European Review for Medical and Pharmacological Sciences 2012; 16: 912-918

3D cone beam (CBCT) in evaluation of frontal recess: findings in youth population

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Abstract – BACKGROUND, Frontal recess is the anatomical region most difficult to manage in endoscopic frontal sinus surgery due to the extreme variability of the cell patterns that may be observed in this area. CT has always been the gold standard in preoperative evaluation, but especially in the assessment of the causes of frontal recess obstruction and surgical failure. In recent years, this accredited and reliable method has been complemented by Computed Tomography Cone Beam (CBCT), which provides similarly detailed anatomical information with a lower dose of radiation.

AIM, The purpose of this paper is to analyze and validate the use of CBCT in the study of frontal recess, and especially its anatomical variants in a youth population.

MATHERIALS AND METHODS, We analyzed 500 CBCT images of paranasal sinuses of young subjects with sinus inflammation pathology between 2009 and 2011.

RESULTS, We observed that the method is very sensitive in detecting anterior and posterior recess cells, also in a youth population and then report on some significant images.

CONCLUSIONS, We confirm the validity of CBCT, which by virtue of its sensitivity and specificity may be used in the analysis of frontal recess pathologies, especially when a young population is involved.

Key words

Frontal recess, TC Cone Beam, Endoscopic sinus surgery.

Introduction

Frontal recess is the anatomical region most difficult to manage in endoscopic frontal sinus surgery due to the extreme variability of the cell patterns that may be observed in this area. Frontal recess is a complex hourglass-shaped space whose most narrow point is at the level of the frontal osteum. This space may be pneumatized by various *cells anterior* to the recess, like agger nasi cells (ANCs) and type 1-4 frontal cells (FCs), and *cells posterior* to the recess, like suprabullar cells (SBCs), frontobullar cells (FBCs), supraorbital ethmoid cells (SOECs), interfrontal sinus septal cells (IFSSs), and the terminal recess (RT)[1,2].

During functional endoscopic sinus surgery (FESS) of the recess, the complete removal of these cells is necessary to ensure adequate opening of the frontal sinus and thus provide for physiological drainage and ventilation. The incomplete removal of cells in the frontal recess is one of the most common causes of FESS failure[3]. A detailed understanding of the radiological anatomy of the frontal recess is, thus, critical to the preoperative evaluation and treatment of frontal sinus pathology, both to increase the efficacy of surgical treatment and minimize the risk of complications.

CT has always been the gold standard in preoperative evaluation, but especially in the assessment of the causes of frontal recess obstruction and surgical failure. Multiplanar reconstruction (MPR) is now routinely used to identify potential causes of frontal recess stenosis and evaluates all of the cell anatomical variables[4,5].

In recent years, this accredited and reliable method has been complemented by Computed Tomography Cone Beam (CBCT), which provides similarly detailed anatomical information with a lower dose of radiation[6]. The continuous increase in sinus inflammation pathology and the frequent recourse to endoscopic sinus surgery also in young subjects (cystic fibrosis, recurrent ethmoid frontal sinusitis, etc.), led us to evaluate the capacity of CBCT for morphological analysis of the frontal recess anatomy, with a lower use of radiating energy. Considering that the development of the frontal sinus and frontal recess is virtually complete at age 15-16, the purpose of this paper is to analyze and validate the use of CBCT in the study of frontal recess, and especially its anatomical variants in a youth population[7,8].

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Patients and Methods

We analyzed 500 CBCT images of paranasal sinuses of young subjects with sinus inflammation pathology between 2009 and 2011. The patients were referred to us by Day-Hospitals, which they visited mostly due to nasal obstruction syndromes and/or headaches or persistent symptoms of frontoethmoidal sinusitis. The patients were 285 males and 215 females, aged between 15 and 21 years. Patients with evident signs of ongoing inflammation were subjected to a cycle of antibiotic therapy (ampicillin/clavulanic acid for 10 days), inhaled local steroids and antihistaminics (if the subjects had allergies). This approach was consistent with standard protocols already in use for the selection and referral to CT imaging of paranasal sinuses with an ongoing inflammation, so as to decrease the risk of overestimating mucosal thickness due to the inflammation; the analysis was performed two weeks after the end of therapy[9].

