

Ethnic and Gender Differences in Bone Erosion in Allergic Fungal Sinusitis

Sarah K. Wise, M.D.,* Giridhar Venkatraman, M.D.,* Justin C. Wise, M.S.,# and John M. DelGaudio, M.D.*

ABSTRACT

Background: Erosion of the bony sinus walls in allergic fungal sinusitis (AFS) is an established phenomenon. Reports of the incidence of bone erosion in AFS vary widely, and definitions of bone erosion lack uniformity. Differences in bone erosion among ethnic and gender groups have not been examined previously in the literature.

Methods: At our institution we reviewed 47 cases of AFS for ethnic and gender differences in presentation and presence of bone erosion.

Results: Caucasians presented at a mean 12 years later than African-Americans ($p = 0.002$); however, this difference was largely carried by Caucasian females. African-Americans presented with a greater incidence of bone erosion than Caucasians ($p = 0.028$). In addition, there are statistically significant differences in the individual paranasal sinuses affected by bone erosion in AFS.

Conclusions: We examine the potential implications of ethnic

and gender differences in presentation and bone erosion in AFS. (American Journal of Rhinology 18, 397–404, 2004)

Initially described by Millar *et al.*¹ in 1981, “allergic Aspergillosis of the paranasal sinuses” was proposed as the upper airway counterpart to allergic bronchopulmonary aspergillosis (ABPA), a well-characterized pulmonary entity in which type I hypersensitivity to fungal antigens results in obstructive mucoid impaction of the bronchi. Allergic *Aspergillus* sinusitis was further characterized pathologically in 1983 by Katzenstein *et al.*² as containing distinctive allergic mucin with layers of necrotic eosinophils and Charcot–Leyden crystals as well as non-invasive fungal hyphae. Following these initial reports, in addition to *Aspergillus*, various fungi such as *Bipolaris*,³ *Curvularia*,⁴ *Alternaria*⁵ and others were noted to cause similar clinical symptoms and histopathological tissue reaction; for this reason, this entity is now termed allergic fungal sinusitis (AFS).

Various authors have proposed criteria for the diagnosis of AFS.^{6–13} The criteria of Bent and Kuhn⁷ are the most widely accepted and were used in the current study. These include type I hypersensitivity, nasal polyposis, characteristic computed tomography (CT) scan, histologic evidence of eosinophilic mucin absent of fungal invasion, and positive fungal stain or culture. Considering the histopathologic requirement, initial diagnosis of AFS may often be delayed until operative intervention is complete. Recently, Dhiwakar *et al.*¹³ proposed a set of preoperative criteria for the diagnosis of AFS, which included nasal polyposis on physical examination, hyperattenuation on CT scan, and increased IgE to *Aspergillus*. Taken together, these criteria were 70% sensitive and 100% specific for the diagnosis of AFS when compared to a control group of patients with ethmoid polyposis and a second control group of patients

From the *Department of Otolaryngology–Head and Neck Surgery, The Emory Clinic, Atlanta, Georgia; and the #Department of Psychology, Georgia State University, Atlanta, Georgia

Presented at the American Rhinologic Society meeting September 20, 2003

Send correspondence and reprint requests to John M. DelGaudio, M.D., Department of Otolaryngology–Head and Neck Surgery, The Emory Clinic, 1365A Clifton Road NE, Suite 2100, Atlanta, GA 30322

Copyright © 2004, OceanSide Publications, Inc., U.S.A.

with invasive aspergillosis. Of note, however, all patients with ultimate diagnosis of AFS had *Aspergillus* on fungal culture or pathology specimen, raising concern for the use of IgE to *Aspergillus* for diagnosis in a patient population that may ultimately demonstrate another fungal species in culture.

Expansion and erosion of the bony paranasal sinus walls is a recognized feature of AFS. Reported occurrence of erosion of bony sinus walls in patients with AFS ranges from 20%^{14,15} to 93%,¹⁰ although uniformity in the definition of bone erosion does not exist across these studies. Ethnicity and gender differences in the incidence and degree of bone erosion in AFS have not been examined previously in the literature. In the current study, we retrospectively reviewed our patient population with a diagnosis of AFS to evaluate potential ethnic and gender differences in bone erosion.

