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OPEN

Bony Changes in a Unilateral Maxillary Sinus Fungal Ball

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Objectives: In the paranasal sinus fungal ball (SFB), changes that occur in the underlying bone have not been well described. Recently, bacterial coinfection has been reported in patients with paranasal SFB. We evaluated whether bone changes occur in patients with unilateral maxillary SFB, and also how bacteria in an SFB affect the bony wall of the sinus.

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Methods: A retrospective study of patients with a unilateral maxillary SFB undergoing endoscopic sinus surgery was conducted from July 2009 to December 2015. Preoperative computed tomography images of the patients were reviewed. Wall thickness (WT) and wall density (WD) of the diseased sinus were measured and compared to the normal sinus. Specimens of the sinus aspirates were obtained during surgery for aerobic and anaerobic cultures.

Results: Forty-three patients were included (mean, 55.7 ± 12.8 years). Thirty-one cultures (72.1%) were positive for bacteria. Thickening was evident in the anterior, lateral, and posterior walls of the diseased sinus. The average WT was 1.69 ± 0.45 mm on the diseased sinus and 1.14 ± 0.31 mm on the normal sinus ($P < 0.001$). In the diseased sinus, the difference in the average WT between the culture-positive and culture-negative groups was not significant ($P = 0.44$). The average WD on the diseased sinus was higher than that on the normal sinus ($P < 0.001$).

Conclusions: Osteitic change occurred in most patients with a unilateral maxillary SFB. The presence of bacteria in sinus secretions does not greatly affect the development of osteitic changes in unilateral maxillary SFB.

Key Words: Bacteria, bone density, fungi, maxillary sinus, osteitis

Fungal balls of the paranasal sinuses, characterized by a tangled aggregate of fungal hyphae, are a noninvasive form of fungal sinusitis. A paranasal sinus fungal ball (SFB) is usually found in a single sinus, most frequently the maxillary sinus. Patients with maxillary sinus involvement complain of nasal obstruction, nasal discharge, postnasal drip, headache, and facial pain. The presenting symptoms and wound healing process are not different from those of chronic sinusitis.^{1,2}

A definitive diagnosis of a fungal ball is based on the characteristic histopathology of the twisted fungal hyphae. The most commonly reported causative organism of fungal balls is *Aspergillus fumigatus*.³ Endoscopic sinus surgery (ESS) is an effective and successful treatment for the management of SFB.² During surgery, purulent secretions are frequently found in the paranasal sinuses of patients with fungal balls. According to previous reports, bacterial coinfection has been reported in 68.0% to 73.4% of patients with paranasal SFB.^{4,5}

Although some studies have reported characteristic computed tomography (CT) features of SFB,^{6,7} the changes that may occur in the underlying bone, especially as demonstrated with CT, have not been well described. Thus, we evaluated whether bone changes occur in patients with a unilateral maxillary SFB. We also investigated how the presence of bacteria in the SFB affects the bony wall of the sinus.

MATERIALS AND METHODS

In total, 43 patients with a unilateral maxillary SFB who underwent ESS from July 2009 to December 2015 were enrolled. We retrospectively reviewed the patients' medical records, endoscopic examination findings, and CT data. Approval for this study was obtained from the Hospital Medical Ethics Committee. Informed consent was obtained from all of the patients.

The fungal ball was diagnosed by radiological and histological criteria, as described by deShazo et al.⁸ With Gomori methenamine silver staining, septated hyphae with acute-angle (45°) dichotomous branching, which is characteristic of *Aspergillus* spp, was found in all patients. There was no evidence of fungal invasion into the sinus mucosa or bone. Patients with allergic fungal sinusitis were not included. No patient had a history of sinus surgery. Specimens of sinus aspirates of purulent secretions were transported immediately

to the microbiology laboratory for aerobic and anaerobic cultures. The time between the collection of materials and inoculation of the specimen was <30 minutes for anaerobes. Identification testing of the bacterial species was performed with a VITEK 2 (bioMerieux Inc, Hazelwood, MO).

