

Radiological sinonasal findings in adults with cystic fibrosis

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ABSTRACT

Background: Care of cystic fibrosis (CF) patients has extended the expected survival far into adulthood. The morphological changes of adult CF patients' paranasal sinuses have not been thoroughly addressed.

Methods: A retrospective review was performed of computed tomography imaging of adult CF patients at an academic medical center. Developmental changes, bone sclerosis, mucocoeles, and degree of inflammation (using a modified Lund-Mackay scoring system) were assessed.

Results: Forty-five patients were included in the study. The majority of frontal and sphenoid sinuses were either aplastic or hypoplastic. Maxillary hypoplasia was less commonly seen. Seven patients had mucocoeles. Sclerosis of the sinuses was a common finding, affecting 84.4% of patients. Inflammation of the sinuses was also common, with a median modified Lund-Mackay score of 15.0 (out of a median 20 possible).

Conclusion: Poor development of the sinuses seen in pediatric CF patients persists into adulthood. Inflammation of the sinuses is a common finding. Bone sclerosis, likely caused by chronic inflammation, affects a large majority of these patients.

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Key words: Adult patients, aplasia, computed tomography, cystic fibrosis, hypoplasia, sclerosis, sinusitis

Cystic fibrosis (CF) causes frequent and recurrent sinus infections. CF previously led to a predicted survival that did not extend into adulthood. Recent advances in CF care have now resulted in predicted median survival that exceeds 35 years.¹

The paranasal sinuses are present at an early age of childhood but normally develop well into adolescence. CF patients tend to have more poorly developed sinuses, although whether this is due to repeated inflammation and infections or some other cause is unknown.² Numerous studies have examined the radiological appearance of CF patient sinuses in childhood but with the predicted survival increasing, little data exist on the sinuses of adult CF patients. Changes consistent with long-term sinusitis, such as mucocoele formation and bone sclerosis, have not been fully investigated in this population. We undertook this analysis to determine the radiological characteristics of the paranasal sinuses of adult CF patients.

METHODS

Patients aged ≥ 18 years with a diagnosis of CF undergoing sinonasal radiological imaging at the University of Utah Department of Radiology were selected. These patients were identified by searching chest radiographs for CF in the diagnosis between the years 1999 and 2008. The data set was then pared down by excluding all patients who were not 18 years of age at the time of the study. The data set was further pared down by excluding patients who had not had a maxillofacial sinus computed tomography (CT) scan, yielding a final data set of adult CF patients who have had a maxillofacial sinus CT. Patients with CF undergoing maxillofacial CTs may have

the diagnosis of "sinusitis" rather than CF in the clinical history portion of their radiology consultation request. The radiological query was therefore begun with chest radiographs rather than maxillofacial sinus CTs, ensuring a sufficiently thorough search.

The evaluations were performed by the authors at a Picture Archiving and Communication System station. All scans had at least coronal images, with more recent scans having axial and sagittal images as well. The CT scans were evaluated for aplasia and hypoplasia of frontal, maxillary, and sphenoid sinuses, using the criteria in Table 1 (Figs. 1–4). The scans were also evaluated for presence of previous ethmoidal surgery, presence and location of mucocoeles, and presence and location of bony sclerosis. Sclerosis was defined as the presence of periosteal reaction, signal attenuation, thickening, indistinct borders, poorly defined cortices, or obvious difference in surrounding bone compared with remaining skull base (Figs. 5 and 6).

Degree of inflammation was determined using a modified Lund-Mackay system, as previously described.³ In the Lund-Mackay scoring system, 0 is assigned to sinuses with no mucosal thickening, 2 is assigned to opacified sinuses, and 1 is assigned to everything in between. The frontal, anterior ethmoid, maxillary, posterior ethmoid, and sphenoid sinuses as well as the ostiomeatal complex on each side is scored, with a total of 24 possible. A modification of this system was used because of the prevalence of aplastic sinuses and resected ostiomeatal complexes. Briefly, in this modification, the ostiomeatal complex was scored either 0 or 2. In addition, if a patient lacked an evaluable sinus or complex the total score was adjusted to account for the lack of this structure. This was done by multiplying the patient's total score by the possible total 24 and dividing by the possible total for that patient ($24 - 2 \times \text{number of missing structures}$). The research was performed following the approval of the Institutional Review Board of the University of Utah.

RESULTS

Forty-seven patients were identified in the search. Two patients' imaging studies were unavailable for electronic retrieval, resulting in a study population of 45 patients. Many

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Table 1 Definitions of aplasia and hypoplasia used in this study

Frontal sinus aplasia

Absence of frontal bone pneumatization

Frontal sinus hypoplasia

Oval-shaped sinus

The lateral margin of the sinus is medial to a vertical line drawn through the medial surface of the globe

No intrasinus septa

Maxillary sinus hypoplasia (three of the following four criteria must be present)

Oval-shaped sinus

No pneumatization of the sinus below the level of the nasal floor

The medial wall of the sinus is lateral to a vertical line drawn tangentially to the medial orbital border; the origin of the inferior turbinate to lateral nasal wall was used as the landmark when prior sinus surgery was performed

Lateral extension of the sinus medial to a vertical line drawn through the middle of the orbit at the level of the infundibulum, in the coronal plane

Sphenoid sinus aplasia

Absence of sphenoid bone pneumatization

Sphenoid sinus hypoplasia

Oval-shaped sinus

Pneumatization limited to the presphenoid, anterior to the vertical plane of the tuberculum sellae

No intrasinus septa

Source: Adapted from Ref. 2.



