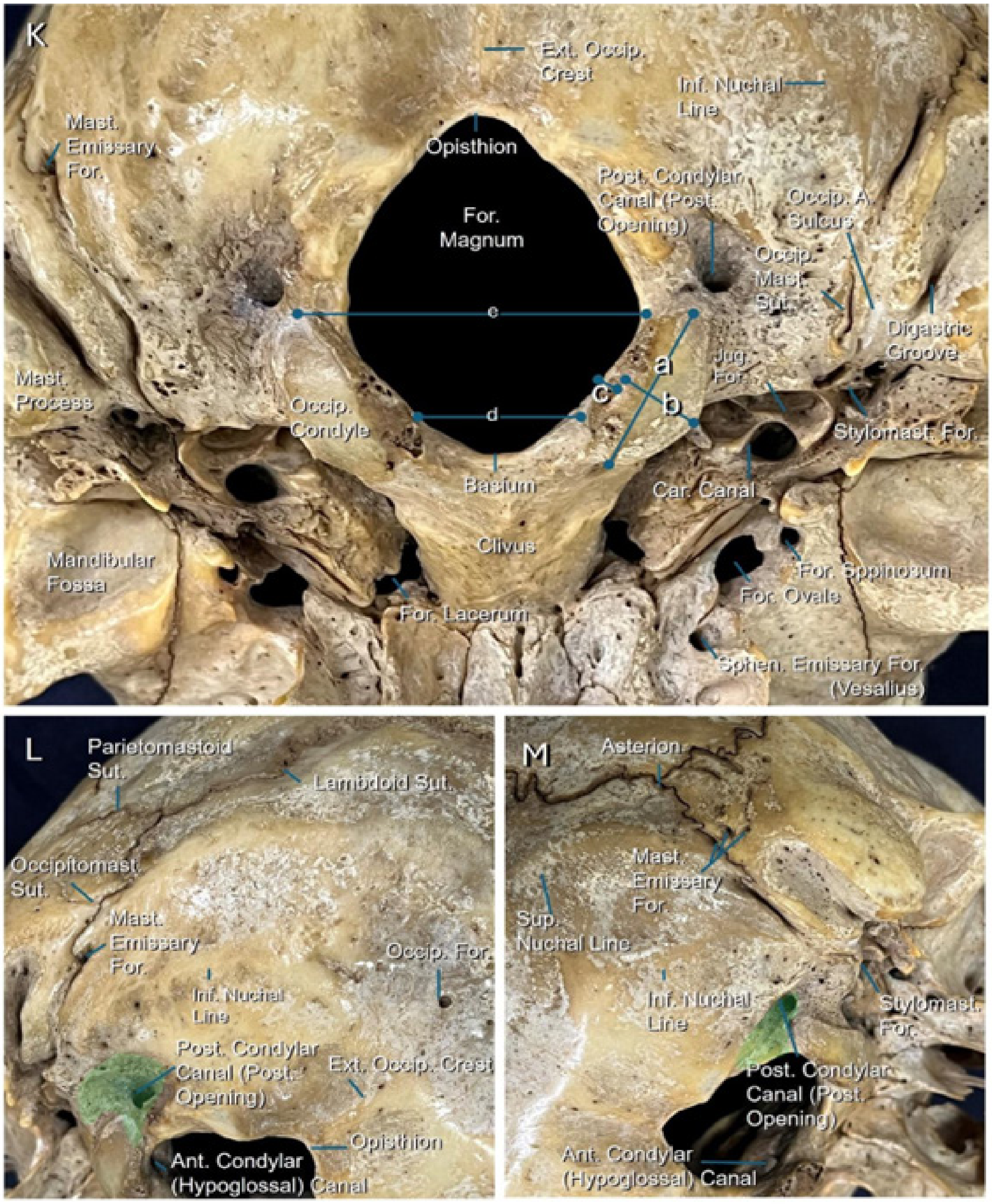


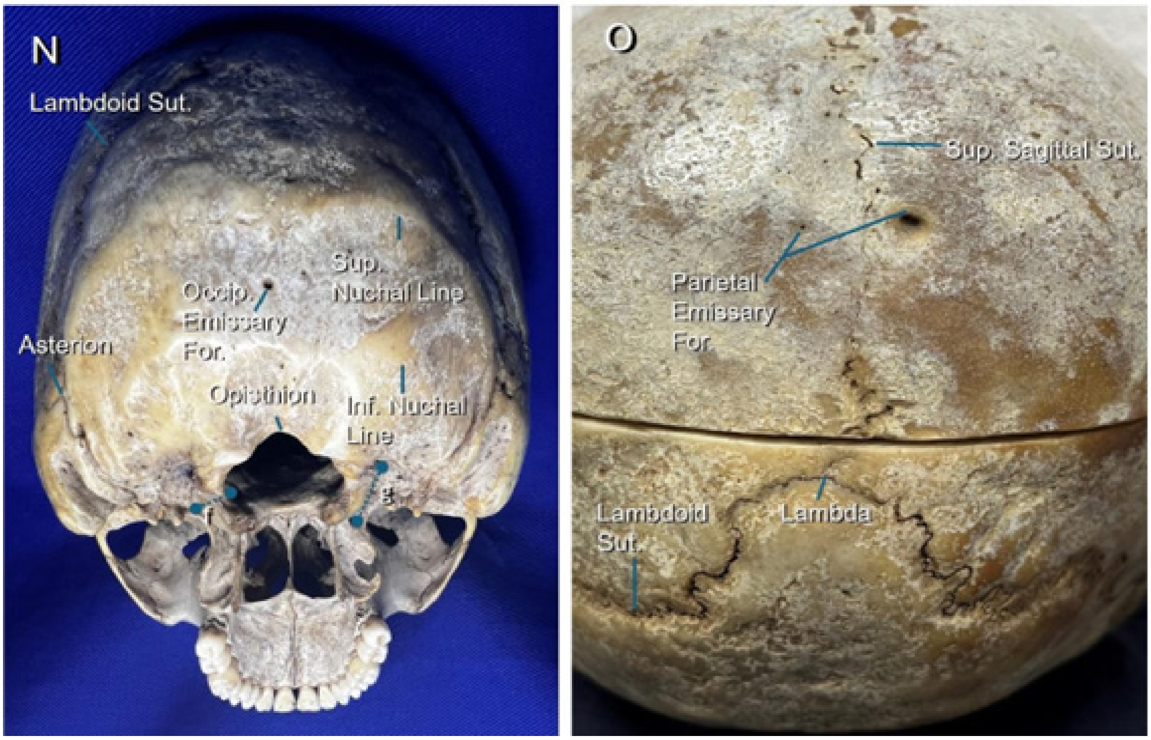
Figure. 1. Adult, human skull, from an unidentified donor from Northeast Brazil (Human body donation for education of Health Professionals at Medical School of Pernambuco, Recife). A. Endocranial surface. B. Exocranial surface. In this specimen, the emissary foramina and bony structures involved in venous drainage have distinct patterns, on the right and left sides. C. and D. Left and right middle fossa foramina. From the endocranial opening of the optic canal four typical foramina can he delineated on the left (C). One additional foramen is seen on the right side, between the foramen rotundum and ovale. This is the middle fossa or sphenoid emissary foramina (Vesalius), which transmits a venous connection from the cavernous sinus to the pterygoid venous plexus. E. Exocranial opening of the foramina on the left side (corresponding to C). F. On the right exocranial side (corresponding to D), the foramen of Vesalius is seen opening at the pterygoid fossa.



Continuation Figure 1. G. An enlarged view of A presents the endocranial opening of the mastoid emissary foramina, which is dual on the left. In both sides it opens at the upper third (or retropetrosal part) of the sigmoid sinus. The sulcus for the sigmoid sinus was measured, at its largest part, being 5 mm on the right and 5.7mm on the left. H. On the right, at the infrapetrosal part of the sigmoid sinus sulcus, at the posterolateral edge of a shallow jugular incisura (which is the temporal contribution to the jugular foramen) there is the anterior opening of the PCC (largest diameter: 1.6 mm). I. No such opening is seen on the left side, where a more capacious jugular incisura is seen. J. The anterior opening of the PCC on this side can only be seen from the exocranial side, as it opens at the posterior wall of the jugular incisura (largest diameter: 2.9 mm). A white thread has been passed through it. Note how this anatomical arrangement of canals through the occipital condyle may easily justify the hypoglossal canal being also denominated anterior condylar canal



