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Original Article

Frontal sinus outflow tract: Multi-detector CT assessment

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ABSTRACT

Introduction: Knowledge of the normal anatomical variants is critical for safe endoscopic navigation during FESS. The frontal sinus outflow tract FSOT includes the frontal infundibulum, ostium and recess respectively in the direction of the drained secretions. The original classification of Bent and Kuhn (B&K) divided the frontal infundibulum cells into four categories. Lund and Mackay scoring system (LMS) is a radiological score that offer effective evaluation of sinusitis. The aim of this work was to revise the radiological classification of frontal air cells by B&K and to correlate it with the clinic-radiological LMS scoring system.

Methods and results: This study was carried out on 200 sides divided into two equal groups. Three types were added to the original B&K description; Type 0 (Not identified frontal cells), Combined type and Couldn't be assessed type. The percentages of each type were calculated according to modified B&K classification and correlated to LMS.

Conclusions: The main limitation of the original B&K classification system is to accurately classify frontal air cells in cases with extensive opacification of the frontal sinus (LMS 2) as well as in cases of complicating sino-nasal polyposis. Three new types are suggested to be added to the original B&K classification system.

1. Introduction

Anatomy of the frontal sinus is challenging for both radiologists and surgeons. Deep knowledge of the normal anatomical variants is critical for safe navigation through the nose and para-nasal sinuses during functional endoscopic sinus surgery (FESS) [1,2].

There is great variability in both development and pneumatization of the frontal air sinuses [1,2]. The frontal sinuses represent funnel-shaped structures with their ostia located in the most dependent portion of the cavities [3,4]. Both the frontal sinuses and ethmoid air cells share a common embryological and anatomical relationships. Several authors even referred to the frontal sinus as a "large ethmoidal air cell" or upper limit of the complex ethmoid labyrinth [5–7].

Historically, the frontal sinus outflow tract (FSOT) was described in many ways and given names, depending on the surgical approach or the perspective by which it was visualized. Today, most authors agree that the FSOT includes the frontal infundibulum, the frontal ostium and the frontal recess respectively in the direction of the drained secretions from the sinus towards the anterior aspect of the middle nasal meatus. These structures resemble an hourglass shape [8–10] (Fig. 1).

The frontal recess is an inverted funnel within the anterior ethmoid complex through which the frontal sinus drains. The apex of the funnel is the frontal ostium. These structures could be easily identified on sagittal CT images. The frontal sinus infundibulum is formed by the most inferior aspect of the frontal sinus representing a funnel that points towards the ethmoid in a postero-medial direction. Both posteromedially angulation and the maximum diameter of this funnel may vary greatly between patients, or even between sides in the same patient [11–17].

For more complexity, wide variety of anterior ethmoidal cells can populate this area and termed *"The frontal recess cells". They include the agger nasi cell, supra-orbital ethmoid cell, inter-frontal sinus septal cell, frontal bulla cell, suprabullar cell, and 4 types of "Bent and Kuhn" frontal cells* [12].

These cell populations might be present in any patient and might alter the normal mucus drainage via the FSOT. An endoscopic surgeon not aware of these cells might confuse them with the frontal sinus. This could result in a surgical failure due to inadequate reestablishment of frontal sinus outflow drainage and continued frontal sinus symptoms (Failed FESS) [12–16].

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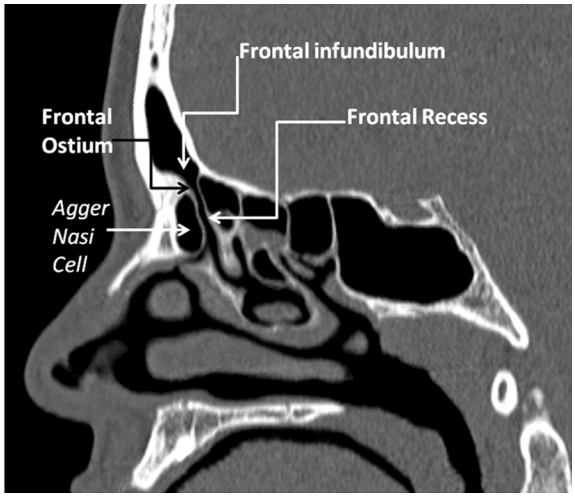

Fig. 1. Direct sagittal para-midline MDCT scan in bone window. It shows the frontal sinus outflow tract (FSOT) including the frontal infundibulum, ostium and recess respectively in the direction of the drained secretions from the sinus towards the anterior aspect of the middle nasal meatus. Note the anterior position of the agger nasi relative to the frontal recess. In this example, there was no frontal recess (Type 0). To be noted, these anatomical structures showed wide anatomical variability and not necessarily showing bilateral symmetry or even clear demonstration as in this example.