MATERIALS AND METHODS

Approval for this study was obtained from the Institutional Review Board of the Emory Clinic and Emory University Hospital in Atlanta, GA. A retrospective review of the medical records and sinus CT scans was performed for all patients with a diagnosis of allergic fungal sinusitis (AFS) treated at our institution from 1987 to 2003. There were a total of 47 patients in this study. Each patient had a diagnosis of AFS based on the Bent and Kuhn⁷ criteria; however, not all patients met all five criteria, as this is not necessary for a diagnosis of AFS. Patients included in this study met at least three of five AFS criteria (atopic history, nasal polyposis, characteristic CT scan findings, fungal isolates on culture or pathology, and allergic mucin on pathology). There were no differences in the criteria utilized for various ethnic and gender groups. Patients with fungus balls or mycetomas were specifically excluded from this study. Each patient had a noncontrast CT scan of the sinuses with axial and coronal images performed before operative intervention.

Demographic data acquired for each patient included age at first diagnosis of AFS, ethnicity, and gender. Pathology and fungal culture results were also obtained, and operative reports were reviewed to determine the extent of surgical intervention.

All sinus CT scans at our institution are read by an attending neuroradiologist, and these reports were reviewed. When available, the CT scans themselves were then reviewed by the senior author (J.M.D.) for verification of reported findings. A total of 42 CT scans (89.4%) were available for review.

The extent of sinus disease on CT imaging for each patient was noted with respect to the presence of unilateral or bilateral disease and sinuses involved. The presence of distinct bone erosion, not expansion, was also examined with regard to each sinus as well as subsites within each sinus. Documentation of sinus bone erosion was based on the 2001 study by Nussenbaum *et al.*¹⁵ Frontal, ethmoid,

sphenoid, and maxillary sinuses were each examined individually. Right and left sides were regarded as being distinct (with the exception of certain sphenoid subsites discussed below). Frontal sinus subsites included bilateral anterior wall, posterior wall, and floor, for a total of six possible subsites. Ethmoid sinus subsites included bilateral ethmoid roof and lamina papyracea, for a total of four possible subsites. Sphenoid sinus subsites included right and left lateral walls and pterygoid plates. The planum sphenoidale, clivus, and posterior wall were not divided into right and left sided due to the central location of this sinus. Therefore, the sphenoid sinus had a total of seven possible subsites. Finally, eight possible subsites were considered for the maxillary sinus, which included bilateral maxillary roof (orbital floor), and anterior, posterior, and lateral walls. In total, there were 25 possible sites of bone erosion considered. The medial wall of the maxillary sinus is nearly universally eroded in AFS with extension of disease intranasally; therefore this subsite has been excluded from analysis, as done previously by Nussenbaum *et al.*¹⁵

Statistical analysis was performed using SPSS for Windows, version 11.0 (Chicago, IL). Data were analyzed with respect to ethnicity and gender for differences in age at presentation, presence of unilateral or bilateral disease, and presence and degree of bone erosion. Additionally, differences in bone erosion among the individual sinuses were evaluated.

RESULTS

A total of 47 patients underwent sinus surgical intervention for AFS at our institution from 1987 to 2003, and these patients composed our study sample. Demographic data revealed a gender division of 28 males and 19 females and an ethnicity division of 21 African-Americans and 26 Caucasians. The mean age at presentation for the total group was 31.0 years, with a range of 8 to 74 years and a standard deviation of 16.1 years. Table I summarizes data for age at presentation among various groups in our sample.

A univariate analysis of variance (ANOVA) was performed to test whether the age at presentation differed among demographic groups. A statistically significant difference was found in age at presentation for ethnicity ($p = 0.002$), with African-Americans presenting at a mean age of 24.5 years and Caucasians presenting at a mean age of 36.2 years. No statistically significant difference was found in age at presentation for gender ($p > 0.05$). Although there was a statistically significant difference in age at presentation for ethnicity, this difference is carried largely by Caucasian females, with a mean age at presentation of 46.8 years. This is evidenced by the significant interaction between ethnicity and gender ($p = 0.014$) displayed in Fig. 1. Tukey *post hoc* analysis revealed no significant difference ($p > 0.05$) in age at presentation among African-American males (25.5 years), African-American females (22.8 years), and Caucasian males (28.4 years). However, age at presentation for Caucasian females (46.8 years) was found to be