CBCT was performed without the administration of contrast medium, with the support of last-generation New Tom VGi QR (Image Works, Verona, Italy). We used the following technical parameters to volumetrically acquire the region to be analyzed: kV110, mA 8, 20 sec (pulsated mode), focal spot 0.3 mm, FOV (field of view) 15 cm × 15 cm, amorphous silica flat panel. A 20-second acquisition determined an exposure of approximately 3.5 seconds (pulsated), with an estimated dose of about 50 micron Sv; this dose is considerably lower than spiral CT.

Images were acquired with the patient in the standing position with the Frankfurt plane perpendicular to the rotation axis and centering being performed by laser. During the rotation of the focus-detector complex, about 600 frames are acquired, which allow for a console reconstruction on the axial, coronal, sagittal and possibly dedicated plane. Patients are invited to cleanse their nasal cavities prior to image acquisition.

We investigated cell variables responsible for the pneumatization of the frontal recess, both as a preoperative analysis before surgery and to evaluate medical treatment. The images were interpreted by two independent readers, a senior ORL surgeon and a senior radiologist.

Results

In the 500 cases examined with CBCT of paranasal sinuses, we investigated the anatomical variants of frontal recess cells, already amply described in the literature in adult population by means of classic multiplanar CT images. We observed that the method is very sensitive in detecting anterior and posterior recess cells, also in a youth population. Following a description and anatomical definition, we then report on some significant images.

Agger Nasi

These cells are pneumatized in 78-98% of subjects[10], and are considered the anterior-most ethmoid cells, thus representing the anterior limit of the frontal recess[11]. If they pneumatize posteriorly, they may narrow the frontal recess[1]. In the coronal plane, their position is inferior to the frontal sinus and anterior to the middle turbinate (Figure 1).

Type 1-4 Frontoethmoid Cells (Kuhn)

Together with agger cells, frontoethmoid cells make up the anterior group of cells in the recess. They were observed in 20-33% of patients, and are thus a frequently occurring anatomical variant[12]. The anterior limit is constituted by the anterior wall of the frontal recess. They do not extend posteriorly towards the skull base.

Kuhn's universally accepted classification breaks them down into 4 types[13].

Types 1-3 are all located above the agger nasi cells:

- *Type 1* was found in up to 37% of frontal recesses[10,12]. A type 1 cell was defined as a single anterior ethmoid cell within the frontal recess above the agger cell (Figure 2).
- *Type 2* cells were found in up to 19% of recesses. Type 2 cells were defined as a strand of one or more anterior ethmoid cells above the agger nasi cells (Figure 3).
- *Type 3* cell (6-8%) is a single cell located above the agger nasi but that extends superiorly from the recess, through the ostium, up to the frontal sinus (Figure 4).
- *Type 4* cells (2-4%) are isolated cells located within the frontal sinus. They are confined at an anterior level by the anterior frontal table. The posterior wall of these cells is the free partition in the frontal sinus.

Frontobullar, suprabullar and supraorbital cells constitute *the posterior group* of cells in the frontal recess.

Frontobullar Cells

Frontobullar cells derive from the pneumatization of the anterior skull base in the posterior