Continuation Figure 1. K. A magnified, dorsal view on the exocranial side of the foramen magnum is undertaken on the same specimen. The right occipital condyle has a kidney shape (See also F), its length (a) is 20.2 mm, its width (b) 10.68 mm, and thickness (c), 7.8 mm. The left condyle (See also E) has an oval shape (a) 20.2 mm, (b) 10.3 mm, (c) 8.9 mm). The anterior intercondylar distance (d) is 20.1mm, and the posterior distance (e) is 41.2 mm. The (single) posterior opening of the PCC opens at each condylar fossa. Its largest diameter is 2.5 mm on the right and 3mm on the left side. The length of the PCC is 16mm on the right and 16.06 on the left side. Several bony pits are seen along the squamous part of the occipital bone in this area, but no corresponding endocranial openings were found. L. and M. Oblique views of the left and right sides. Note the distinctive shapes of the condylar fossae, which house the posterior opening of the posterior condylar canal, on each side (green shaded areas). This view also depicts the endocranial openings of the anterior condylar (hypoglossal) canals, seen through the foramen magnum. Measurements of their endocranial openings revealed the largest diameter to be 4.2 mm on the right and 5.58 mm on the left. The view extends up to the asterion – the meeting point between the occipitomastoid, lambdoid and parietooccipital sutures. The asterion is a useful surrogate for the transition between the transverse and sigmoid sinuses. Following the occipitomastoid suture, from the stylomastoid foramen to the asterion, the mastoid emissary foramina on each side could be found. On the left side, a single dimple could be found 27.36 mm above the stylomastoid foramen, while on the right, as many as three openings were found at 31 mm from the stylomastoid foramen (See G for the corresponding endocranial openings for these canals). When observing the nuchal lines, useful surgical landmarks on the occipital bones, as they provided for muscular insertion in this area, the exocranial opening of the mastoid emissary canals were above the level of the inferior and just below or at the level of the superior nuchal lines.



Continuation Figure 1. N. View from below, along the occipital squama, reveals a single occipital emissary foramen, located 33.7 mm above the opisthion, which is the midpoint along the posterior edge of the foramen magnum, to the left of the external occipital crest. The lines (f) and (g) have been plotted along the anterior and posterior condylar canals, respectively. Note that while the anterior condylar (hypoglossal) canal veers from medial to lateral and inferior to superior from its endocranial to exocranial ends (f), the posterior condylar canal passes from medial to lateral and has a slight inferior inclination when coursing from its anterior to posterior end. O. Two parietal emissary foramina – the right being many times larger than the left - can be seen 33.7 mm above lambda, which is the meeting point between the lambdoid and superior sagittal sutures. Please note how less serrated in the sagittal suture in this area, justifying its nomenclature obelion (5). A.: Artery; Ac.: Acoustic; Ant.: Anterior; Car.: Carotid; Ext.: External; Fiss.: Fissure; For.: Foramen, Foramina; Inf.: Inferior; Int.: Internal; Jug.: Jugular; Lat.: Lateral; Max.: Maxilla, Maxillary; Mast.: Mastoid; Men.: Meningeal; Orb.: Orbital; Petr.: Petrous, Petrosal; Petrotymp.: Petrotympanic; Post.: Posterior; Pterygomax.: Pterigomaxillary; S.: Sulcus, Sulci; Sphen.: Sphenoid, Sphenoidal; Sup.: Superior; Sut.: Suture; Stylomast.: Stylomastoid; Occip.: Occipital, Occipito; Transv.: Transverse; Tub.: Tubercle.