TABLE I

Sample Descriptives								
	<i>n</i>	Mean Age	Median Age	Age SD	Age Range	% Bilateral	% Bone Erosion	No. of Eroded Subsites*
Total	47	31.0	25.0	16.1	8–74	66.0	44.7	4.5
Male	28	27.1	23.0#	14.6	8–74	67.9	53.6	4.5
Female	19	36.7	35.0	17.0	15–72	63.2	31.6	4.5
African American	21	24.5§	23.0	9.4	11–47	76.2	71.4¶	5.1
Caucasian	26	36.2§	35.0	18.6	8–74	57.7	23.1	2.8
African American								
Male	13	25.5	23.0	10.5	11–47	84.6	76.9	5.2
Female	8	22.8	21.5	7.6	15–38	62.5	62.5	5.2
Caucasian								
Male	15	28.4	23.0	17.7	8–74	53.3	33.3	3.2
Female	11	46.8	47.0	14.6	19–72	63.6	9.1	1.0

*Per patient with bone erosion.

#Median ages reported because of positive skew of male group.

§Significant difference in age at presentation for race ($p = 0.002$).

¶Race is a statistically significant predictor of bone erosion ($p = 0.028$).

||Ethnicity-by-gender interaction in age at presentation carried by Caucasian females.

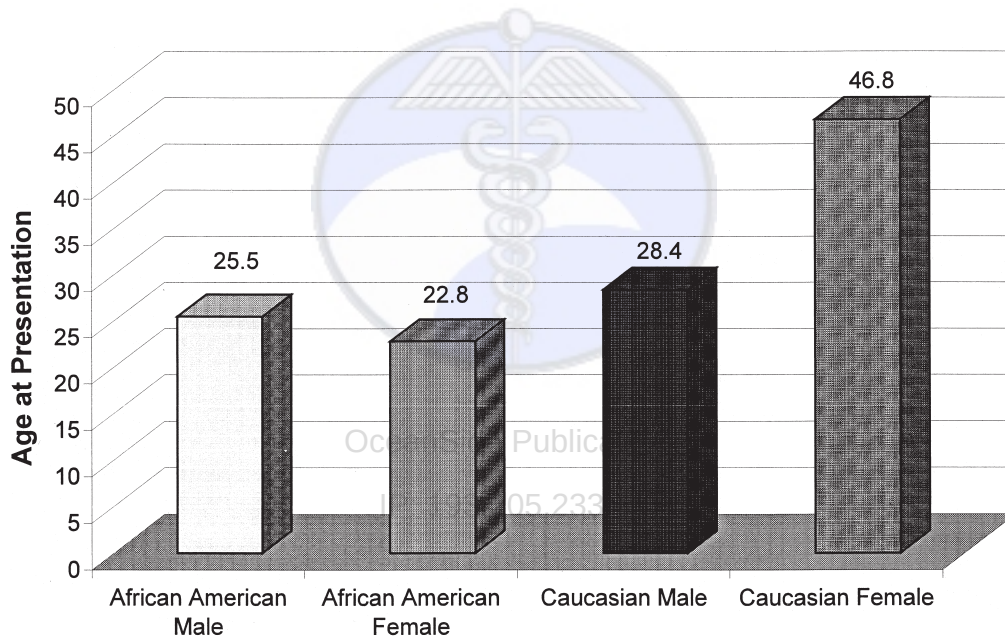


Figure 1. Ethnicity by gender interaction for age at presentation.

statistically significantly different from all other groups ($p < 0.05$).

Forty-five of the 47 total patients had fungal culture results available. Of these, 29 (64.4%) had positive fungal cultures. The average number of fungal isolates in positive cultures was 1.4. *Curvularia* was the most common fungal isolate with 10 positive cultures, followed by 9 each of *Bipolaris* and *Aspergillus*; *Exserohilum* was present in 6 cultures. *Fusarium*, *Alternaria*, *Cunninghamella*, *Paecilomyces*, and *Verticillium* were present in fewer numbers (Table II).

myces, and *Verticillium* were present in fewer numbers (Table II).

Disease extent in this study was first assessed with respect to the unilateral or bilateral presence of disease. In the total study sample, 34.0% of patients presented with unilateral disease and 66.0% with bilateral disease (Table I). Logistic regression analysis was performed using the variables ethnicity, gender, and the ethnicity-by-gender interaction (i.e., the relationship between Af-

TABLE II

Fungal Isolates

Fungal Isolate	Positive Cultures
<i>Curvularia</i> sp.	10
<i>Bipolaris</i> sp.	9
<i>Aspergillus</i> sp.	9
<i>Exserohilum</i> sp.	6
<i>Fusarium</i> sp.	2
<i>Alternaria</i> sp.	1
<i>Cunninghamella</i> sp.	1
<i>Paecilomyces</i> sp.	1
<i>Verticillium</i> sp.	1

frican-American males and females as compared to the relationship between Caucasian males and females) as predictors of unilateral or bilateral presence of disease in AFS. None of the aforementioned variables significantly predicted the presence of bilateral disease in this sample ($p > 0.05$).