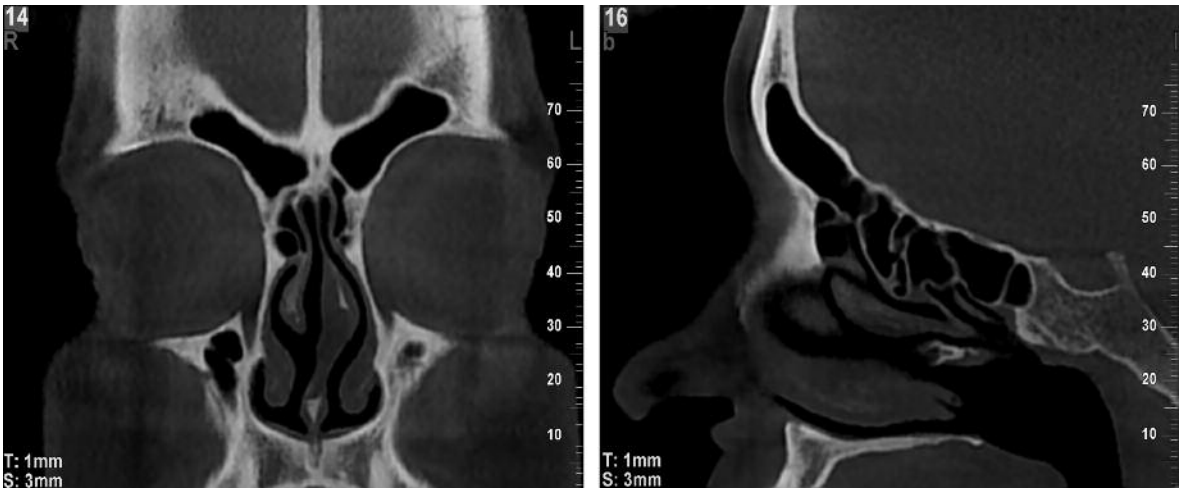

Figure 1. Agger nasi cells (coronal and sagittal plane).

part of the frontal recess with an extension into the frontal sinus. These cells are located above the ethmoid bulla. When present, they represent part of the posterior limit of the recess and of the frontal sinus, and may thus narrow the recess posteriorly (visible in the sagittal plane) (Figure 5).

Suprabullar Cells

Suprabullar cells are very similar to frontobullar cells, the only difference being that suprabullar cells are located completely below the osteum of the frontal sinus and that they do not extend into the frontal sinus. Like frontobullar cells, suprabullar cells are located above the bulla and delimit part of the posterior wall of the frontal recess. These cells are correlated with the suprabullar recess (whose middle-lower portion is the lateral sinus). They may contain the anterior ethmoidal artery in conjunction with supraorbital cells (visible in the sagittal plane).

Supraorbital Cells

Supraorbital cells are anterior ethmoid cells which extend superiorly and laterally above the orbit from the frontal recess. These cells (up to 15% of subjects) express the pneumatization of the orbital plate of the frontal bone posterior to the frontal recess and the frontal sinus. At times, they may simulate the presence of a concamerated multiple frontal sinus (Figure 6).

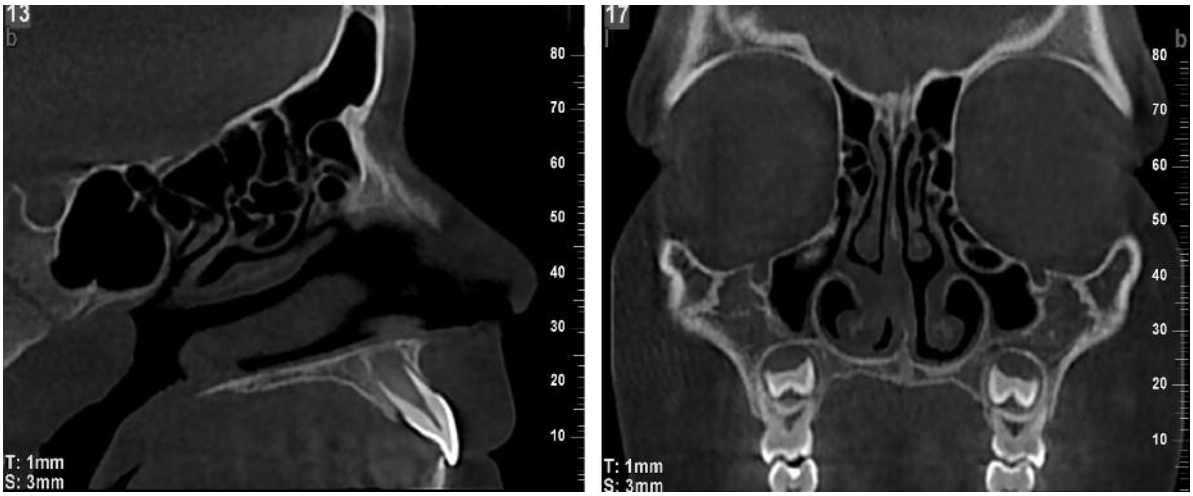

Figure 2. Frontoethmoid cells type 1 (coronal and sagittal plane).

