Multiplanar Computed Tomographic Analysis of Frontal Recess Cells

Effect on Frontal Isthmus Size and Frontal Sinusitis

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Background: Frontal recess anatomy can be very complex, with accessory cells such as frontal, agger nasi, and intersinus septal cells encroaching on the frontal recess and possibly contributing to obstruction of the frontal sinus. In this study, we determined the prevalence of these cells and their relationship to frontal sinusitis in patients who have (revision group) and have not (primary group) had previous sinus surgery.

Design: Multiplanar computed tomographic images were reconstructed on a computer workstation to determine the presence of frontal, agger nasi, and intersinus septal cells and frontal sinusitis. We also measured the diameter and area of the frontal isthmus for each sinonasal cavity. We were able to retrieve 106 of 117 images from a surgical database encompassing the previous 2 years.

Setting: Tertiary care academic practice of the senior author.

Results: Frontal cells were found in 25.5% of frontal recesses, including 29.6% of sides in the primary group and 21.9% of sides in the revision group. We identified 33.0% of patients as having unilateral or bilateral frontal cells. Type I cells were the most common cell (18.4% of primary sinuses). The presence of frontal sinusitis and the diameter and area of the frontal isthmus were not significantly different for those patients with compared with patients without frontal cells. Intact agger nasi cells were identified in 86.7% of primary sinuses and 53.5% of revision sinuses. There was no increased incidence of frontal sinusitis in patients with persistent agger nasi cells in the revision group.

Conclusions: When we evaluated multiplanar reconstructions, we identified frontal cells in 33.0% of patients overall, which was more common than previously reported. The findings of agger nasi cells indicated that these cells were likely addressed in less than half of previous sinus procedures. However, frontal cells and retained agger nasi cells were not associated with a higher incidence of frontal sinusitis, and there was no association between the size of the frontal isthmus and the presence of frontal sinusitis. Although anatomic variations in the frontal recess are likely to play a role in frontal sinusitis, mucosal inflammatory processes are likely to be a much more important etiologic factor.


Surgery for inflammatory disease of the frontal sinus is challenging because of the tight confines and variable anatomy of the frontal recess. Endoscopic techniques allow for better visualization, and fine instrumentation allows for less mucosal trauma and better mucosal preservation with the hope of better outcomes. Because of the narrow confines of the frontal recess, care must be taken to avoid undue trauma and to restore adequate ventilation to the frontal sinus. This involves removal of all possible causes of obstruction in the frontal recess. Preoperative recognition of anatomic variations is paramount to performing an adequate and successful procedure in the frontal recess. Failure to remove obstructing cells in the frontal recess adequately may lead to persistent or recurrent frontal sinus disease.

The complex and variable anatomy of the frontal recess can be difficult to appreciate with standard axial or coronal computed tomographic (CT) images of the sinus. The advent of multiplanar CT imaging with the addition of sagittal reconstructions greatly improves the understanding of the frontal recess.12 In addition to the inherent variation in size and diameter, the presence of various accessory cells such as frontal sinus cells and intersinus septal cells also contributes to the anatomic complexity of the frontal recess and the potential for obstruction of the frontal sinus.3 Persistence of anatomic causes of obstruction of the frontal re-
cess has been reported as a major cause of failure of endoscopic sinus surgery.4-6

Frontal cells have been described in the literature as early as 1916.7 It was not until the most recent decade that Bent et al,3 in a report on frontal cells as a cause of frontal sinus disease, categorized these cells into 4 types on the basis of their number and the pattern of pneumatization into the frontal sinus. All frontal sinus cells are located superior to the agger nasi cell. A type I frontal sinus cell is a single cell located above the agger nasi cell (Figure 1). Type II cells are multiple-tiered cells above the agger nasi cell (dashed arrow). Type III cells are single frontal cells located above the agger nasi cell that pneumatize into the frontal sinus (Figure 2). Type IV cells are completely contained in the frontal sinus (Figure 3 and Figure 4). Frontal sinus cells located above the agger nasi cell that pneumatize into the frontal sinus (Figure 2). Type III cells are single frontal cells located above the agger nasi cell that pneumatize into the frontal sinus (Figure 3 and Figure 4). Type IV cells are completely contained in the frontal sinus.
without an obvious connection to the frontal recess (Figure 5). Not all cells that can be identified in the frontal recess fit into one of these categories, but this is the most specific and inclusive staging system available for these cells.

