Computed tomography of intra- and extramural ethmoid cells: iconographic essay*

Tomografia computadorizada das células etmoidais intra e extramurais: ensaio iconográfico

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Abstract The development of the paranasal sinuses is an intricate process that begins in the intrauterine life and terminates in early adulthood. Among the paranasal sinuses, the ethmoid cells or labyrinth are probably the most complex structures, being associated with the highest number of normal variants. Variations in the pattern of pneumatization of the ethmoid cells can be divided into intra- and extramural cells. Intramural cells are those which develop within the ethmoid labyrinth. Extramural cells are those that develop isolatedly. Computed tomography is the most useful tool in the evaluation of inflammatory processes of the paranasal sinuses. Computed tomography also plays a relevant role in the preoperative planning as well as in the postoperative follow-up, since it demonstrates exact anatomical details of normal structures with accuracy in the detection of variants. In the present pictorial essay, the authors describe the most common anatomical variants of the ethmoid labyrinth and their relationship with adjacent structures. Endoscopic sinonasal surgery has become increasingly less invasive, requiring more detailed anatomical imaging of this region.
Keywords: Computed tomography; Ethmoid sinus.

Resumo O desenvolvimento dos seios paranasais é um processo intricado que se inicia na vida intrauterina e termina na idade adulta. Dos seios da face, as células etmoidais são provavelmente as estruturas mais complexas e as que estão associadas com o maior número de variantes da normalidade. Variações no padrão de pneumatização das células etmoidais podem ser divididas em intra ou extramurais. Intramurais são aquelas que ao se desenvolverem mantêm contato com o labirinto etmoidal, e extramurais as que se desenvolvem isoladamente. A tomografia computadorizada é a ferramenta mais útil na avaliação de processos inflamatórios dos seios paranasais. De igual modo, ela é importante para o planejamento pré-operatório e controle pós-operatório, pois possibilita grande detalhe anatômico das estruturas normais e detecção precisa de suas variantes. Neste ensaio iconográfico os autores descrevem as principais variantes da normalidade do labirinto etmoidal e suas relações com estruturas adjacentes. Cirurgias endoscópicas para o tratamento de afecções dos seios paranasais têm-se tornado cada vez menos invasivas, o que certamente aumentará a demanda por relatórios de imagem cada vez mais ricos em detalhes desta região.
Unitermos: Tomografia computadorizada; Seio etmoidal.

INTRODUCTION

Computed tomography (CT) is considered the method of choice in the evaluation

of uncomplicated paranasal sinuses inflammatory processes[1,2]. Additionally, CT is extremely useful in the preoperative planning and in postoperative control in cases of endonasal interventions for providing important details on the normal anatomy and its variants[3,4]. Most recently, multiplanar and three-dimensional reconstruction has been utilized as a part of the routine in the study of paranasal sinuses, for providing higher quality diagnostic images and data than conventional CT, particularly in the identification of some anatomic variants[4–6]. Anatomical variants arising from ethmoidal cells development process are the most common, frequently associated with inflammatory processes and responsible for most of paranasal sinuses revision surgeries[7–10].

Present at birth, ethmoid cells present a variable and heterogeneous development until the early adulthood[11]. At different stages of the ethmoid labyrinth development, there are two main groups of normal variants: the intramural and extramural ethmoid cells. Extramural ethmoid cells are structures that pneumatize and develop protruding externally to the ethmoid labyrinth. This group is comprised of agger nasi cells, frontal cells, supraorbital ethmoid cells and Haller and Onodi cells. On their turn, intramural ethmoid cells are structures that pneumatize and remain intimately related to the ethmoid labyrinth, characterized by the frontal bulla cells, suprabullar cells, and ethmoid bulla[12]. The recognition of different anatomical variants is of

utmost importance for the rhinologist. Because of their proximity with the main drainage pathways of the paranasal sinuses, some cells may reduce the mucociliary clearance thus predisposing to inflammatory processes and causing endonasal endoscopic revision surgery.