Ostiomeatal CT scans were reviewed retrospectively using a Picture Archiving and Communication System (PACS[®], Seoul, Korea). CT examinations were performed with a MDCT (GE, Milwaukee, WI). Noncontrast scan parameters were as follows: 120 kVp; 140 mAs; scan time, 600 ms; matrix size, 512 × 512. The patients were scanned in the supine position (gantry tilt, 30 degree), and coronary editing of 1-mm-thick slices from the front of the frontal sinus to the end of the sphenoid sinus was performed. The CT scans were routinely evaluated with a window width of 2000 and a level of 300. One radiologist and an otolaryngologist who were blinded to the clinical and pathological data checked all of the CTs for the bilateral maxillary sinus wall thickness (WT) and bilateral maxillary sinus wall density (WD).

All of the measurements were taken in the same axial plane at the level where the inferior turbinate attaches to the maxillary sinus wall. The sinus WT was measured at the midportion of 3 separate areas (anterior, lateral, and posterior walls of the maxillary sinus) by a direct line perpendicular to the wall, calculated in millimeters (Fig. 1). The measurements were averaged. Density measurements in Hounsfield units (HU) were performed at the same 3 points as in the WT and averaged. The same test was applied symmetrically to both diseased and normal sinuses. All of the patients underwent ESS. Following ESS, postoperative care modalities included nasal saline irrigation, sinus cavity debridement, topical nasal steroids, and short-course antibiotics.

Statistical Analyses

Data are expressed as mean ± standard deviation. Statistical analyses were performed using SPSS software (ver. 16.0; SPSS Inc, Chicago, IL). We analyzed the results using *t* tests and Pearson correlation coefficient (*r*). A *P* value of <0.05 was considered statistically significant.

RESULTS

The study group included 28 females and 15 males, with an age range of 18 to 76 (mean, 55.7 ± 12.8) years. Bacteria were recovered from 31 of 43 (72.1%) patients. In total, 44 isolates were



FIGURE 1. Axial computed tomography measurements of sinus wall thicknesses in both maxillary sinuses. Lines were drawn perpendicular to the midportions of three separate walls (the anterior, lateral, and posterior walls of the maxillary sinus), and wall thicknesses were measured.

TABLE 1. Distribution of 44 Bacterial Isolates From Purulent Secretions in 43 Patients With Maxillary Sinus Fungus Ball

Bacteria	Number of Isolates
Aerobic bacteria	
G (+) cocci	
<i>Staphylococcus aureus</i>	6
<i>Streptococcus pneumoniae</i>	5
Viridans-group <i>Streptococcus</i>	3
Coagulase-negative staphylococci	3
<i>Staphylococcus epidermidis</i>	1
<i>Streptococcus anginosus</i>	1
<i>Streptococcus constellatus</i>	1
G (-) rod	
<i>Enterobacter aerogenes</i>	6
<i>Klebsiella pneumoniae</i>	3
<i>Enterobacter cloacae</i>	2
<i>Pseudomonas aeruginosa</i>	1
<i>Providencia rettgeri</i>	1
<i>Haemophilus influenzae</i>	1
<i>Serratia marcescens</i>	1
<i>Achromobacter xylosoxidans</i>	1
Subtotal aerobes	36
Anaerobic bacteria	
<i>Peptostreptococcus</i> spp	4
<i>Prevotella</i> spp	3
<i>Fusobacterium nucleatum</i>	1
Subtotal anaerobes	8
Total	44

recovered from the 31 patients: 20 (45.4%) Gram-positive cocci, 16 (36.4%) Gram-negative rods, and 8 (18.2%) anaerobes. Frequently isolated organisms were *Staphylococcus aureus* (13.6%), *Enterobacter aerogenes* (13.6%), *Streptococcus pneumoniae* (11.4%), *Peptostreptococcus* spp. (9.1%), coagulase-negative staphylococci (6.8%), viridans-group streptococci (6.8%), *Klebsiella pneumoniae* (6.8%), and *Prevotella* spp (6.8%) (Table 1).

The WT on the diseased sinus was thicker than that on the normal sinus in 41 of 43 patients (95%). The average WT was 1.69 ± 0.45 mm on the diseased sinus and 1.14 ± 0.31 mm on the normal sinus (*P* < 0.001)(Table 2).

When comparing the thicknesses of walls on the diseased side and those on the normal side, the difference was greater in the following order: lateral wall, posterior wall, and anterior wall (Table 2). On the diseased sinus, the average WT in the culture-positive group (*n* = 31, 1.75 ± 0.53 mm) was thicker than that in the culture-negative group (*n* = 12, 1.57 ± 0.35 mm), but there was no statistically significant difference between them (*P* = 0.44) (Table 2).