Posterior condylar canal (PCC) and posterior condylar emissary vein (PCEV) (Figure 2)

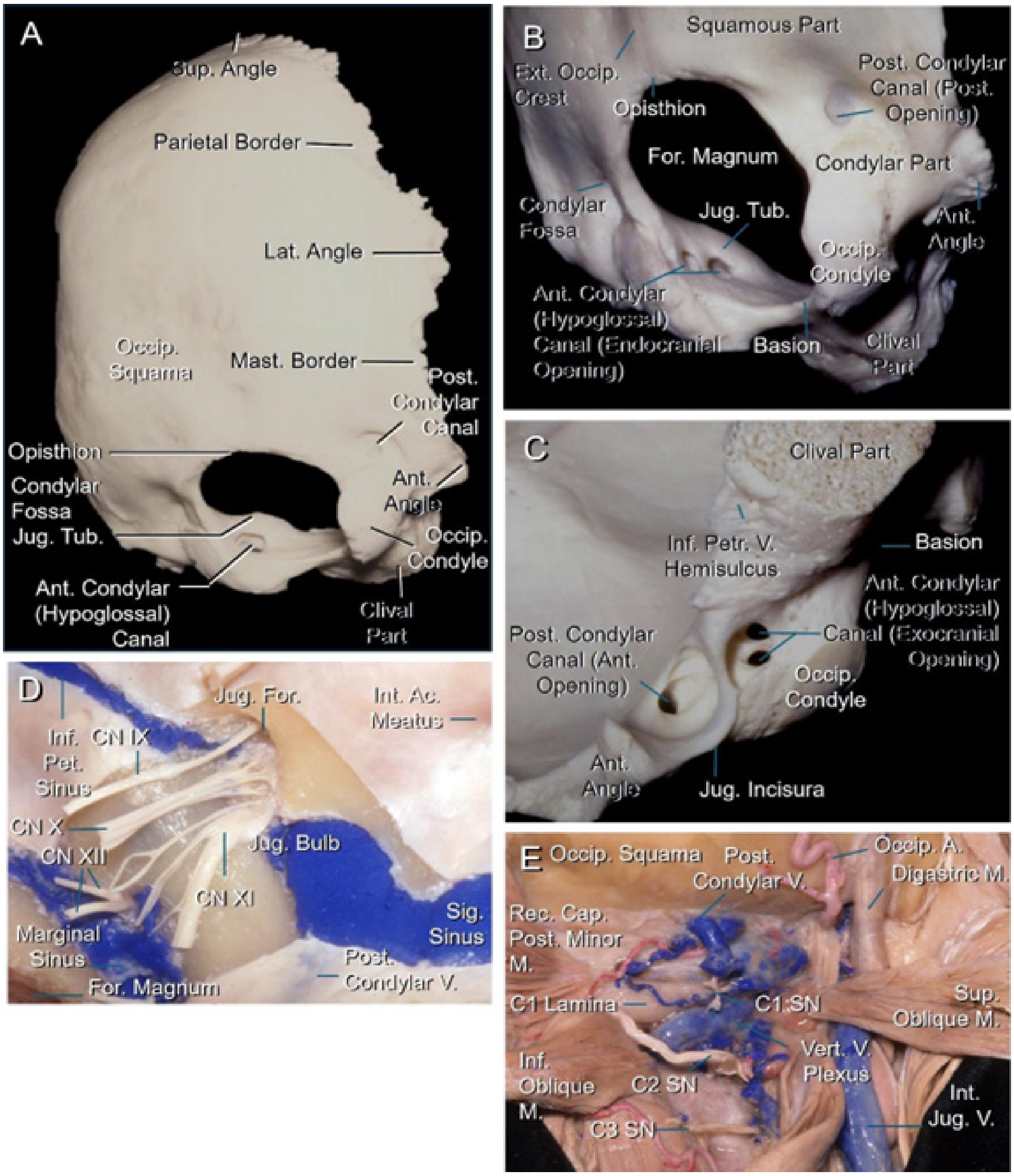


Figure 2. A. An isolated occipital bone is presented. Each occipital bone has three parts: basal (or clival), condylar (one on each side of the foramen magnum) and squamous part; and five angles: a single superior angle and double lateral and anterior angles. The superior angle fits at the lambda. The border between the superior and each lateral angle articulates with the parietal bones, forming the lambdoid sutures. The lateral angle points to the asterion. The border between each lateral and anterior angles articulate with the mastoid part of the temporal bone, forming the occipitomastoid suture. The anterior angle projects laterally from the condylar part of the occipital bone, forming the most lateral part of a quadrilateral piece of bone, the jugular process. Medial to the anterior angle, it is the petrosal part of the temporal bone which articulates with the occipital bone forming the petroclival junction. As in this area each part of the temporal and occipital bones carries a hemisulcus, when these bones are articulated, on the endocranial side there is the sulcus for the inferior petrosal sinus, while on the exocranial side, the sulcus for the inferior petrosal vein is formed. The occipital condyles are distinctive features at each antero-lateral side of the foramen magnum. The opisthion is the central point at the posterior rim of the foramen magnum, while basium is the central point of its anterior rim. Above and posterior to each condyle, on the exocranial side, there is a condylar fossa (also called supracondylar or posterior condylar fossa), where the posterior condylar canal opens. B. Enlarged view of A. Note the position of the condylar fossa (on the exocranial side of the occipital bone) and the jugular tubercle (on its endocranial side). It is because of this relationship that the condylar fossa is considered surgically a surrogate marker for the jugular tubercle and the anatomical basis for the condylar fossa approach (6). The anterior condylar canal, better known as the hypoglossal canal, transmits the hypoglossal nerve, an arterial branch of the ascending pharyngeal artery (7) and the anterior condylar vein. Occasionally, the canal is divided by fibrous or osseous bridge (as in this case) and the twigs forming the hypoglossal nerve will only fuse within the canal. The endocranial opening of the anterior condylar (hypoglossal) canal is located in a posterior situation. C. The exocranial opening of the anterior condylar (hypoglossal) canal is anteriorly located. The direction of this canal is therefore from posterior to anterior, from medial to lateral and slightly superior-inferior (See also Figure 1N), to open adjacent to the jugular