The purpose of this study was to determine the frequency of occurrence of frontal sinus cells. We also wanted to determine whether the size of the frontal isthmus or whether the presence of frontal sinus cells is related to the presence of frontal sinus disease in patients undergoing sinus surgery. In addition, we sought to determine whether agger nasi cells and frontal sinus cells were being addressed at initial surgery and whether these cells were related to persistence of frontal sinusitis after initial surgery of the frontal recess.

**METHODS**

We identified patients from the practice of the senior author (J.M.D.) who had undergone CT of the sinuses with an image-guided protocol. During the past 2 years, 117 patients were identified and 106 image-guided protocol scans were available for review. Scans were performed on GE Lightspeed CT scanners (GE Medical Systems, Milwaukee, Wis) with overlapping 1-mm-thickness axial cuts. Imaging was performed without gantry tilt and with the head in the neutral position. The images were then forwarded into an imaging laboratory and evaluated using a standard triplanar reconstruction protocol on a Vitrea workstation (Vital Images, Plymouth, Minn). Contrast, brightness, and imaging angles could be adjusted on the workstation to improve bony detail, which was particularly useful in significantly diseased sinuses. We then evaluated images for the presence and classification of agger nasi cells, intersinus septal cells, and frontal sinus cells. All images were evaluated for the presence of frontal sinusitis. In this study, frontal sinusitis was considered to be present when the frontal sinus had mucosal thickening of greater than 3 mm involving the entire sinus or the dependent portions of the sinus.

The anterior-to-posterior (A-P) diameter and area of the frontal isthmus were also determined. The diameter and area were measured using tools that are standard in the workstation software. The diameter of the frontal isthmus was determined by using a sagittal reconstruction and measuring the distance between the most posterior projection of the frontal beak to the junction of the posterior wall of the frontal sinus and the anterior ethmoid roof (Figure 6). The area of the frontal isthmus was determined in the following manner. An axial plane image was created in a plane that paralleled the plane used to measure the frontal isthmus diameter. This method rendered an image that was not a true axial image but rather an image that was tilted slightly upward in the A-P plane. The margins of the isthmus were outlined using the pencil function of the software (Figure 7). The software then calculated the area of the frontal isthmus.

Data were then analyzed for multiple variables using a 1-sided t test. A value of $P<.05$ was considered significant for all measurements.
We identified 117 CT images, 106 of which could be retrieved from the electronic archives for analysis and reconstruction. Of the study patients, 54 were men and 52 were women. Left and right sinuses were considered individually. We identified 98 sinuses that underwent primary procedures (primary group) and 114 that underwent revision (revision group) for a total of 212 sinuses from 106 patients.

In this study, frontal cells were categorized according to the classification of Bent et al.\(^3\) We differentiated type I frontal sinus cells from type III cells by determining whether the cell crossed the plane of the frontal isthmus. If the cell was entirely below this plane it is considered a type I cell, whereas if it extended superior to this plane it was defined as a type III cell.

Frontal cells were found in 25.5% of frontal recesses overall, including 29.6% of the primary sides and 21.9% of the revision sides. Frontal cells were found in 33.0% of patients, with an equal number of unilateral and bilateral frontal cells. Type I cells were the most common, found in 15.6% of cases overall. Type II cells were found in 1.4% of cases; type III, in 6.1% of cases; and type IV, in 2.4% of cases. There were no significant differences in the percentage of frontal cells present between the revision and primary sides (Table 1). There was no difference in the frequency of frontal sinusitis in sides with frontal cells compared with sides without frontal cells.

The diameters and areas of the frontal isthmus are listed in Table 2. There were no statistically significant differences in the diameters and areas of the frontal isthmus between sinuses with various types of frontal cells, with the exception of primary sinuses with type IV cells having a statistically larger A-P diameter than the other sinuses.

Table 3 compares the diameter and area of the frontal recess of primary and revision sides with respect to the presence of frontal sinusitis. A significant difference is seen in the primary sides between healthy and infected sinuses in both the A-P diameter and the area of the frontal recess, with the uninfected group being statistically significantly smaller. No significant difference was seen in revision sides.

According to our findings on CT images, an agger nasi cell was present in 86.7% of the 98 primary sides and 53.5% of the 114 revision sides. Interfrontal septal cells were present in 12.2% of primary cases and 11.4% of revision cases. A significant difference was found between the percentage of agger nasi cells in primary vs revision sides. No difference was found in the presence of frontal sinusitis with respect to the presence of agger nasi cells in patients in the primary or the revision group. Inter-sinus septal cells were found in similar frequency in primary and revision sinuses (12.2% and 11.4%, respectively).

