The Relationship Between Frontal Sinusitis and Localization of the Frontal Sinus Outflow Tract

A Computer-Assisted Anatomical and Clinical Study

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Objective: To evaluate the relationship between frontal sinusitis and the localization of the frontal sinus outflow tract medial or lateral to the superior attachment of the uncinate process (UP).

Design: A retrospective anatomical and clinical study.

Setting: An ear, nose, and throat clinic in işli Etfal Teaching and Research Hospital, Istanbul, Turkey.

Patients: Paranasal sinus computed tomographic scans of 486 sides of the frontal sinuses (hereafter referred to as sides) of 243 patients who had chronic sinusitis were evaluated. In 125 sides (26%), the superior attachment of the UP could not be identified. In the remaining 361 sides (74%), the prevalence of superior attachment of UP types and the presence of frontal sinusitis in each side were recorded. Localization of the frontal sinus outflow tract was determined according to the superior attachment of the UP. Drainage of the frontal sinus to the middle meatus (medial to the superior attachment of the UP [types 1-3]) was classified as group 1, and drainage of the frontal sinus to the ethmoid infundibulum (lateral to the superior attachment of the UP [types 4-6]) was classified as group 2.

Results: Frontal sinusitis was found in 125 (35%) of 361 sides. The distribution of frontal sinusitis was 97 (41%) of 237 in group 1 and 28 (23%) of 124 in group 2. Group 1 drainage had a statistically significant presence of frontal sinusitis ($\chi^2=12.11, P<.001$). The prevalence of superior attachment of UP types was 63% for type 1/2, 3% for type 3, 12% for type 4, 14% for type 5, and 8% for type 6.

Conclusions: Frontal sinus outflow tract, which is medial to the superior attachment of the UP, is more common than the lateral one. There is a statistically significant relation between the presence of frontal sinusitis and the frontal sinus outflow tract, which is medial to the superior attachment of the UP.


Although frontal sinusitis is a potentially devastating infection with a tendency for intracranial spread, intracranial complications of frontal sinusitis are still very rare. Several factors have been previously discussed regarding the pathophysiologic process of chronic frontal sinusitis. Kuhn1 classified a number of cells that can lead to obstruction of the frontal recess and cause frontal sinusitis. These are namely frontal recess cells including agger nasi, supraorbital ethmoid cells, frontal cells, frontal bulla cells, suprabullar cells, and interfrontal sinus sepal cells. In addition to anatomical obstruction, mucosal obstruction of the frontal recess plays an important role in chronic frontal sinusitis.2 There are also different factors such as hypoxia, dehydration, infection, foreign bodies, environmental irritants, trauma, tumor, and allergens that can affect the frontal sinus physiologic functions by disrupting the mucociliary clearance.3

The superior attachment of the uncinate process (UP) is an important anatomical structure for the frontal recess region. Landsberg and Friedman4 defined 2 types of frontal sinus outflow tracts that were medial or lateral to the UP. To our knowledge, there are no clinical studies that mainly focus on the relationship between the frontal sinusitis and the localization of the frontal sinus outflow tract. In this study, our aims were to determine the rate of superior attachment types of UP and to evaluate the relationship between the frontal sinusitis and the frontal sinus outflow tract (medial or lateral to the superior attachment of the UP).

METHODS

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A total of 486 sides from 243 patients were evaluated. The study group comprised 146 men and 97 women (age range, 20-66 years [mean ± SD, 35.2 ± 4.2 years]). In 361 (74%) of the 486 sides, we were able to identify the superior attachment of the UP, and these cases were excluded. The lack of identification was due to unclear anatomy.

FRONTAL SINUS OUTFLOW TRACT AND THE UP

Group 1 drainage (frontal sinus opens medial to the UP [types 1-3]) was found in 237 (66%) of the 361 sides, and group 2 drainage (frontal sinus lateral to UP [types 4-6]) was found in 125 (35%) of the 361 sides. The following tabulation gives the distribution of the presence of frontal sinusitis according to groups:

<table>
<thead>
<tr>
<th>Frontal Sinusitis</th>
<th>Group 1. No. (%) of Sides</th>
<th>Group 2. No. (%) of Sides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>97 (41)</td>
<td>28 (23)</td>
</tr>
<tr>
<td>None</td>
<td>140 (59)</td>
<td>98 (77)</td>
</tr>
</tbody>
</table>

Insertions of the UP into the lamina papyracea were the most common type (type 1/2). This was found in 226 (63%) of the 361 sides. Insertion of the UP into the skull base was the second most common type and was found in 52 (14%) of the 361 sides. Types 3, 4, and 6 were rare (Table). The superior attachment of the UP in 1 side showed an identical pattern contralaterally in 65% (118 patients, 236 sides) of the cases, and the remaining 125 sides (35%) included a nonidentical pattern of the UP and the presence of frontal sinusitis on each side. Classification of the superior attachment of the UP was made according to the criteria of Landsberg and Friedman. The present study did not focus on dimensions of these structures.