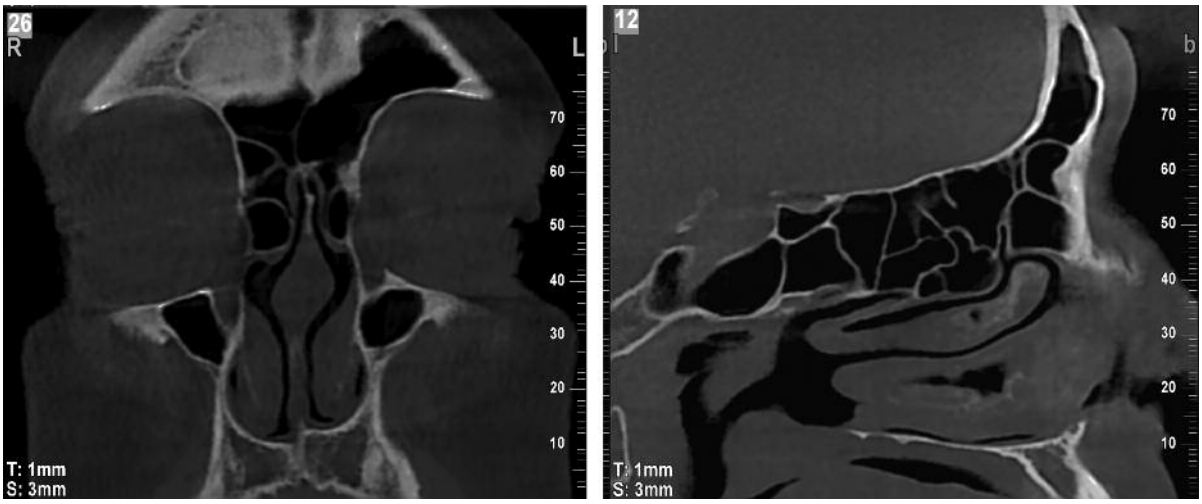

Figure 3. Frontoethmoid cells type 2 (coronal and sagittal plane).

Interfrontal Sinus Septal Cells

These cells depict the pneumatization of the frontal intersinus septum. When the pneumatization is very estensive, it may reach the crista galli (visible in the axial and coronal plane).

Discussion

The anatomy of paranasal sinuses is significantly different in children and adults, with the frontal sinus reaching its maximum size at 18 years of age[14,15].

The anatomical variability of frontal recess cells is related to particular embryological features of the ethmoid sinus: the ethmoid derives from cartilage. Unlike the other sinuses which derive from septation and that histologically comprise a rigid and robust bony tissue, ethmoid cells with thin bony lamellae may easily migrate to other paranasal sinuses[11,16]. When this extramural extension is directed upwards, it generates the various cell combinations observed in the frontal recess (frontal cells, supraorbital cells, etc.). The preoperative identification of the frontal recess anatomical variants may contribute to greatly optimizing surgery and reducing intraoperative risks, causes of failures and possible complications[17]. Until quite recently, high definition multiplanar CT was the gold standard[18,19] proposed in preoperative anatomical evaluations, mucosal pathologies, anatomical ratios and bone