Surgery within the frontal recess is often difficult because of the size of the recess relative to the instrumentation and also because of the acute angle required to reach into the recess. Incomplete removal of cells within the recess has been reported to be the most common reason for continued frontal sinus symptoms after frontal sinus surgery.\(^3,5\) This study was undertaken to determine the incidence of frontal cells and whether they have an influence on the size of the frontal isthmus and the frequency of frontal sinusitis. Also, we wanted to see whether frontal and agger nasi cells were being addressed at the time of the primary sinus surgery, and whether retained agger nasi cells were related to an increased incidence of frontal sinus disease in revision cases.

Frontal cells are reported to develop from the anterior ethmoid cells after development of the frontal sinus itself.\(^7,8\) Frontal cells have been reported in 20% to 41% of sinus specimens.\(^8-11\) Van Alyea\(^6\) found a 41% incidence of frontal cells, but this likely included supraorbital ethmoid, agger nasi, and intersinus septal cells, possibly making this figure much higher than the actual incidence.\(^5,9,13\) In a recent review of coronal CT images of 768 patients who had not undergone previous surgery, Meyer et al.\(^10\) showed that 20.4% of patients had frontal cells, with type I cells being the most common in 14.9% of patients and types II through IV being found in 1.7% to 3.1% of patients.

### Table 1. Percentage of Frontal Sinus Cells Identified on CT Image

<table>
<thead>
<tr>
<th>Type of Frontal Cell</th>
<th>% of Sinuses</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>74.5</td>
</tr>
<tr>
<td>I</td>
<td>15.6</td>
</tr>
<tr>
<td>II</td>
<td>1.4</td>
</tr>
<tr>
<td>III</td>
<td>6.1</td>
</tr>
<tr>
<td>IV</td>
<td>2.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sinus Type</th>
<th>None</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>74.5</td>
<td>15.6</td>
<td>1.4</td>
<td>6.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Revision</td>
<td>78.1</td>
<td>13.2</td>
<td>0.9</td>
<td>6.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Abbreviation: CT, computed tomographic.

*Primary indicates sinuses that have not undergone previous operation; revision, sinuses that have undergone previous operation. Cell types are described in the introductory section.

### Table 2. Diameter and Area of Frontal Isthmus of Primary and Revision Sinuses

<table>
<thead>
<tr>
<th>Sinus Type</th>
<th>A-P diameter, mm</th>
<th>NF isthmus area, mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>7.4</td>
<td>88.3</td>
</tr>
<tr>
<td>Revision</td>
<td>7.8</td>
<td>87.7</td>
</tr>
</tbody>
</table>

Abbreviations: A-P, anterior to posterior; NF, nasofrontal.

*Primary indicates sinuses that have not undergone previous operation; revision, sinuses that have undergone previous operation. Cell types are described in the introductory section. Data are expressed as mean measurements.

\(^{†}P = .02\)
In our series, we evaluated each individual frontal recess separately and found that frontal cells were present in 25.5% of sides. This number increased to 29.6% of sides in the primary case group and 21.9% of sides in the revision case group (Table 1). In our series, frontal cells were found in 33.0% of patients, with unilateral and bilateral frontal cells occurring equally. The higher percentage of patients with frontal cells in our series compared with others may be related to our use of multiplanar reconstructions and the ability to manipulate the contrast of the images on the workstation to allow for better delineation of structures, even in significantly diseased sinuses. Also, our patient population was biased, consisting almost exclusively of patients undergoing primary or revision sinus surgery.

The presence of frontal cells did not correlate with a greater incidence of frontal sinusitis in our series. This finding is in contrast to the data from Meyer et al, who found a higher incidence of frontal sinusitis in patients with types III and IV frontal cells. This difference may be related to the smaller numbers of patients in our series compared with others may be related to our use of multiplanar reconstructions and the ability to manipulate the contrast of the images on the workstation to allow for better delineation of structures, even in significantly diseased sinuses. Also, our patient population was biased, consisting almost exclusively of patients undergoing primary or revision sinus surgery.