In the present pictorial essay, extramural and intramural cells are described in detail, with illustrative images from each one. Additionally, the authors emphasize some relevant aspects of the ostiomeatal unit, frontal recess and sphenoethmoidal recess, structures of great importance in the mucociliary drainage of paranasal sinuses. All the images in the present essay were selected from paranasal sinuses computed tomography studies of patients from the otorhinolaryngology clinic at Hospital Universitário de Brasília, by the authors F.G.G. and C.L.J., with respectively eight- and three-year experience in radiology. All the paranasal sinuses studies were performed with the volumetric acquisition technique in a 4-channel multidetector CT apparatus. The images were reviewed and reconstructed in multiple planes on General Electric Advantage 4.2 workstations.

Ostiomeatal unit and frontal and sphenoethmoidal recesses

The ostiomeatal unit is the common drainage pathway of the anterior paranasal sinuses, acting as a unit that controls and modulates the mucociliary drainage of the frontal sinuses, anterior ethmoid cells and maxillary sinus. This is composed of the following structures: uncinate process, ethmoid bulla, middle turbinate, and the spaces between these structures (infundibulum, middle meatus and semilunar hiatus) (Figure 1)[13,14].

The frontal recess is the drainage pathway of the frontal sinuses. Each frontal recess is surrounded by the following structures: the agger nasi cells, ethmoid bulla, middle turbinate, basal lamella and anterior ethmoidal cells[1] (Figure 2). The sphenoethmoidal recess is the drainage pathway of the sphenoid sinus, a rather small structure next to the midline, posteriorly to the upper turbinate, between the anterior sphenoid sinus wall and the posterior wall of the ethmoid cells[13] (Figure 3).
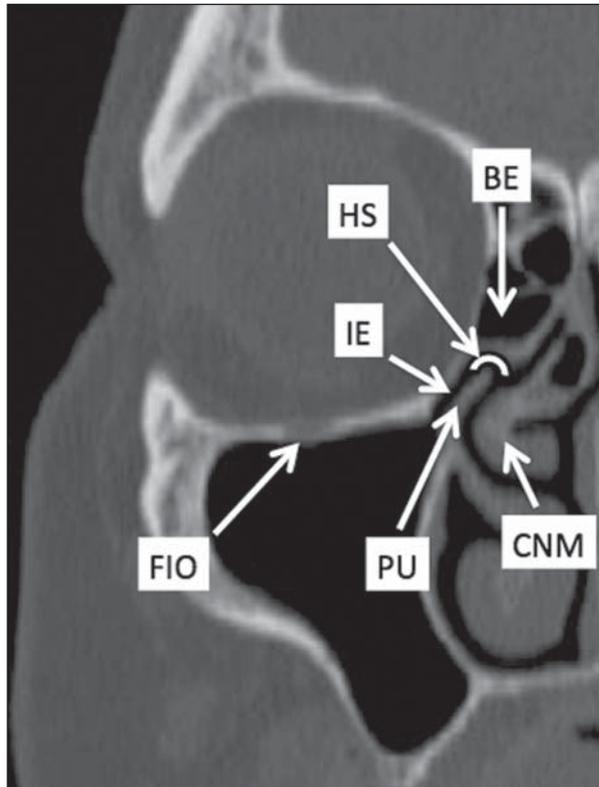
Figure 1. Coronal image demonstrating the components and anatomic relationships of the ostiomeatal unit. Highlights: ethmoid bulla (BE), middle nasal concha (CNM), hiatus semilunaris (HS) ethmoid infundibulum (IE), uncinate process (PU), infraorbital foramen (FIO), part not belonging to the ostiomeatal unit.
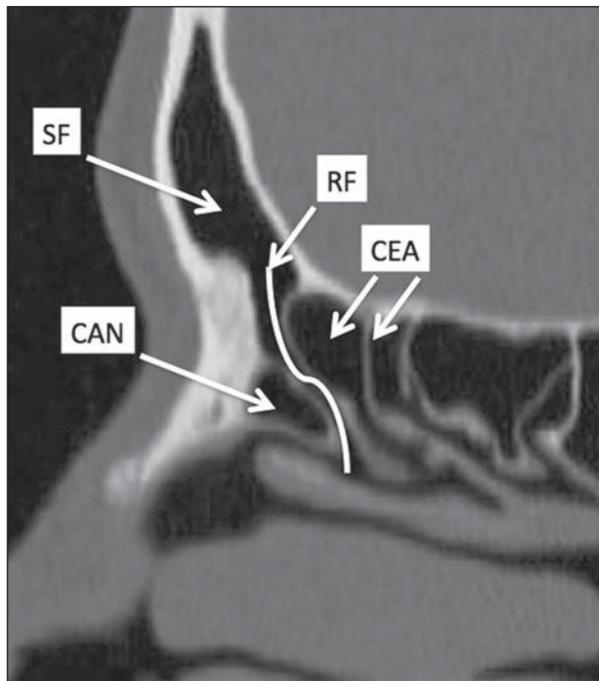
Figure 2. Frontal recess (RF) anatomy in the sagittal plane and its relationship with the anterior ethmoid cells (CEA). Highlights: Agger nasi cell (CAN) and frontal sinus (SF). The frontal recess, usually funnel shaped, is the drainage pathway of the frontal sinus and some agger nasi cells.