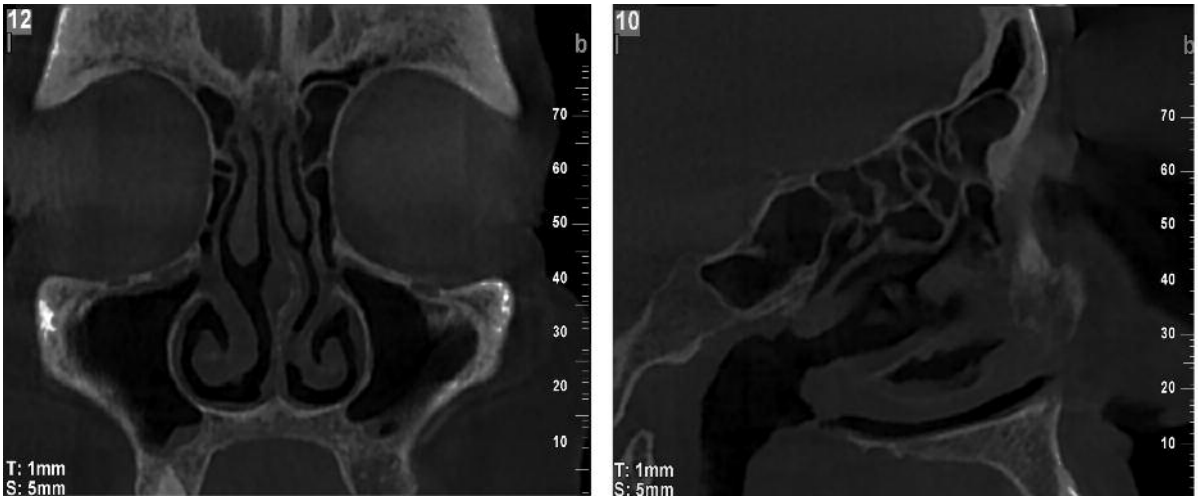

Figure 4. Frontoethmoid cells type 3 (coronal and sagittal plane).

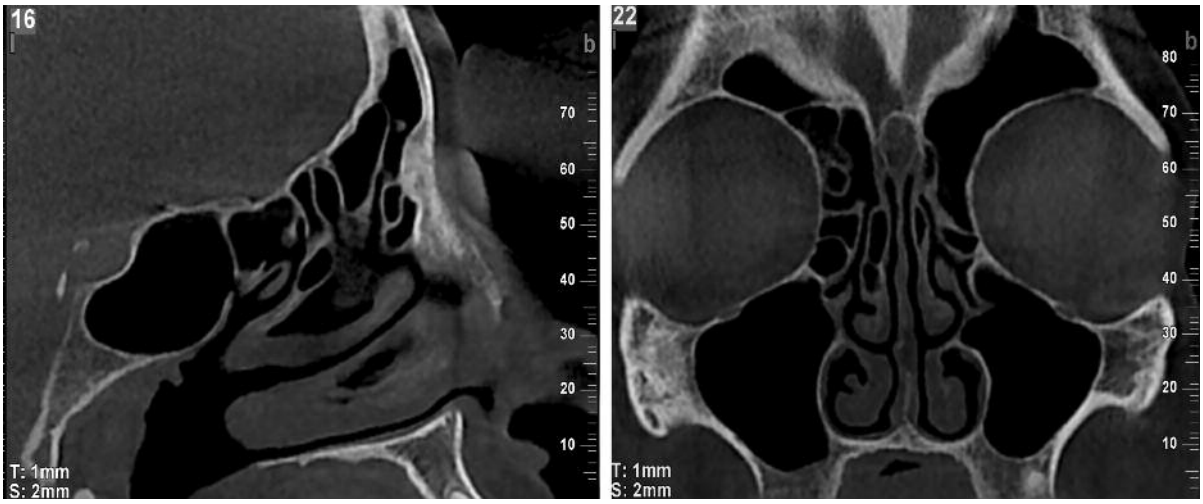

Figure 5. Frontobullar cells (coronal and sagittal plane).

integrity[20-22]. The classification and identification of the different cells in the frontal recess allows for a better understanding, facilitates the exchange of information and the comparison between different surgical techniques.

Recent studies[21] have shown that frontoethmoid cells posterior and posterolateral to the frontal recess (suprabullar, frontobullar and supraorbital cells) may be more significantly related to the development of frontal sinusitis compared to cells anterior to the frontal recess (agger nasi and Kuhn frontal recess cells). Some Authors attribute the failures of systemic and local medical therapy in this pathological location to an obstruction at the level of the frontal recess[1].

Moreover, many cases of relapsing frontal sinusitis following FESS may be attributed to frontal recess stenosis[23]. One of the most frequent causes of stenosis is the inadequate removal of agger nasi and frontal recess cells[24,25]. Not only are residual pneumatized cells likely to obstruct the frontal recess[26,27], but they may actually serve as the basis for tissutal fibrosis[28].