Table 3. Presence of Frontal Sinusitis vs the Diameter and Area of the Frontal Isthmus in Primary and Revision Sinuses

<table>
<thead>
<tr>
<th></th>
<th>Primary Sinuses</th>
<th></th>
<th>Revision Sinuses</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Sinusitis</td>
<td>Without Sinusitis</td>
<td>With Sinusitis</td>
<td>Without Sinusitis</td>
</tr>
<tr>
<td>A-P diameter, mm</td>
<td>8.3 ± 2.6</td>
<td>7.0 ± 2.5†</td>
<td>7.4 ± 2.5</td>
<td>7.8 ± 2.7</td>
</tr>
<tr>
<td>Area of frontal isthmus, mm²</td>
<td>103.2 ± 41.8</td>
<td>75.7 ± 40.4‡</td>
<td>87.1 ± 35.5</td>
<td>84.5 ± 47.1</td>
</tr>
</tbody>
</table>

*Primary indicates sinuses that have not undergone previous operation; revision, sinuses that have undergone previous operation. Data are expressed as mean ± SD.
†P.<.01.
‡P.<.001.

In our series, the presence of frontal cells did not correlate with a greater incidence of frontal sinusitis, in contrast to the data from Meyer et al, who found a higher incidence of frontal sinusitis in patients with types III and IV frontal cells. This difference may be related to the smaller numbers of patients in our series compared with others. The presence of frontal sinusitis, regardless of whether frontal or agger nasi cells are present, may be due to mucosal inflammatory disease, rather than anatomic obstruction by retained cells. The presence of intact intersinus septal cells was similar in primary and revision sinuses, at 12.2% and 11.4%, respectively. It is likely that these sinuses were not addressed during the previous surgical procedure(s) in the revision group.

Because many of the patients included in this study had their prior surgical procedures performed at outside institutions, there is no way to know the previous intended extent of surgical clearing of the frontal recess. Clearing of all frontal recess cells may not have been the goal of the initial procedures in all cases. Despite this shortcoming, our results show that the primary and revision sides have no differences in the frequency of frontal sinusitis, regardless of whether frontal or agger nasi cells are present. This may be because mucosal inflammatory disease, rather than anatomic obstruction by retained cells, appears to be the most important underlying factor in frontal sinusitis. This is supported by the finding of Otto and DelGaudio that mucosal inflammatory disease was a factor in 66% of cases of frontal sinusitis in patients undergoing revision frontal sinus surgery (Kristen Otto, MD, and J. M. D., unpublished data, April 2004).

The lack of statistically significant differences in the frequency of frontal sinusitis based on the presence of frontal and agger nasi cells and the size of the frontal isthmus indicates that the most important factor leading to frontal sinusitis is the mucosal inflammatory component. In fact, the group of patients with no frontal sinusitis who had not undergone previous surgery had a statistically significantly smaller A-P diameter and area of the frontal isthmus than patients with frontal sinusitis who had not undergone previous surgery. The size of the frontal recess seems not to play a vital role in the development of frontal sinusitis in most cases. Surgery in the frontal area should be directed at specific areas of disease and not be based on the relative narrowness of the frontal recess or frontal isthmus.

In a review of patients undergoing revision frontal sinus surgery for persistent or recurrent frontal sinus disease, two thirds of patients were found to have significant mucosal disease in the frontal recess at the time of surgery (Kristen Otto, MD, and J. M. D., unpublished data, April 2004). Mucosal inflammatory disease was the most common operative finding in this group of patients, fol-
ollowed by retained frontal recess cells. In postoperative patients, smaller frontal sinus neo-ostia have a greater incidence of obstruction, specifically due to scarring and the nonspecific mucosal inflammation that occurs in the frontal recess after endoscopic procedures. Bone exposure in this area may lead to granulation, greater degrees of fibrosis, scarring of the superior middle turbinated to the lamina papyracea, and osteoneogenesis. Therefore, trauma to the frontal recess as a result of surgical manipulation should be minimized.

CONCLUSIONS

When evaluated with multiplanar technology, frontal cells were identified in 25.5% of frontal recesses, including 29.6% of the primary sides and 21.9% of the revision sides. We identified 33.0% of patients as having unilateral or bilateral frontal cells. Unilateral and bilateral occurrence of frontal cells was found equally, and type I cells were the most common type of frontal cell (18.4% of sinuses in the primary group). The incidence of frontal sinusitis was no different between patients with and without frontal cells. The dimensions of the frontal recess were not affected by the presence of frontal cells, and the incidence of frontal sinusitis was not influenced by the size of the frontal isthmus. Intact agger nasi cells were identified in 86.7% of the primary sides and 53.5% of the revision sides, indicating that the agger nasi cell was surgically addressed in less than half of the previous surgical procedures. Despite this finding, there was no increased incidence of frontal sinusitis in patients in the revision group who had persistent agger nasi cells. Based on these findings, although anatomic variations in the frontal recess are likely to play a role in frontal sinusitis, mucosal inflammation appears to be a more important etiologic factor.

REFERENCES

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