FRONTAL SINUSITIS

Of 361 sides, 125 (35%) were diagnosed as having frontal sinusitis. In cases with group 1 drainage (frontal sinus outflow tract medial to the UP), frontal sinusitis was found in 97 (41%) of 237 sides, and in cases with group 2 drainage (frontal sinus outflow tract lateral to the UP), frontal sinusitis was found in 28 (23%) of 124 sides (see tabulation). Compared with cases with group 2 drainage, cases with group 1 had an increased presence of frontal sinusitis that was statistically significant ($\chi^2=12.11$; $P=.001$).
The distribution of frontal sinusitis according to types 1 through 6 is given in the Table. Frontal sinusitis was bilateral in 37 patients (59%) (74 of 125 sides). The prevalence of an identical pattern of superior attachment of UP type contralaterally in cases of bilateral frontal sinusitis was 23% (28 patients: 56 sides, 236 types), and the prevalence of a nonidentical pattern of superior attachment of UP type between sides in cases of bilateral frontal sinusitis was 14% (9 patients: 18 sides, 125 types).

**COMMENT**

The limits, width, and depth of frontal recess in adults are determined by embryologic pneumatization pattern of anterior ethmoid cells and the development of surrounding bony plates. The most relevant bony plate is the superior attachment region of the UP. Interest was given mostly to the posterior-inferior segment of the UP. The superior attachment of the UP was first referred to by Stammberger and Hawke in 1991, and they described 3 possible extensions to the lamina papyracea, skull base, or middle turbinate. However, they did not state other possible variations and combinations. Friedman et al emphasized the importance of thorough knowledge of the superior attachment of the UP anatomy for the precise dissection through the frontal recess and adequate exposure of the frontal sinus. Recently, Landsberg and Friedman identified 6 types of superior attachment of the UP and mentioned their prevalence by using an image guidance system and led us to understand the superior attachment in more detail.

When the UP inserts into the lamina papyracea, the ethmoid infundibulum is closed superiorly to form a blind pouch called terminal recess (recessus terminalis). In this case, frontal recess ultimately communicates with the middle meatus or the suprabullar recess. Kim et al reported that the communication of the frontal recess with the suprabullar recess is only 1%. Thus, frontal recess practically opens to the middle meatus in the case of terminal recess, where it is limited by the UP laterally and by the lateral side of the middle turbinate medially (medial to the superior attachment of UP [types 1-3]). When the UP inserts into the skull base, the middle turbinate, or the junction of middle turbinate with cribriform plate, the frontal recess drains to the middle meatus via the ethmoid infundibulum (lateral to the superior attachment of UP [types 4-6]). These findings emphasized that the superior attachment of the UP not only determines the anterior, lateral, or medial boundaries of the frontal recess but also the drainage pattern of the frontal sinus.

Of the sides examined in our study, group 1 drainage was found in 66% and group 2 in 34% of the sides, whereas Landsberg and Friedman found 88% and 12%, respectively. Kim et al reported that the medial border of frontal recess was conchal plate in 60% of the cases and suprabullar plate (joining of the superior portion of the UP to the superior portion of the bulla ethmoidalis) in 40%. Kasper found that the frontal sinus drained anterior to the UP (group 1) in 57% of the specimens and drained to the ethmoid infundibulum or posterior to the

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**Figure 2.** Type 2: insertion of the uncinate process into the posterior wall of the agger nasi cell and then to the lamina papyracea (arrows).

**Figure 3.** Type 3: insertion of the uncinate process into the lamina papyracea and the junction of middle turbinate with cribriform plate (arrows).

**Figure 4.** Type 4: insertion of the uncinate process into the junction of the middle turbinate with cribriform plate (arrows).
UP (group 2) in 43%. We assumed that draining anterior and medial to the UP reflects the same situation as draining posterior and lateral to the UP. Opposed to these results, Gaafar et al\textsuperscript{14} and Lee et al\textsuperscript{15} reported that the frontal sinus outflow tract was anterior to the UP (group 1) in 23% and 29%, respectively, of the cases and posterior to the UP (group 2) in 63% and 61%, respectively. The difference between these studies may be attributable to racial differences.