The exact prevalence of frontal sinusitis following FESS, therefore, has not been established. However, in the literature some Authors have reported persistent frontal sinusitis symptomatology and pathology in 2-11% of cases with a short-term follow-up[29,30], while the failure rate reaches 15-20% in long-term follow-up[27], with

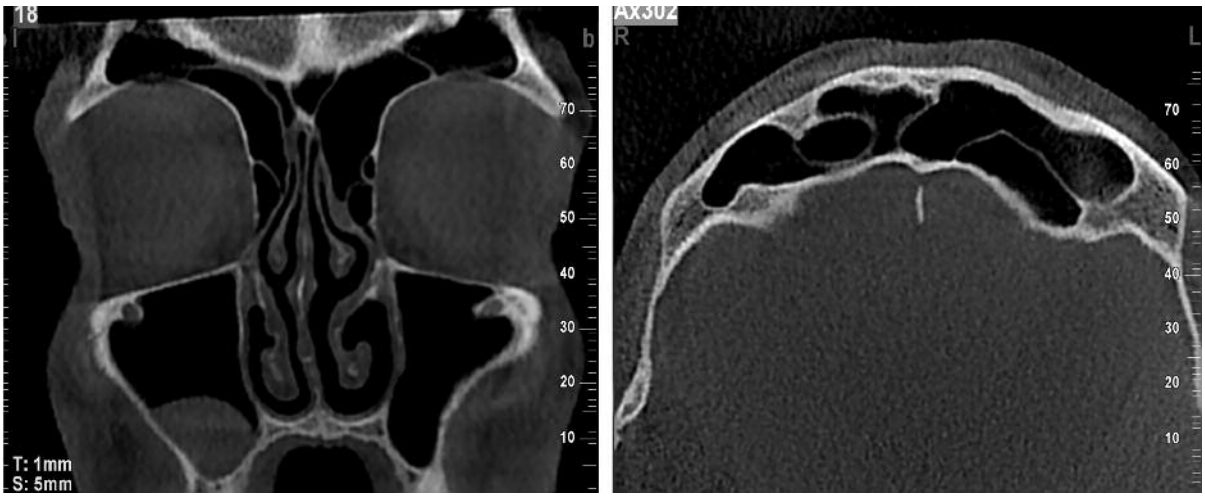

Figure 6. Supraorbital cells (coronal and axial plane).

11% of patients requiring revision surgery[31]. Following endoscopic revision surgery, preserved agger nasi cells were reported in 49-93% of cases[32]; unremoved frontal recess cells in 11.9%[28], and incomplete anterior ethmoidectomies up to 64% of cases. Del Gaudio et al[12] observed frontoethmoid cells (I-IV) through CT imaging in 21.9% of cases subjected to revision surgery, and frontal intersinus cells in an additional 11.4% of frontal recesses.

Only an accurate radiological anatomical definition postoperatively can guide the surgeon towards a complete removal of recess cells also with the assistance of video navigation[33]. An accurate radiological definition is even more necessary when evaluating medical treatment outcomes in sinus pathology in a youth population. Indeed, only imaging techniques can certify the resolution of the pathological condition. Also, frequently resorting to multiplanar CT may determine anxiety, concerns and uncertainty in the parents of young patients. These aspects should help us to determine whether CBCT is viable, considering the sensitivity and specificity of this method in the analysis of frontal recess cells.

Recently published studies in the literature have reported on the use of CBCT in the evaluation of frontal recess anatomy[34-36]. We have already stressed that CT has always been absolutely crucial in the identification and anatomical characterization of the frontal recess, and has thus always required multiplanar images[37]. According to our caseload, CBCT may definitely take on the same role in the planning of endoscopic surgery of the frontal recess, making it possible to obtain reconstructions as thin as 0.30 mm.

In our analysis of the 500 young patients, we found CBCT to be an accurate method to evaluate the various frontal recess cells, which were extremely superimposable with images traditionally obtained with CT Fan Beam. This technique may also be used in computer-assisted navigation surgery, which allows for intraoperative guidance in real time, thus reducing the risk of disorientation and iatrogenic damage[38,39]. The system provides a good resolution of bony tissues and a fair resolution of soft tissues, with a low radiating does, which thus allows a repeated intraoperative use[34]. In patients affected by sinus disease and particularly in young subjects, pharmacological and/or surgical therapeutic effects should be monitored by CBCT for dose-related reasons, as described previously.

In accordance with Kew et al[10], we too observed that the sagittal plane is the most useful for the characterization of frontal recess anatomy, especially of ANC, FC, SBC and FBC cells.

In conclusion, we confirm the validity of CBCT, which by virtue of its sensitivity and specificity may be used in the analysis of frontal recess pathologies, especially when a young population is involved.

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