Bone erosion among the 47 patients in this sample was considered with respect to presence and degree. Presence of bone erosion was defined as erosion of one or more subsites in any sinus. Degree of bone erosion was defined as the total number of sinus subsites eroded of the 25 possible subsites defined in the Methods section.

Twenty-one patients (44.7%) exhibited the presence of bone erosion in this study (Table I). Again utilizing the variables ethnicity, gender, and the ethnicity-by-gender interaction as predictors of the presence of bone erosion, logistic regression analysis was performed. Ethnicity was found to be a significant predictor for the presence of bone erosion in this sample ($p = 0.028$), such that 15 (71.4%) African-Americans presented with bone erosion, whereas 6 (23.1%) Caucasians presented with bone erosion. Gender and ethnicity-by-gender interactions were not found to significantly predict the presence of bone erosion.

Of the 21 patients who exhibited bone erosion, a mean of 4.5 sinus subsites were eroded (Table I). African-Americans had erosion of a mean of 5.1 subsites versus a mean of 2.8 subsites eroded in Caucasians. Males and females in this sample each had a mean of 4.5 sinus subsites eroded. A univariate ANOVA failed to show a statistically significant difference in mean number of sinus subsites eroded between ethnicity or gender groups, or a significant ethnicity-by-gender interaction ($p > 0.05$).

In the 21 patients that exhibited bone erosion, the frontal, ethmoid, sphenoid, and maxillary sinuses were examined individually for differences in proportion of bone erosion within each sinus. Due to the differences among the sinuses with regard to the potential subsites of bone erosion (i.e., four potential subsites in the ethmoid versus eight potential subsites in the maxillary), analyses were conducted using the proportion of bone erosion in each sinus rather than the total number of subsites eroded (Figures 2–6). The ethmoid sinus was eroded to the greatest degree with a mean proportion of 0.38, followed by the sphenoid (0.24), frontal (0.17), and maxillary (0.04). These differences are depicted in Fig. 2. A repeated measures ANOVA indicated that there was a significant difference in the proportion of bone erosion among the sinuses ($p < 0.001$). To determine which sinuses differed, Tukey *post hoc* analyses were conducted ($p < 0.05$). Although the proportion of bone erosion in the maxillary sinus was less than that found in the ethmoid, sphenoid, or frontal sinuses, this proportion was statistically significantly different only from the sphenoid and ethmoid sinuses, but not from the frontal sinus. Additionally, proportion of bone erosion in the frontal sinus showed a statistically significant difference from the ethmoid sinus but not from the sphenoid sinus. The ethmoid and sphenoid sinuses did not show a statistically significant difference in the proportion of bone erosion (Table III).

All 47 patients in this sample underwent surgical intervention endoscopically. In 38 patients (80.9%), an endoscopic approach was the sole procedure. The remaining nine

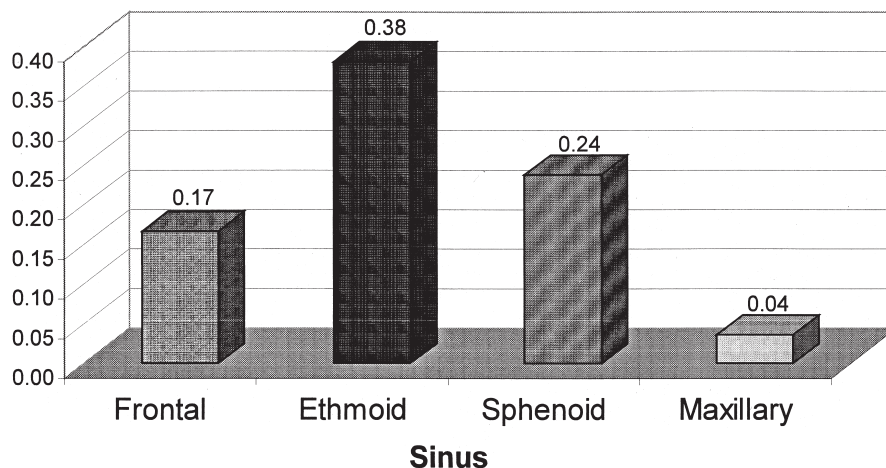


Figure 2. Mean proportion of bone erosion.