Agger nasi cell

Agger nasi cell, first described by H. Meyer[15], is the most anterior ethmoid cell, present in up to 98% of cases. Its anterior and posterior walls constitute part of the frontal recess walls, endoscopically corresponding to a bulging in the nasal wall anteriorly to the middle turbinate[16]. The agger nasi cells are best visualized on sagittal and coronal images (Figure 4). Abnor-

malities related to the agger nasi cells are the most frequent causes for endonasal endoscopic revision surgery[17].

Frontal cells

Frontal cells or Kuhn's cells[12], are ethmoid cells intimately related to agger nasi cells. According to their pneumatization pattern, frontal cells may be divided into four different types (types I thru IV). By far the most common ones, type I frontal cells are single cells, located above the agger nasi cell and inferiorly to the frontal sinus floor (Figure 5). Type II frontal cells correspond to two or more anterior ethmoid cells which pneumatize above the agger nasi cell, sometimes extending towards the interior of the frontal sinus (Figure 6). Type III frontal cells are single anterior ethmoid cells, which, because of their large volume, pneumatize above the agger nasi cell superiorly extending into the frontal sinus (Figure 7). Less frequent, type IV frontal cells are isolated cells located within the frontal sinus, above the agger nasi cell (Figure 8)[13]. Park et al. have found a frontal cell in 32% of the 105 studied patients, and the prevalence of types I thru IV frontal cells was, respectively, 24.2%, 4.2%, 3.1% and 0%[18].
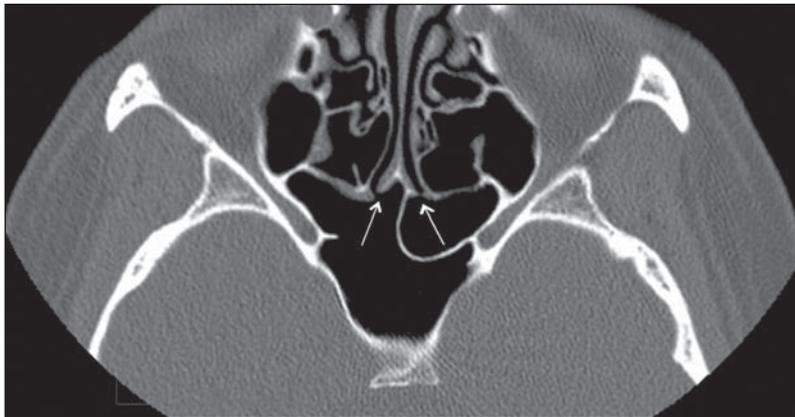

Figure 3. Axial image at the level of the sphenoethmoidal recesses (arrows). The sphenoethmoidal recess is best visualized in the axial plane and drains the sphenoid sinuses and some posterior ethmoid cells.