incisura, which is the occipital contribution to the jugular foramen. The jugular incisura therefore is medial to the anterior angle, lateral to the jugular tubercle (endocranial side) and superior to the opening of the anterior condylar (hypoglossal) canal (exocranial side). On the posterior wall of the jugular incisura there is the anterior opening of the posterior condylar canal. In contrast, this canal has an anterior-posterior, superior-inferior and slightly medio-lateral direction (See also Figure 1N). D. A silicone-injected cadaveric head has been dissected to expose the venous elements at the right side of the foramen magnum (See a similar, dry bone view, in Figure 1H). The dura has been removed to expose the venous sinuses in the area. The inferior petrosal sinus runs along.the petroclival junction, at the sulcus formed by contributions of the temporal and occipital bones. The sigmoid sinus courses in a bony sulcus along the mastoid part of the occipital bone. Both sinuses open at the jugular foramen, which also transmits the cranial nerves IX, X and XI. The marginal sinus runs along the edge of the foramen magnum and is connected with the jugular venous system by the anterior condylar vein - this being the reason why the hypoglossal canal is considered an emissary foramen. The posterior condylar emissary vein is seen by transparency, under the dura, reaching the jugular fossa at the posterolateral ridge of the jugular foramen. E. View into the suboccipital region on the right side. The occipital squama is seen just above the edge of the foramen magnum. The occipital artery is coursing on its sulcus at the occipito-temporal junction and the posterior belly of the digastric muscle is seen attached at the mastoid notch (or digastric groove) of the temporal bone. Muscles attached to the inferior nuchal line - as the rectus capitis posterior major and minor as well as the superior oblique muscles - have been reflected to expose the occipital-C1 area. The posterior condylar emissary vein is seen connecting with the vertebral venous plexus. A.: Artery; Ac.: Acoustic; Ant.: Anterior; CN: Cranial Nerve; Cap.: Capitis; For.: Foramen; Inf.: Inferior; Int.: Internal; Jug.: Jugular; Lat.: Lateral; M.: Muscle; Mast.: Mastoid; Occip.: Occipital; Petr.: Petrosal; Post.: Posterior; Rec.: Rectus; SN: Spinal Nerve; Sup.: Superior; Tub.: Tubercle; V. Vein, Venous; Vert.: Vertebral.