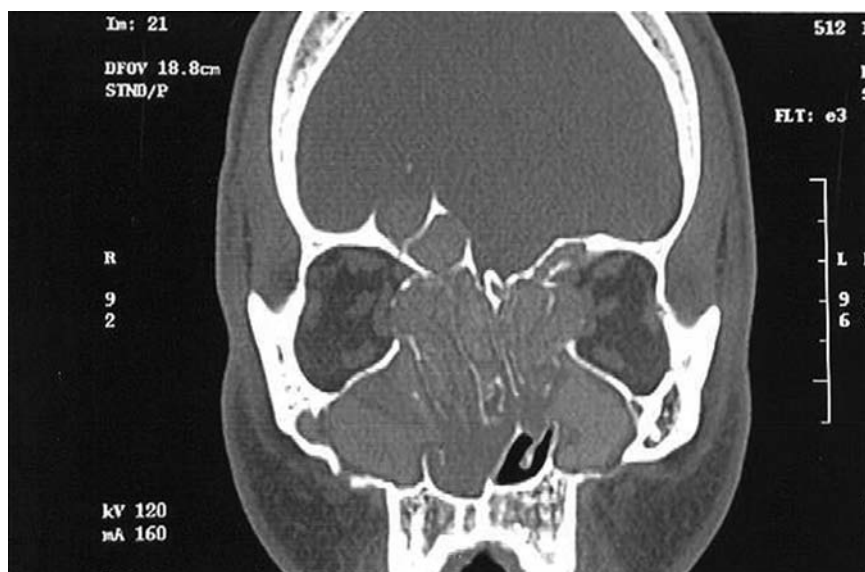


Figure 3. Noncontrast coronal CT scan in bone algorithm revealing erosion of bilateral lamina papyracea, right ethmoid roof, and bilateral anterior maxillary walls.



Figure 4. Noncontrast axial CT scan in bone algorithm exhibiting erosion of the posterior wall of the right frontal sinus.

patients had additional open procedures such as frontal sinus cranialization in four patients. One patient each underwent frontal sinus trephination, frontal sinus obliteration, external ethmoidectomy, and Caldwell-Luc. The majority of these open procedures were performed between 1987 and 1995, before widespread experience in treating AFS endoscopically. Of the nine patients who had open procedures in addition to endoscopic procedures, eight had bone erosion present.

DISCUSSION

Allergic fungal sinusitis is reported to occur in ~6–7% of patients with chronic rhinosinusitis.^{2,16} Patients are typically young adults, although the age range is wide.

There is no history of immunocompromise; however, significant atopy is exhibited, as is nasal polyposis on physical examination. Geographically, a higher percentage of AFS cases occur in the warm, humid climates of the south central United States along the Mississippi river basin, with an incidence of up to 22% of chronic rhinosinusitis patients exhibiting AFS in Memphis.¹⁷ Although various authors have examined bone erosion in AFS,^{8–10,14,15,16,18–20} this is the first study to evaluate this disease for ethnic and gender differences in presentation as well as in bone erosion.

Reports of a gender predilection for AFS vary. Certain authors note an equal incidence of AFS in males and females,^{6,14} whereas others note a male predominance with male-to-female ratios ranging from 1.5–2.6 to 1.7–12. Inter-