Figure 4. Coronal image at the level of the agger nasi cells (highlighted – asterisk). Agger nasi cells are considered to be the most anterior ethmoid cells.
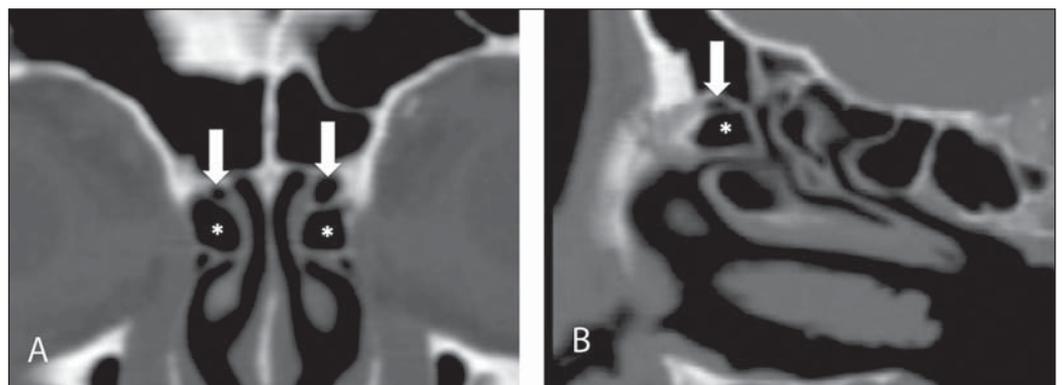
Figure 5. Coronal (**A**) and sagittal (**B**) images demonstrating type I frontal cells (arrows) and their intimate relationship with agger nasi cells (asterisks). Type I frontal cells are single and do not extend into the frontal sinus.
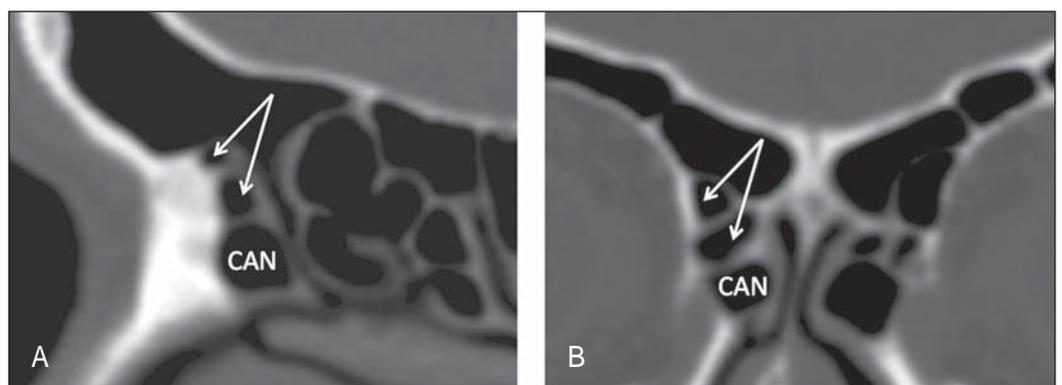
Figure 6. Sagittal (**A**) and coronal (**B**) images demonstrating type II frontal cells (arrows). Type II frontal cells present a ladder-like appearance of two or more cells, and are located above the agger nasi cells (CAN).

Supraorbital ethmoid cell

Supraorbital ethmoid cell is the ethmoid cell that extends superolaterally between the middle orbit wall and the ethmoid roof (Figure 9)[13]. Supraorbital ethmoid cells may simulate multiple frontal sinuses, type III frontal cells, suprabullar cells, frontal bulla cells or interfrontal sinus septal cells on coronal CT images. According to Zhang et al., its incidence may reach 5.4%[19].

Haller's cells

Haller cells, also known as orbitomaxillary cells, were first described by Albert Von Haller in 1743[20]. They are extramural eth-moidal cells that pneumatize inferiorly to the orbital floor, extending from the ethmoid labyrinth, below the ethmoid bulla, towards the interior of the maxillary sinus (Figure 10). Because of its location, next to the ostiomeatal unit, and depending on its number and size, the presence of such cells may cause obstruction of mucociliary drainage and be related to sinusopathy[13]. According to Stackpole and Edelstein, Haller cells are present in 34% of the patients with sinusopathy. Additionally, such authors have demonstrated that the higher the number of Haller's cells, the greater the chances of maxillary sinus inflammation[21].