Table 1. Skull structures involved in the venous drainage of the posterior part of the head

Posterior Part of the Head	Endocranial opening	Exocranial opening	Definition	Observations
Anterior condylar or hypoglossal canal	Anterior third of the occipital condyle, inferomedial to the jugular tubercle of the occipital bone	Condylar part of the occipital bone, inferior to the jugular incisura and superior to the inferior rim of the occipital condyle	Transmits the anterior condylar (or hypoglossal) vein, a branch of the ascending pharyngeal artery (7) and the XII cranial nerve (or its twigs, fusing into a nerve within the canal)	Not aways considered a traditional emissary foramen in the past (2) - it establishes connections between the intracranial sinuses around the foramen magnum (marginal sinus) and the anterior condylar confluent, being first described by Trolard in 1868 (8). Once included it becomes the most frequent emissary foramina, being present in all specimens (9). Its endocranial opening is on average 4.66 x 3.21mm (varying from 7.5 x 5mm to 2 x 0.92mm) (9). Its exocranial opening tending to be slightly larger: on average 5.51 x 4.25 (varying from 10 x 5 to 3 x 2.5mm) (9). Sometimes it is divided by a fibrous or osseous band (See Figure 2A-C). This occurs on the left side, on average in 20% of cases and on the right, on 8% of cases. Bilaterally divided hypoglossal canals are reported in 4% of cases (9).
Posterior condylar canal	Posterior wall of the jugular incisura, at the postero-lateral ridge of the jugular foramen or at the posterior edge of the distal third of the sigmoid sulcus of the occipital bone	At the posterior condylar fossae	Connects the jugular bulb or the final third of the sigmoid sinus (10) with the veins of the suboccipital triangle and through them to the VVP	Its posterior opening is present on both sides in 46.6 – 54% of cases (2,9) a higher figure than any other foramen (2), except the hypoglossal canal. It is absent in 10-23.1% of cases (2,9). A unilateral foramen is more often on the right side (16.5-21%, versus 13.8-15% on the left). It is the largest emissary foramina (2,9) after the hypoglossal canal. In 1930 (2), its diameter was reported as less than 1mm in 10% of cases and larger than 2mm in 15%, tending to be larger on the right side. A 2001 study revealed it to be less than 1mm in only 4% and larger than 2mm in 72% of cases. It has reported its average diameter as 2.94 x 2.56mm, varying from as large as 6 x 4.5mm to 0.41 x 0.41mm (9). Multiple posterior openings are described (11), being double in 4% of cases, and triple in <1% (9).
Mastoid foramen	Along the sigmoid sulcus of the occipital bone	Along the mastoid edge of the temporal bone and/or occipitomastoid suture	Connects the upper and middle thirds of the sigmoid sinus (10) with the posterior auricular and/or occipital veins, and through those to the VVP (2)	In a study of 1.500 crania, it was absent in 31.9% of cases, bilaterally present in 34.4%, and equally present in one side in 16.1 (right) to 17.6% (left). In almost 11% of cases, the mastoid foramina were multiple on one or both sides, usually the right side (2). A more recent study (9) found remarkably different figures including: total absence in 1% and unilaterally in 10% (6% on the right and 4% on the left), and 4% of multiple foramina, usually on the right side. Our case example shows that a precise endocranial and exocranial counting is required on each side, a factor seldom made clear in previous reports (10) - one reason being a study exclusive of the outer surface of the skull
Occipital foramen	Along the external occipital crest, from the inion to the foramen magnum	Along the internal occipital crest	Usually single (12)	Connects the transverse or occipital sinus with the occipital veins and through that to the VVP (12). The overall prevalence of this foramen was 7% on the right side and 4% on the left (13)
Parietal foramen	Along the sagittal border of the parietal bone	Along the hemisulcus for the superior sagittal sinus (SSS) in the parietal bone	Connects the SSS with the occipital vein, and through that with the VVP system (12)	By passing a thread through it, the parietal foramen was deemed present bilaterally in 20% of cases, unilaterally in 15-21%, being more common on the right side. A median foramen was present in almost 5% of cases and was multiple in one or both sides in 2.5% of cases(2). It was found in 84,3% of dry skulls (14)