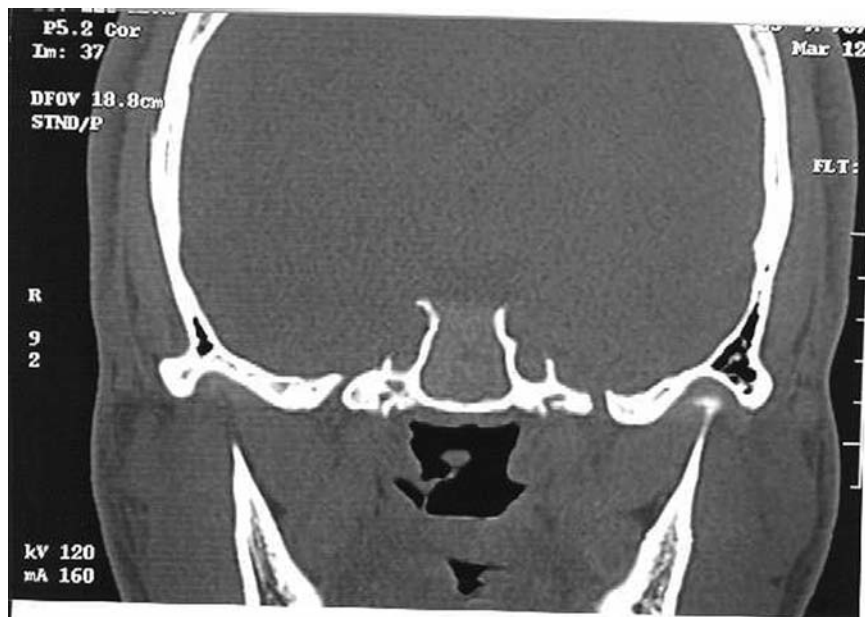


Figure 5. Noncontrast coronal CT scan in bone algorithm showing erosion of the sphenoid roof.



Figure 6. Noncontrast axial CT scan in soft tissue algorithm revealing hyperdense inspissated secretions characteristic of AFS, as well as erosion of bilateral lamina papyracea.

estingly, a recent study from India noted a reverse gender ratio, with a female-to-male prevalence of 2.3 to 1.¹³ A general trend may be observed, however, in that studies with larger sample sizes tend to report equal male-to-female ratios.^{6,14} Males predominated in our sample, with a male-to-female ratio of 1.5 to 1. Regarding ethnicity, the Caucasian-to-African-American ratio in our study was 1.2 to 1. Analysis of ethnicity within the population of AFS patients has not been studied previously.

The mean age at presentation of AFS for our sample was 31.0 years. This corresponds to mean ages of 16 to 37 that have been reported by other authors.^{2,6–13,16,21} With regard

to ethnicity and gender analysis for age at presentation, some interesting findings were noted in the current study. A statistically significant difference in age at presentation was noted for ethnicity, with Caucasians presenting at a mean age 11.7 years older than African-Americans. As represented in Fig. 1, however, this ethnicity difference is carried by the subset of Caucasian females who were diagnosed at a mean age of 46.8 years, which is 20.7 years older than the mean of the three remaining subsets. The reason for the older presentation in Caucasian females in our sample is unclear at this time.

Previous authors have noted nearly equivalent rates of

TABLE III		
Bone Erosion by Sinus		
	No. of Subsites Eroded	Mean Proportion of Erosion
Total erosion	94	
Frontal	21	0.17
Anterior wall	2	
Posterior wall	11	
Floor	8	
Ethmoid	32	0.38
Roof	15	
Lamina papyracea	17	
Sphenoid	35*	0.24
Planum sphenoidale	9	
Clivus	5	
Posterior wall	7	
Lateral wall	11	
Pterygoid plates	3	
Maxillary	6	0.04
Roof (orbital floor)	1	
Anterior wall	2	
Posterior wall	2	
Lateral wall	1	

*Although the number of eroded subsites is greater for the sphenoid compared to the ethmoid, the mean proportion of erosion was actually greater for the ethmoid because of the smaller number of possible subsites in the ethmoid sinus.

unilateral and bilateral presentation of AFS overall,^{10,14} although children tended to present more often with unilateral disease (70%) in a study by McClay *et al.*¹⁴ Analysis of our sample revealed bilateral disease to be more common, at a rate of 64%. The ethnicity and gender variables did not have a statistically significant effect in the prediction of unilaterality or bilaterality in the presentation of AFS. Of note, in their description of the diagnostic criteria for AFS, Bent and Kuhn⁷ reported an 87% incidence of unilateral disease.

Erosion of the bony sinus walls is an acknowledged phenomenon of AFS and has been described by several authors.^{8–10,14,15,16,18–20} Bone erosion is reported to occur in 20%^{14,15} to 93%¹⁰ of AFS cases. However, inconsistency in the definition of bone erosion across studies makes direct comparison of these percentages misleading.

The greatest reported incidence of bone erosion in AFS (defined by the authors as thinning of the wall of an opacified sinus) is 93% by Mukherji *et al.*¹⁰ Manning *et al.*⁹ also note a high frequency of bone erosion (9 of 10 patients); however, in this particular study, the design was to compare imaging modalities rather than to report the true incidence of bone erosion. Other studies by Ence *et al.*¹⁶ and Handley *et al.*²⁰ report the presence of bone erosion to be 50% and

64%, respectively, with erosion of the medial wall of the maxillary sinus included in these cases. A 21% incidence of erosion of the cranial base is reported by Kinsella *et al.*¹⁸ Finally, McClay *et al.*¹⁴ note no significant difference in the presence of bone erosion between adults and children.