Onodi cells

Also known as sphenoethmoidal cells, Onodi cells were first described by the Hungarian laryngologist Adolf Onodi, in 1904[22]. Onodi cells are considered as the most posterior ethmoid cells. Recent data on the prevalence of Onodi cells at CT studies, particularly in cases where more modern techniques are utilized, are scarce. According to anatomy studies on cadavers, Onodi cells are very common, with a prevalence ranging between 39% and 60%[23,24]. The presence of a horizontal septum dividing the sphenoid sinuses in "two floors" suggests the presence of an Onodi cell (Fig-
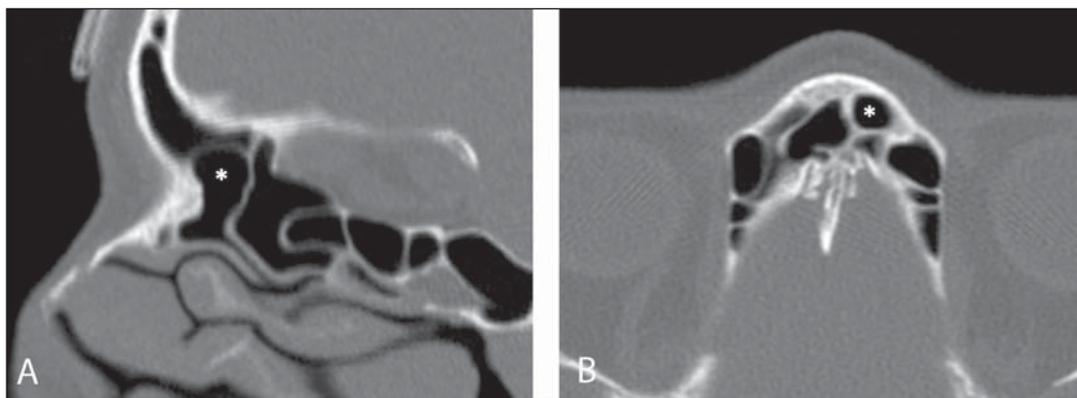
Figure 7. Sagittal oblique (**A**) and axial (**B**) images demonstrating a type III frontal cell (asterisk), extending into the frontal sinus. Type III frontal cells are also located above the agger nasi cells, not seen on the images.
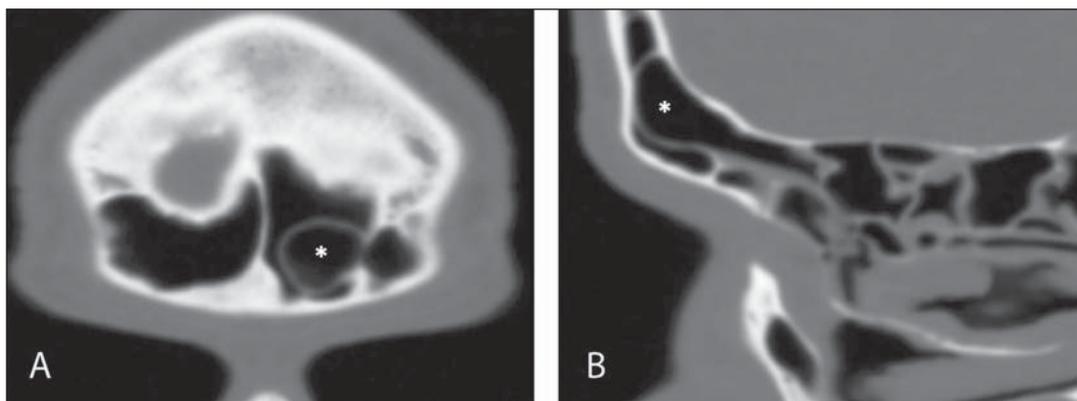
Figure 8. Coronal (**A**) and sagittal oblique (**B**) images demonstrating a type IV frontal cell (asterisk). Type IV frontal cells are generally single and are isolatedly located within the frontal sinuses.
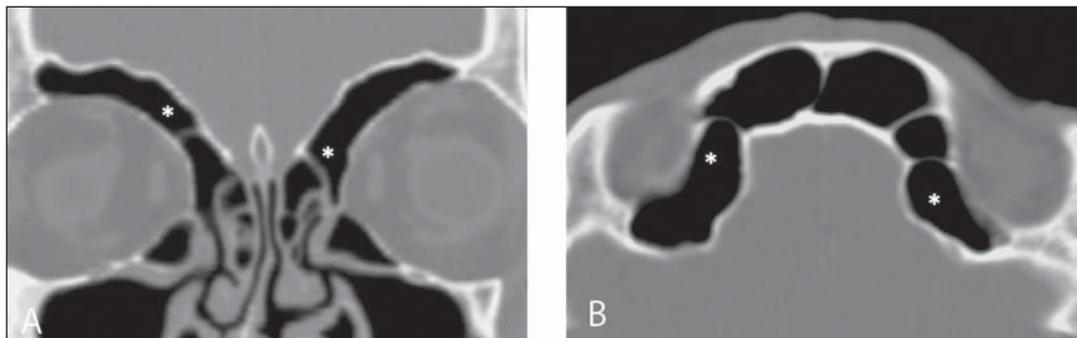
Figure 9. Coronal coronal (**A**) and axial (**B**) images demonstrating supraorbital ethmoid cells (asterisks). Such cells pneumatize above the orbits floor, sometimes causing the impression of septate frontal sinuses. Supraorbital ethmoid cells are best identified on coronal and axial views.