Bent and Kuhn divided the frontal infundibulum cells into four categories, according to their relationship to the agger nasi cell and the orbital roof [12]. Type 1 was defined as a single anterior ethmoid cell within the frontal recess above the agger cell. Type 2 was defined as a strand of two or more anterior ethmoid cells above the agger nasi cells. Type 3 represented a single cell located above the agger nasi and extending superiorly from the recess, through the ostium, up into the frontal sinus with occupation of nearly 50% of the sinus. Type 4 described as a single, but isolated cell existing completely within the frontal sinus and has no connection to the frontal recess. These cells are confined anteriorly by the anterior frontal table. The posterior walls of these cells are free partitions within the frontal sinus [12–22].

Under physiologic conditions, the sinuses are normally sterile. Secretions leave the sinuses by the unidirectional ciliary movements via the ostia towards the nasal cavity. Obstruction of the natural sinus ostia blocks the mucus drainage and invites contamination with pathogens. The ostia can be blocked either mechanically (as by mucosal swelling, polyps, foreign bodies, deviated septa, or tumors) or functionally due to impaired ciliary function [23–28]. Frontal cells representing anatomical variants that could intervene with the patency of FSOT and consequently jeopardizing the sinus to infection.

Lund and Mackay (LMS) scoring system still used as a standard rhinological staging system for sinusitis. It is a radiological score that offer both effective evaluation and good communication with other specialists about the presence and severity of sinusitis [29–31]. Each side of the sinuses was divided into six portions, including maxillary sinus, anterior ethmoid sinuses, posterior ethmoid sinuses, sphenoid sinus, frontal sinus, and ostiomeatal complex. The severity of sinus mucosal inflammation or fluid accumulation for the above six portions were unilaterally and bilaterally summed to respectively give separate unilaterally and bilaterally total LMS values [29–33]. MDCT scans should be obtained only after acute sinusitis episodes have been adequately treated. Waiting for at least 6 weeks before obtaining a scan is recommended to determine the patient's baseline disease status [34].

Functional endoscopic sinus surgery (FESS) is a minimally invasive technique used to restore sinus ventilation and normal function. In this technique the sinus air cells and sinus ostia are opened under direct endoscopic visualization. Among all sinuses, the frontal sinus is the most difficult to treat endoscopically owing to its location and complex anatomy. The frontal recess is a location that can be difficult to visualize at endoscopy. Since its introduction over 2 decades ago, FESS has revolutionized the surgical management of chronic sinusitis. When FESS failure occurs, it is typically due to postoperative scarring or unaddressed outflow tract obstruction in the region of the frontal recess [35–38].

MDCT is superior to MRI in the evaluation of the bony anatomical structures of the skull base and para-nasal sinuses [39–40]. It has become indispensable in evaluation of patients before and after FESS [35–38].

2. Aim of the work

The aim of this work was to revise the radiological classification for frontal air cells by Bent and Kuhn [12] and to correlate it with the clinic-radiological Lund and Mackay (LMS) scoring system [29].

3. Subjects and methods

This study was carried out on 100 individuals. Both design and methodology were reviewed and accepted by the local institutional medical ethics committee.

Group A: 50 patients were referred to our MDCT unit complaining from frontal sinusitis.
Group B: Another 50 patients with matched age and sex were uses as control group. This group of patients was not complaining from frontal sinusitis. The MDCT examination of the head and neck were performed for other reasons as headache, bleeding, trauma of other orbital or hearing problems.

Each side (right and left) was examined as separate entity. Total of 200 sides were studied.

3.1. Exclusion criteria

1. Patients with any contraindications to MDCT.
2. As complete development and pneumatization of the frontal sinus are not completely achieved until adulthood, patients below 18 years old were excluded from this study.
3. Patients with invasive lesions obscuring normal anatomy as malignancy and fungal sinusitis.
4. Other types of frontal recess cells like frontal inter-sinus septal cells, supraorbital cells, suprabullar cells and frontobullar cells were not included in this study.
5. Lund and Mackay score was only calculated for the frontal sinus. Other sinus groups were not included.

All examinations were performed by using a high resolution MDCT scanner, General Electric (GE) Bright Speed eight rows detector scanner. The patients were in the supine position. The head was strapped to the head rest and positioned as symmetrically as possible. The patients were informed about the investigation and instructed not to move during examination. A lateral scout view was taken and used for planning. Axial images were taken with 0Tilt. The following parameters were applied 120 mA, 120 Kvp, 1.2 mm slice thickness, large field of view (FOV) and 1.35 pitch and matrix of 512 × 512. Axial scans were obtained from the upper margin of the frontal sinus down to the lower walls of maxillary sinus. Coronal sections were reconstructed as perpendicular as possible to the axial plane. The images were displayed in standard soft tissue and bone windows. All images were prospec-

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