Nussenbaum *et al.*¹⁵ reported a 20% incidence of bone erosion in AFS in a sample of 142 patients. The authors excluded erosion of the medial wall of the maxillary sinus and osteomeatal complex from consideration, as this area is frequently eroded in patients with AFS. Our study design was based on this concept and considered areas of bone erosion with the exception of the medial maxillary wall. In our sample, bone erosion was present in 21 (44.7%) patients. Considering ethnic and gender variables, the presence of bone erosion in Caucasians closely approximated that found by Nussenbaum *et al.*¹⁵ at 23.1%. However, African-Americans presented with bone erosion at a statistically significantly higher rate (71.4%, $p = 0.028$). Ethnicity was found to be a significant predictor of bone erosion by logistic regression analysis. There was no statistically significant difference in bone erosion for gender in our sample, with males exhibiting bone erosion at 53.6% versus females at 31.6%. Interestingly, examination of further group divisions revealed 10 of 13 African-American males demonstrating bone erosion, while only 1 of 11 Caucasian females displayed bone erosion. Statistical analysis of the smaller ethnic-gender groups did not reveal a difference in bone erosion; however, with increased power, a difference may be seen in future studies.

Alteration in the bony structure of AFS patients is thought to result largely from pressure remodeling rather than overt bone destruction,²² as fungal invasion is not present in this disease. Additionally, major basic protein released from eosinophils may contribute to bony changes with its known tissue-toxic effects.¹⁶ Although bone erosion in AFS may at times be impressive on radiographic studies, Marple and Mabry²³ have commented that the natural bony expansion in this disease may allow for improved accessibility to anatomically narrow passages such as the frontal recess. They also note that despite erosion of structures such as the planum sphenoidale and clivus, endoscopic surgical debridement is feasible provided the underlying dura, periorbita, and periosteum remain undisturbed.

A rationale for the difference in presentation of AFS patients with bone erosion between Caucasian and African-American ethnic groups currently remains unexplained. One possible explanation of the higher incidence of bone erosion in African-American patients may be a delay in presentation to an otolaryngologist in comparison to Caucasian patients. Access to health care among certain ethnic groups may be delayed for financial reasons. An assessment of the presence of health insurance among the patients in our sample revealed that all patients had health insurance at the time of presentation, with the exception of two African-American patients, both of whom had bone erosion. Nineteen other patients in our sample who carried health insur-

ance also had bone erosion, so insurance was not a significant factor in predicting bone erosion, but may serve as an indicator of possible delay in health care for certain groups. A second potential explanation for the greater incidence of bone erosion in the African-American population may be a genetic or multifactorial susceptibility of this particular group to bone erosion in AFS. Various other pathologies have predilection for a given group (i.e., sarcoidosis in African-Americans and systemic lupus erythematosus in females). Future studies may determine a genetic or multifactorial cause for the higher incidence of bone erosion in certain ethnic groups. Finally, given the allergic rather than infectious nature of AFS,¹² one additional consideration for explaining the ethnic difference in bone erosion in AFS is a potential difference in environmental exposure to fungi between African-Americans and Caucasians. Should one group be exposed to a higher environmental fungal load, it is possible that the disease may progress at a faster rate.

It should be noted that due to the limited sample size among the groups in this study, our results may not be generalizable to larger populations of ethnic and gender groups. Therefore, the results of this study should be interpreted cautiously.

In concurrence with a previous report by Nussenbaum *et al.*¹⁵ regarding individual sinuses affected by bone erosion in AFS, we found the ethmoid sinus to exhibit bone erosion in the greatest proportion, followed by the sphenoid, frontal, and maxillary sinuses (Fig. 2). In fact, there were statistically significant differences in bone erosion among the sinuses in our sample. The propensity for certain sinuses to exhibit bone erosion has potential implications in surgical treatment of AFS. Although endoscopic sinus surgery for AFS has been proven safe in experienced hands,²³ the surgeon must be aware of the presence of bone erosion and take care not to injure underlying orbital or intracranial structures.

CONCLUSION

This study evaluated ethnic and gender differences in AFS with regard to age at presentation and presence of sinus wall bone erosion. We found a statistically significant difference in age of presentation for Caucasians as compared to African-Americans, with Caucasians presenting at a mean age 11.7 years later than African-Americans. Interestingly, this difference was largely carried by the subset of Caucasian females. Additionally, we found ethnicity to be a statistically significant predictor of bone erosion in AFS, with a larger number of African-Americans presenting with erosion of the bony sinus walls. The cause for these findings is as yet undefined, and additional studies will be necessary to determine the basis and implications of ethnic and gender differences in AFS.