ure 11). Onodi cells are intimately related to the optical nerves and internal carotid arteries, hence their clinical relevance in the event of sinusopathy[13].

Frontal bullar cell

Frontal bullar cell is the ethmoidal cell located above the ethmoid bulla that pneumatizes along the skull base towards the frontal sinus, sometimes causing convexity in its floor (Figure 12)[7,23]. Accord-

ing to Park et al., its prevalence may reach 10%[18].

Suprabullar cell

Suprabullar cells are ethmoid cells also located above the ethmoid bulla, which, as the frontal bulla cells, are best visualized on sagittal reformations. The suprabullar cell differentiates from the frontal bullar cell because its anterior edge does not extend towards the frontal sinus (Figure

13)[7,25]. According to Park et al., its prevalence is around 8%[18].

Ethmoid bulla

Classically, ethmoid bulla is described as the largest and most constant of the anterior ethmoid cells. It is an intramural ethmoid cell in intimate relationship with the ostiomeatal unit, embracing the lamina papyracea and which drains into the middle meatus through a pneumatized retrobullar tract[26] (Figure 1). Because of its consistency, the ethmoid bulla is an important repair for the rhinologist. In addition, together with the uncinate process, it defines the hiatus semilunaris, the exit pathway to the ethmoidal infundibulum, located on the lateral wall of the nasal cavity[13–15]. Wright & Bolger[26], after detailed macroscopic analyses of 14 nasal cavities in 8 specimens, have observed that all the ethmoid bullas presented incomplete posterior walls independently from their pneumatization degree and from the presence of internal septations. According to those authors, it is debatable whether the ethmoidal bullas actually represent a true cell or should be considered a lamella. In spite of being known as ethmoid bulla since 1893 (Zuckerkandl[27]), according to the authors, "from an anatomical perspective, bulla is not, however, the best description for such a structure"[26].