The WD of the diseased sinus was higher than that of the normal sinus in 30 of 43 patients (69.8%). The average WD was 1078.3 ± 200.3 HU on the diseased sinus and 944.5 ± 261 HU on the normal sinus (*P* < 0.001) (Table 3).

When comparing the bone density of walls on the diseased side and those on the normal side, the difference was greater in the following order: posterior wall, anterior wall, and lateral wall (Table 3). On the diseased sinus, the difference in the average WD between the culture-positive group (1078.2 ± 204.3 HU) and the culture-negative group (1074.8 ± 194.5 HU) was not statistically significant (*P* = 0.96) (Table 3).

The WT on the diseased sinus did not correlate with the WD on the ipsilateral side (*r* = -0.096, *P* = 0.552), and a similar result was

TABLE 2. Maxillary Wall Thicknesses of Diseased and Normal Sinuses

WT, mm	Diseased Sinus			Normal Sinus		
	Anterior Wall	Lateral Wall	Posterior Wall	Anterior Wall	Lateral Wall	Posterior Wall
(Mean ± SD)	1.53 ± 0.44*	1.89 ± 0.68*	1.65 ± 0.72*	1.11 ± 0.37	1.24 ± 0.39	1.13 ± 0.51
Total (Mean ± SD)		1.69 ± 0.45*			1.14 ± 0.31	
		Culture (+): 1.75 ± 0.53 (0.85–3.21), NS				
		Culture (-): 1.57 ± 0.35 (1.12–2.55)				

SD, standard deviation. NS indicates that there is no significant difference between the culture positive group and the culture negative group.

* $P < 0.001$, diseased sinus versus normal sinus.

noted on the normal side of the maxillary sinus ($r = -0.103$, $P = 0.522$).

DISCUSSION

Fungal balls of the paranasal sinuses mostly occur in older individuals, and predominantly in women.⁹ These epidemiological characteristics were also noted in our study. The mean patient age was 55.8 (range, 18–76) years, and 65.1% of the patients with SFB were women.

The bone of the sinus wall is not a static structure. It is a dynamic substance and responds to various stimuli, such as mechanical stress and inflammation, by altering and repairing its structure through a process referred to as remodeling.¹⁰

Osteitis is the generally accepted term for inflammation in bone that lacks a marrow space, which is characterized by a proliferative reaction of the periosteum, bone remodeling, and subsequent neoosteogenesis.¹¹ It is known that osteitis may play a key role in the pathogenesis of chronic rhinosinusitis (CRS),^{12,13} and it has been identified in 36% to 53% of patients with CRS using radiographic and histopathological criteria.^{13,14} Generally, osteitic bone appears as a thickened, irregular, heterogeneous lining of the involved sinus walls on a CT scan.¹⁵

SFB is chronic disease of the paranasal sinuses, so it can be predicted that osteitic changes may occur in the bony wall in SFB. Some studies have described supposedly characteristic computed tomography (CT) features of SFB: heterogeneous soft tissue density in the sinus cavity, erosion of the inner wall of the sinus, sclerosis of the sinus lateral wall, calcification, absence of an air–fluid level, and mucosal thickening.^{16–18} However, the changes that occur in the underlying bone in SFB have been less well studied.

In only one study that compared CT findings of SFB and unilateral CRS patients, sclerotic changes in the sinus lateral wall occurred in 72.9% of patients with SFB and in 37.5% of patients with CRS.¹⁹ In the study, the authors mentioned that bone changes

only occurred in the lateral wall of the sinus, and they did not mention the degree of these bone changes.

In the present study, we explored whether bone changes occurred in patients with unilateral maxillary SFBs, and, if so, we evaluated the extent of bone changes present. We found that sinus wall thickening occurred in 41 of 43 (95%) patients and bone changes were evident in the anterior, lateral, and posterior walls of the involved sinus. When the thicknesses of the walls on the diseased side were compared to those of the normal side, the anterior, lateral, and posterior walls of the diseased side were significantly thicker than the walls on the normal side ($P < 0.001$). Of the involved sinus walls, changes were most prominent in the lateral wall. The average WT of the anterior, lateral, and posterior walls of the diseased side was also significantly greater than that of the normal side ($P < 0.001$). This indicates that new bone formation or osteitic changes occurred throughout the sinus walls including the lateral wall in maxillary SFB patients.