REFERENCES

1. Millar JW, Johnston A, and Lamb D. Allergic aspergillosis of the maxillary sinuses. *Thorax* 36:710, 1981.
2. Katzenstein AA, Sale SR, and Greenberger PA. Allergic *Aspergillus* sinusitis: A newly recognized form of sinusitis. *J Allerg Clin Immunol* 72:89–93, 1983.
3. Gourley DS, Whisman BA, Jorgensen NL, et al. Allergic *Bipolaris* sinusitis: Clinical and immunopathologic characteristics. *J Allerg Clin Immunol* 85:583–591, 1990.
4. Bartynski JM, McCaffrey TV, and Frigas E. Allergic fungal sinusitis secondary to dermatiaceous fungi—*Curvularia lunata* and *Alternaria*. *Otolaryngol Head Neck Surg* 103:32–39, 1990.
5. Allphin A, Strauss M, and Abdul-Karim FW. Allergic fungal sinusitis: Problems in diagnosis and treatment. *Laryngoscope* 101:815–820, 1991.
6. DeShazo RD, and Swain RE. Diagnostic criteria for allergic fungal sinusitis. *J Allerg Clin Immunol* 96:24–35, 1995.
7. Bent JP, and Kuhn FA. Diagnosis of allergic fungal sinusitis. *Otolaryngol Head Neck Surg* 111:580–588, 1994.
8. Manning SC, Schaefer SD, Close LG, et al. Culture-positive allergic fungal sinusitis. *Arch Otolaryngol Head Neck Surg* 117:174–178, 1991.
9. Manning SC, Merkel M, Kriesel K, et al. Computed tomography and magnetic resonance diagnosis of allergic fungal sinusitis. *Laryngoscope* 107:170–176, 1997.
10. Mukherji SK, Figueroa RE, Ginsberg LE, et al. Allergic fungal sinusitis: CT findings. *Radiology* 207:417–422, 1998.
11. Manning SC, Mabry RL, Schaefer SD, et al. Evidence of IgE-mediated hypersensitivity in allergic fungal sinusitis. *Laryngoscope* 103:717–721, 1993.
12. Manning SC, and Holman M. Further evidence for allergic pathophysiology in allergic fungal sinusitis. *Laryngoscope* 108:1485–1496, 1998.
13. Dhiwakar M, Thakar A, Bahadur S, et al. Preoperative diagnosis of allergic fungal sinusitis. *Laryngoscope* 113:688–694, 2003.
14. McClay JE, Marple B, Kapadia L, et al. Clinical presentation of allergic fungal sinusitis in children. *Laryngoscope* 112:565–569, 2002.
15. Nussenbaum B, Marple BF, and Schwade ND. Characteristics of bony erosion in allergic fungal sinusitis. *Otolaryngol Head Neck Surg* 124:150–154, 2001.
16. Ene BK, Gourley DS, Jorgensen NJ, et al. Allergic fungal sinusitis. *Am J Rhinol* 4:169–178, 1990.
17. Ferguson BJ, Barnes L, Bernstein JM, et al. Geographic variation in allergic fungal sinusitis. *Otolaryngol Clin North Am* 33:441–449, 2000.
18. Kinsella JB, Rassekh CH, Bradfield JL, et al. Allergic fungal sinusitis with cranial base erosion. *Head & Neck* 18:211–217, 1996.
19. Zinreich SJ, Kennedy DW, Malat J, et al. Fungal sinusitis: Diagnosis with CT and MR imaging. *Radiology* 169:439–444, 1988.
20. Handley GH, Visscher DW, Katzenstein AA, et al. Bone erosion in allergic fungal sinusitis. *Am J Rhinol* 4:149–153, 1990.
21. Quraishi HA, and Ramadan HH. Endoscopic treatment of allergic fungal sinusitis. *Otolaryngol Head Neck Surg* 117:29–34, 1997.
22. Kupferberg SB, Bent JP, Kuhn FA. Prognosis for allergic fungal sinusitis. *Otolaryngol Head Neck Surg* 117:35–41, 1997.
23. Marple BF, and Mabry RL. Comprehensive management of allergic fungal sinusitis. *Am J Rhinol* 12:263–268, 1998. □