CONCLUSION

The development of the ethmoid labyrinth is a heterogeneous and variable process. From such an intricate process, two specific cell groups originate: the extramural ethmoid cells and the intramural ethmoid cells. Computed tomography with

Figure 10. Haller's cells (asterisks) are ethmoid cells that pneumatize inferiorly to the orbits towards the interior of the maxillary sinuses. In special situations such cells may reduce the ostiomeatal unit and predispose to obstruction of the maxillary infundibulum.
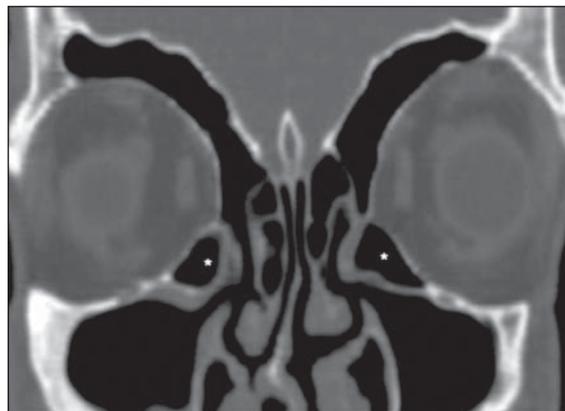
Figure 11. Coronal image demonstrating an Onodi cell (asterisk) immediately below the optical nerve channel. The "two-floor" aspect of sphenoidal sinus in the coronal plane is useful in the identification of this type of cell.
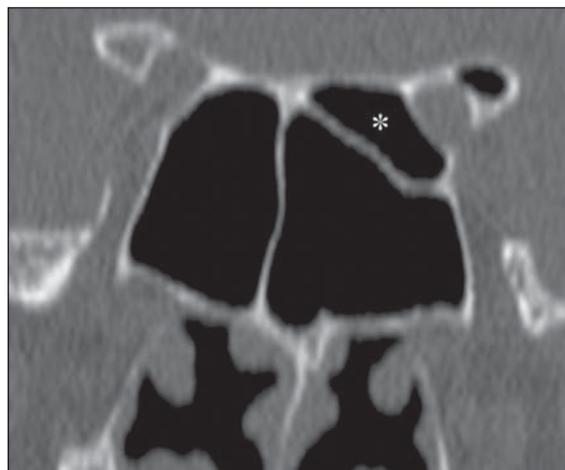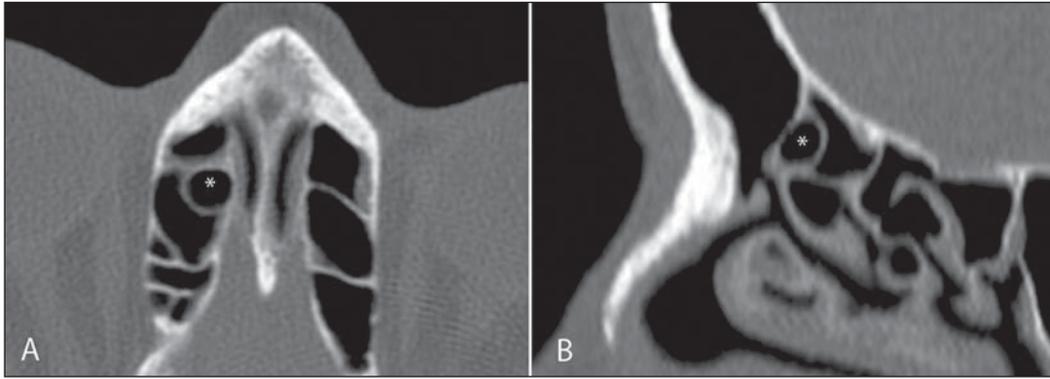

Figure 12. Sagittal oblique (**A**) and axial (**B**) images demonstrating a frontal bulla cell (asterisk) and its relationship with the skull base and the frontal sinus. The anterior edge of a frontal bulla cell does not extend into the frontal sinuses.

Figure 13. Axial (**A**) and sagittal (**B**) images demonstrating frontal bulla cell at right (asterisk). The frontal bulla cell differentiates from the suprabullar cell as its anterior edge extends towards the frontal sinus.

multiplanar reformation provides greater anatomical detail and higher spatial resolution for the study of the paranasal sinuses anatomy. Recognition of the anatomical variants in paranasal sinuses studies may be useful for the assisting physician in the management of patients with sinusopathies. The improvements in minimally invasive endoscopic surgeries of the paranasal sinuses will probably increase the demand for reports with more anatomical details of the paranasal sinuses and their variants.

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