Frequency

The PCC is considered the second most common emissary foramen in the human skull (2), after the anterior condylar (hypoglossal) canal (9), and its frequency varies pending on the population consulted, type of study (post mortem or in vivo), as well as, in each of these categories, the method applied: in 1) post mortem studies: (a) the use of dry skulls (1,2,9) (Table 1) - in these, access to exo as well and endocranial surfaces of the skull base, (b) non-injected or injected cadaveric specimens; 2) in vivo studies: the use of (a) radio or tomograms (1), (b) contrast-injected studies or (b) non-radiological exams. These methodological differences preclude from freely comparing data regarding the PCC - or for this matter - any other emissary foramina study (13), nevertheless, comparisons abound in the literature. In this scenario, though, one clear uniformity can be seen between studies involving PCC mostly deal with the extracranial opening and fail to describe or detail its endocranial counterpart, which also bears significant surgical importance.

Role of PCC

Anthropological studies (12) have demonstrated that skull changes related to bipedalism involved enlarged occipital/marginal venous sinuses, followed by the epigenetic adaptations related to the selection for such trait, including development and/or appearance (particularly favoured by the evolutionary thinning of the skull) of several emissary foramina, including the anterior and posterior condylar canals, occipital, mastoid and parietal foramina. All such changes have allowed for the development of alternate venous systems, to which blood could – under certain conditions - be derived.

In modern humans these are a) the jugular and b) the vertebral venous plexus (VVP) systems. This phylogenetic development may be partially rememorated during embryology, starting at the end of the 3rd (and following a predictable sequence) up to the 7th month of intrauterine life (17). Usually the anterior condylar (hypoglossal) vein appears first, followed by the PCEV and - occasionally - the occipital emissary. At 5 months of intrauterine life the mastoid emissaries are well developed. By the 7th month, both venous systems and their connections can be seen, but at birth the "jugular sinus" or primitive jugular bulb (a comparative "stenotic" junction between the sigmoid sinus and internal jugular vein) is still present. It is the postnatal development, during the first years of life, including the erect posture achieved during this period that guarantees the ascending, hammering, atrial-originated wave pulses that will result in the formation of the jugular fossa on the temporal bone, to accommodate a mature form of the jugular bulb, seen from 2 years of age onwards (17). Detailing of the jugular and VVP systems are beyond the scope of this review, however landmark papers in this understanding have been listed (17,23).

The emissary venous channels - this review being limited only to the transcranial ones (Table 1) - establish connections between these systems (1) and the interplay between them is such that while the VVP is the preferred system to drain blood from the cranium when the individual assumes an upright position, the jugular system drains most of the blood from the head in reclining individuals (12,23) - a fact bearing direct implications to neurosurgical practice, when considering the venous drainage during different operative approaches.

Beyond the normal interplay, this dual system has particular importance whenever one system is compromised temporarily (as in rotation of the head towards one side or under pressure - direct, or through the airway - and catheterization) of definitively (as in thrombosis or ligature of the jugular system). In these situations, the other system becomes the anatomical basis, guaranteeing venous drainage of the head (10).

Clinical and surgical implications

A large PCEV may be associated with a false-positive Queckenstedt test, suggesting spinal block (24). In such instances - and also because flow patterns can change and invert (25,26) - doppler evaluation might prove of value. Emissary venous channels have also been known, for long, to function as a path through which infection is carried to the intracranial cavity (2) and to be related to cranial sinuses thrombophlebitis (27).

But it is for the patient being evaluated for an intervention - either surgical or endovascular that these anatomic elements bear most significance. Because emissary veins connect extracranial venous system with blood sinuses and meningeal veins (2), being called into action as alternative exit route for venous drainage, they have been used as a means of access to blocked sinus for the endovascular treatment of dural arteriovenous fistulae (28). Besides, if a state of high flow through these pathways establishes early in life, these veins might, consequently, induce enlargement of their foramina (1,27). Therefore - as a safety neurosurgical principle – any enlarged emissary foramina, beyond known anatomical limits (9), should be a red flag - pending further clarification, whenever accessing the preop imaging of a given patient.