The UP is a very thin structure. It has a thin bony lamella and a 2-sided mucosal covering. In CT scans, although it is generally easy to identify the inferior portion of the UP, it is sometimes difficult to trace the precise path of the superior attachment, especially in the presence of polyp and/or mucosal disease. We could not identify the superior attachment of the UP in 26% of the sides from the CT scans, which were obtained by 5-mm contiguous coronal and axial sections and then reconstructed into 1-mm–thick coronal and sagittal (if needed) images. We excluded operated sides (ie, previous endoscopic surgery). Our difficulty in identification was mostly due to unclear anatomy and less mucosal disease or a combination of both. Although Landsberg and Friedman\textsuperscript{4} used image-guided surgery software with simultaneous 1-mm sections, they could not identify the superior attachment in 115 sides (40%). We think that the difference in the percentage is due to the exclusion of operated sides because Landsberg and Friedman\textsuperscript{4} reported that in 43 (15%) of 115 unidentified sides, nonidentification was due to previous endoscopic sinus surgery. In fact, the rates of the inability to identify the superior attachment of the UP are similar in these studies and may show that CT scans of fine-cut sections will not improve the identification rate enough. Further studies (such as detailed 3-dimensional reconstruction) are needed to improve the identification rate. On the other hand, new possible variations and combinations of superior attachment of the UP may be defined in further studies.

In our study population, the superior attachment of the UP in 1 side showed an identical pattern contralaterally in 65% of the cases. There may be an argument whether the individual patient with frontal sinusitis should undergo this process in both sides of the frontal sinus regardless of anatomic type. The prevalence of bilateral frontal sinusitis in an identical pattern of superior attachment of UP type contralaterally was 23%, and the prevalence of bilateral frontal sinusitis in a nonidentical pattern of UP type between sides was 14%. This means that bilateral frontal sinusitis was seen in more than an identical pattern of UP type contralaterally than in a nonidentical pattern between sides ($P<.05$). It may show that UP type plays a role in the pathogenesis of frontal sinusitis in addition to an individual’s own risk factors.

In this study population, the prevalence of frontal sinusitis was 41% in those with group 1 drainage and 23% in those with group 2 drainage. Group 1 (the frontal sinus outflow tract is medial to the superior attachment of the UP [types 1-3]) and drainage to the middle meatus has a statistically significant higher rate of frontal sinusitis compared with group 2 (frontal sinus outflow tract is lateral to the superior attachment of the UP [types 4-6]) and drainage to the ethmoid infundibulum ($\chi^2=12.11; P<.001$).

The pathophysiologic basis of our findings are unclear. It is well-known that ventilation and drainage are the main functions of the ostial channels of the paranasal sinuses. Functional theory of the sinusitis depends on these functions. Messerklinger\textsuperscript{16} first emphasized the ciliary function and secretion transport in the paranasal sinuses. The frontal sinus is unique in that it is the only sinus that has recirculation phenomenon. The mucus travels along the lateral side of the sinus and turns medially over the sinus floor and down the lateral frontal recess wall. Of the secretion, 60% is directed back into the sinus cavity as it reaches the frontal recess.\textsuperscript{1} In this manner, an unspecified amount of mucus and debris may recycle through the frontal sinus many times.\textsuperscript{11} In the region of the frontal recess just inferior to the ostium that transports mucus in a retrograde manner, opposing mucosal surfaces impair efficient drainage, because outward-flowing debris may mix with mucus on its way back into the sinus.\textsuperscript{3}
Sinusitis without rhinitis is rare. The mucosa of the nose and paranasal sinuses is contiguous, and rhinitis generally precedes sinusitis. Thus, the term rhinosinusitis has begun to be used instead of sinusitis. In group 1, a direct connection between the frontal recess and middle meatus and so on along the nasal cavity may make it easy to reach the rhinogenic infections in the frontal sinus. In group 2, the UP acts as cleft or anatomic barrier between the middle meatus and frontal recess, which causes the frontal sinus outflow tract opening to the ethmoid infundibulum. This physiologic process may play a role in the pathogenesis of frontal sinusitis in individuals who have frontal sinus outflow tract medial to the UP (group 1) due to lack of an anatomical barrier against ascending irritants, allergens, and/or rhinogenic infection. In addition, there may be a narrowing effect of both the UP and vertical lamella on the frontal recess in a subgroup. This may cause hypoventilation of the sinus and tendency toward sinusitis. Further studies are needed to prove these speculations.

In conclusion, frontal sinus outflow tract that is medial to the superior attachment of UP is more common than the lateral one. There is a statistically significant relation between presence of frontal sinusitis and frontal sinus outflow tract medial to the superior attachment of the UP. Further studies are needed to understand this relationship.

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REFERENCES