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The age-related maturational pattern of the human subarcuate fossa (petromastoid canal). Preliminary results from the application of a new three-dimensional analytical approach

Caractéristiques de maturation de la fossa subarcuata (canal pétromastoïdien) chez l'homme en fonction de l'âge. Résultats préliminaires à partir de l'application d'une nouvelle approche analytique tridimensionnelle

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ABSTRACT

The subarcuate fossa, or petromastoid canal, is a hypostotic feature of the temporal bone used for assessing the age at death of immature individuals. The present study uses the high-resolution micro-CT record of 20 extant human infant and juvenile temporal bones to more precisely assess the age-related maturational pattern of this bony structure. In the perspective of the application of our analytical protocol to the study of the hominid fossil record, the main goals of this contribution are to extend the amount and to improve the quality of the linear and volumetric information on the human subarcuate fossa by the application of new 3D imaging techniques.

Mots clés :
Os temporal humain
Labyrinthe osseux

RÉSUMÉ

La fossa subarcuata ou canal petromastoïdien, est un caractère hypostotique de l'os temporal utilisé pour estimer l'âge au décès des individus immatures. La présente étude utilise

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Fossa subarcuata
Développement
Scanner micro-CT
Analyse d'image 3D

les images haute résolution micro-CT de 20 os temporaux humains immatures et juvéniles, afin d'estimer plus précisément la maturation en lien avec l'âge de cette structure osseuse. En vue d'appliquer notre protocole analytique à l'étude du registre fossile hominidé, les principaux objectifs de ce travail sont d'améliorer la quantité et la qualité des informations volumétriques et linéaires de la fossa subarcuata, par l'application de nouvelles techniques d'imagerie 3D.

1. Introduction

In paleobiological and palaeoanthropological research, interpreting the maturational patterns of anatomical regions is of great interest for the assessment of the accurate age at death of immature individuals, notably in the case of isolated fossil specimens. Among the intracranial features, the subarcuate fossa (SF), or petromastoid canal (CPM), has been recognized as a valuable hypostotic trait of the temporal bone to assess developmental age in human and nonhuman extant and fossil primates (e.g., Braga et al., 2013; Coqueugniot et al., 2004; Gannon et al., 1988; Jeffery et al., 2008; Spoor and Leakey, 1996; Weaver, 1979). This anatomical structure (hereinafter referred to as SF, i.e., subarcuate fossa) is located in the bony labyrinth, which includes the sense organs of hearing in the cochlea and of balance in the vestibule and the semicircular canals. It is circumscribed by the three semicircular canals and is more precisely located on the posterior surface of the petrous pyramid, superolateral to the internal acoustic meatus (Jeffery and Spoor, 2004, 2006). The SF is present in the prenatal stages of all primate species but, in some taxa, it may be obliterated after birth (Spoor and Leakey, 1996).

Among humans, the particularity of SF depends on its postnatal ossification, making an osseous depression termed the petromastoid canal (CPM). This extends posterolaterally through the arch of the anterior canal toward the mastoid antrum. At birth, the bony labyrinth has reached its adult size and will remain invariant. In contrast, the FS will gradually decrease during the first 2 years, reaching its final size in c. 3 years (Dutailly et al., 2007).

Rapid advances in computer technology offer nowadays the opportunity of high quality two- (2-) and three-dimensional (3D) reconstructions and provide increasingly precise imaging techniques for noninvasively investigating inner fossil structures (e.g., Bayle et al., 2011; Clément and Geffard-Kuriyama, 2010; Weber and Bookstein, 2011). By using biometric references with a more precise imaging technique and at a higher resolution than medical computed tomography (Maret et al., 2010, 2014), in this preliminary study we investigate the age-related maturational pattern of the human subarcuate fossa. More precisely, the objectives of this contribution are to improve previous methods applied to the analysis of the human fossil record (e.g., Coqueugniot et al., 2004) and to test a new 3D imaging approach allowing a more subtle quantitative assessment of this bony structure.

2. Materials and methods

2.1. Sample and scanning procedures

The investigated sample consists of 20 crania of immature modern individuals (*H. sapiens*) selected from the reference anatomical collection of the Faculty of Medicine of Strasbourg. Details are given in Table 1. Both sex (11 males and 9 females) and age (ranging from new-born to 10 years) were known for all individuals (Rampont, 1994).

The temporal region of each specimen was scanned at the Institute for Space Medicine and Physiology (MEDES) of Toulouse with a Scanco Medical™ X-Treme micro-CT scanner by using the following parameters: 60 kV, 1 mA, 41 μm isotropic resolution. Image data were interpolated to form isometric voxels. The resulting voxel size from which the volumetric measurements were taken was $0.041 \times 0.041 \times 0.041$ mm. Data were exported in DICOM format before being converted to TIFF format for subsequent segmentation of the bony labyrinth and the subarcuate fossa. The software used for 3D visualization of the internal structures of the petrous pyramid and for linear and volumetric measurements was Amira 5.0® (Mercury Computer System®).

2.2. Measurements

The height and width of the SF opening are spatially associated with the arc height and width of the anterior semicircular canal (Jeffery and Spoor, 2006). Based on the micro-CT record, the SF was quantitatively assessed by means of linear and volumetric measurements.

2.2.1. Linear measurements

Two-dimensional measurements of the subarcuate fossa were performed on micro-CT slices. Its degree of obliteration was measured using the method elaborated by Coqueugniot et al. (2004). The SF maximum width (*f* wid) was measured along a segment joining the two lumens of the anterior semicircular canal (whose width corresponds in this study to the variable *c* wid) in a plane parallel to the arc of the lateral semicircular canal. The linear measurements were taken to the nearest hundredth of a millimetre and the SF width (*f* wid) was expressed as a percentage of the arc width of the anterior semicircular canal (*c* wid) in the same slice (ratio = *f* wid/*c* wid). A first series of measurements was taken (*f* wid 1/*c* wid 1). To test intra-observer reproducibility, we carried out a second series of measurements (*f* wid 2/*c* wid 2) after an interval of 1 week. Left and right sides were averaged for each individual.