We studied only unilateral maxillary SFB to avoid any bias attributable to differences in bone structure among patients. We did not evaluate the medial wall of the involved maxillary sinus because in most cases erosion of the medial wall was evident.

During surgery, purulent secretions are frequently found in the paranasal sinuses of patients with fungal balls. According to previous reports, bacterial coinfection has been reported in 68.0% to 73.4% of patients with paranasal SFB.^{4,5} In our study, bacteria were recovered from 31 of the 43 (72.1%) patients; this result is similar to that seen in previous reports.^{4,5} The average WT of the culture-positive group was thicker than that of the culture-negative group on the diseased side, but there was no statistically significant difference between the groups ($P = 0.44$). Based on this fact, although our number of patients was low, we postulate that osteitic changes in maxillary SFB are triggered by chronic inflammation caused more by the fungus than bacteria.

TABLE 3. Maxillary Wall Densities of Diseased and Normal Sinuses

WD (HU)	Diseased sinus			Normal sinus		
	Anterior Wall	Lateral Wall	Posterior Wall	Anterior Wall	Lateral Wall	Posterior Wall
(Mean ± SD)	997.6 ± 280.6*	1162.4 ± 264	1065.9 ± 280.7*	858.5 ± 394.4	1054.1 ± 336.6	924 ± 355.4
Total (Mean ± SD)		1078.3 ± 200.3†			944.5 ± 261	
		Culture (+): 1078.2 ± 204.3 (645.7–1491), NS				
		Culture (-): 1074.8 ± 194.5 (681.7–1343.7)				

SD, standard deviation. NS indicates that there is no significant difference between the culture positive group and the culture negative group.

* $P < 0.05$, diseased sinus versus normal sinus.

† $P < 0.001$, diseased sinus versus normal sinus.

HUs are a quantitative scale for describing radiodensity. The clinical use of HU has been reported in many diseases, including gallstones, renal stones, and sinus aspergillosis.^{20–22} Cho et al²³ postulated that HU may be a useful objective marker of bone remodeling in unilateral rhinosinusitis. In our present study, the average WD of the diseased side was significantly higher than that of the normal side in unilateral maxillary SFB patients. We thus explored the association between WT and WD in the maxillary SFB and found that WT did not correlate with WD on the diseased or normal sides of the maxillary sinus. This result is similar to that of another report conducted in patients with CRS.²⁴ The reasons for the difference with Cho's result²³ may be because of the different methods of measurement used and the different sinuses that were assessed.

In previous reports, the thickness or density of the bony sinus wall was checked at only one point or the most prominent portion of the pertinent sinus.^{14,23} In this study, we measured at 3 separate areas of the sinus wall, and they were averaged and also measured at the same plane in all patients; therefore, this may add to the objectivity and reproducibility of the measurements.

Although osteitic changes were evident in patients with unilateral maxillary SFBs, being most prominent in the lateral wall of the involved sinus, the precise mechanism of their development remains unknown.

There are 2 portions of the sinus wall; namely, the mucosa and underlying bone. In our study, we only evaluated bone changes in patients with SFB. Further studies are needed to evaluate the relationship between the degree of mucosal inflammation and underlying changes in the bone.

In conclusion, we showed that new bone formation or osteitic changes occurred in most patients with a unilateral maxillary SFB. Changes were evident in the anterior, lateral, and posterior walls of the involved sinus. We suggest that the presence or absence of bacteria in sinus secretions does not greatly influence the development of osteitic changes in patients with unilateral maxillary SFBs.

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Proposal of a Budget-Friendly Camera Holder for Endoscopic Ear Surgery

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Abstract: Endoscopic ear surgery (EES) is increasingly a preferred technique in otologic society. It offers excellent visualization of the anatomical structures directly and behind the corners with variable angled telescopes. It also provides reduced operative morbidity due to being able to perform surgical interventions with less invasive approaches. Operative preparation and setup time and cost of endoscopy system are less expensive compared with surgical microscopes. On the other hand, the main disadvantage of EES is that the surgery has to be performed with 1 single hand. It is

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