Another point regarding all emissary veins is their transoperative control. Although bony wax has been traditionally used, the fundamental role of these structures in connecting venous channels may advocate for – at least when a sizable channel needs control - by temporary pressure, skillful drilling of bone around the emissary vein followed by bipolar control or ligation – least repetitive filling with wax may block a sinus or venous outlet to dire consequences (27,29). Such maneuvers are paramount when dealing with the PCEV or the anterior condylar (hypoglossal) canal during the extensions of the far lateral approaches (6,30).

Due to the importance of the PCC and the PCEVs as anatomical landmarks in lateral approaches to the foramen magnum and the justacondylar approaches (6), a classification based into its course, location of its openings, as well as structures being connected, has been achieved by the use of combined studies of anatomic specimens and angio-CTs (15). The jugular bulb type of PCC has proved to be the most frequent (67% of cases) (15). It connects the medial wall of the posterior part of the jugular foramen and the suboccipital venous plexus, as seen on the left side of our case-example (Figure 1I-J). The sigmoid sinus type – as seen on the right side of our case-example - happens in 25% of cases (15). Here the PCC's intracranial opening is at the posterolateral (also called posterojugular) ridge of the jugular foramen (Figure 1H), which is the border between the distal end of the sigmoid groove and the jugular foramen. The PCEV therefore, originates from the distal end of the sigmoid sinus, running in a higher level at the anteromedial end of the cerebellar fossa. Additionally, the PCC and its PCEV have been shown to connect to the occipital sinus (6%), or the anterior condylar (hypoglossal) canal and vein (3%) (15).

We have applied this classification to the cases described in the literature since 1930, in which enough data has been presented about both, the anterior and posterior openings of the PCC, considering text description and images presented, to the satisfaction of finding it thorough and inclusive. Only one case would escape the initial proposed classification (16). In such case, the right PCC bifurcated into two canals. The larger, lateral canal opened at the posterior edge of the jugular foramen (as would a Matsushima type 1), while the medial one opened extracranially, lateral to the anterior condylar (hypoglossal) canal. To accommodate such cases, we therefore extended the Matsushima's classification (15) to include a Type 1, Subtype a.

Such findings, when appreciated at the light of our case example and other reports in the literature, emphasize how variable the PCC can be, even between sides in the same patient, asking for careful preop evaluation whenever invasive procedures are being planned in the condylar area.

Future Directions

At first glance, in the literature, populational studies have shown differences in frequency and morphology of the PCC and PCEV. Considering the lack of uniformity between methods - even when apparently the same methodology seems to have been applied (i.e.: dry skulls, with and without exploration of the endocranial surface) – this data may need to be revisited. Furthermore, if the venous foramina of the skull are contextualized within the framework of a dynamic, evolving venous system, the remarkable differences between populational studies almost a century apart may also justify - not only a modern reassessment of the anatomy of this region - but the application of recent technological advances in neuroimaging. Applied to a particular population of interest, those efforts will help further characterize such groups and then refine anatomical classifications of surgical interest.

For the individual patient, it is long past the time when lack of anatomical knowledge or insufficient neuroimaging led to spurious diagnosis of pathology when dealing with venous variations of the structures mentioned here (1). For the surgical patient which can now be so studied and characterized, the PCC/PCEV findings will have its role weighted as part of the venous circulation in a comprehensive understanding of his/her cerebrovascular dynamics.

In the neurosurgical and interventional scenarios, the knowledge compiled in this review, and additional studies as just described, might set in motion customized protocols and personalized approaches which will possibly lead to optimizing outcomes by preventing or minimizing complications. This will be particularly important in procedures involving the foramen magnum and adjacent areas, where the presence and variation of the PCC can be a major influence over surgical strategy.

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Gabriele Maria de Oliveira Lucena
https://orcid.org/0000-0002-0651-7049
Gabriela Jardim de Paula Lemos
https://orcid.org/0009-0007-8397-1492
Luanna Simonetti Meira Pires de Araújo
https://orcid.org/0009-0000-6207-8741
Marília Soares Alencar
https://orcid.org/0009-0008-2302-7923
Antonio Cavalcanti de Albuquerque Martins
https://orcid.org/0000-0002-1249-8622
Carolina Martins
https://orcid.org/0000-0002-0197-3520

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