Figure 1. Aplastic frontal sinus, coronal view.

patients had multiple scans and the most recent scan was used for the analysis. Only one scan per patient was used in the analysis. The mean age at the time of imaging study was 29.0 years (range, 18–52 years).

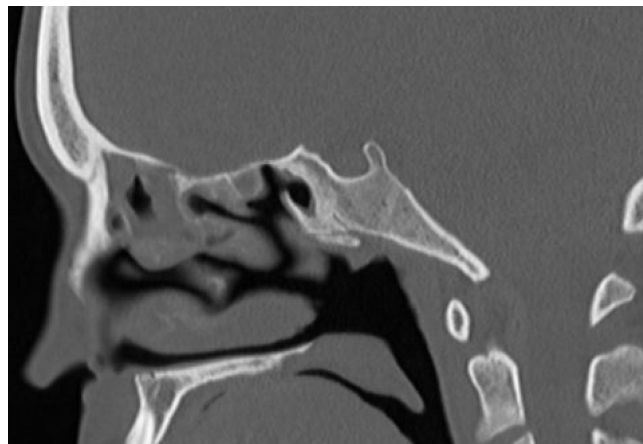


Figure 2. Aplastic frontal sinus, sagittal view.



Figure 3. Hypoplastic sphenoid sinuses, axial view.

Overall, 65.9% of frontal sinuses were either aplastic or hypoplastic. Twelve frontal sinuses (13.3%) were aplastic and 41 (52.6%) of the remaining 78 frontal sinuses were hypoplastic. Likewise, 74.2% of sphenoid sinuses were poorly developed, with 4 (4.4%) being aplastic and 60 (69.8%) of the remaining 86 being hypoplastic. Maxillary hypoplasia was less common, affecting 22.2% of maxillary sinuses. The presence of aplasia and hypoplasia did not correlate with previous surgery ($p = 0.33$, chi-square analysis).

Thirty-two (71.1%) patients had had previous surgery. Seven patients had mucocoeles present, with one patient having bilateral frontal mucocoeles, four patients having a unilateral frontal mucocoele, and one each having a maxillary or sphenoid mucocoele. Two patients (15%) with no previous surgery and five patients (16%) with previous surgery had mucocoeles. Previous surgery was not statistically associated with the presence of mucocoeles ($p = 0.98$, chi-square analysis). Sclerosis was a common finding in our study group, with 38 (84.4%) patients manifesting bone sclerosis in their sinuses. Sclerosis was not evenly distributed among the sinuses, being present in 28 (35.9%) of frontal sinuses, 8 (8.9%) of ethmoid

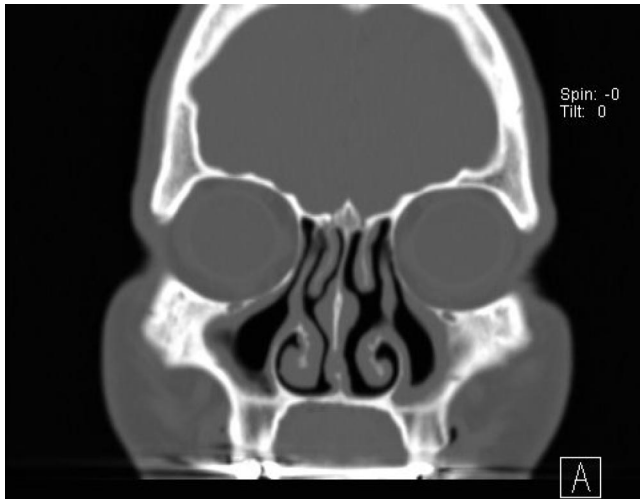


Figure 4. Hypoplastic left maxillary sinus, coronal view.



Figure 5. Sclerosis of the maxilla surrounding the maxillary sinus, axial view

sinuses, 73 (81.1%) of maxillary sinuses, and 63 (73.3%) of sphenoid sinuses. The presence of sclerosis was not statistically associated with previous surgery ($p = 0.35$, chi-square analysis).

Sinus inflammation was a common finding in our study group. The median modified Lund-Mackay score was 15.0 (standard deviation, 3.9; range, 5.0–24.0; Fig. 7). Table 2 displays the distribution of scores by sinus. The modified scoring system resulted in a median possible score of 20 (range, 16–24). Previous surgery did not impact the Lund-MacKay score ($p = 0.42$, unpaired t -test).

DISCUSSION

The thickened secretions seen in CF result in paranasal sinus inflammation, often seen early in childhood. Polyps occurring before adulthood are also seen and may be due to



Figure 6. Sclerosis of the maxilla surrounding the maxillary sinus, coronal view.

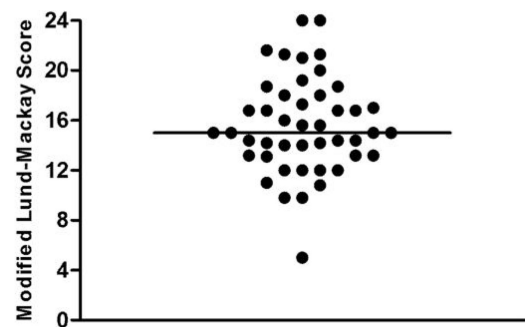


Figure 7. Distribution of modified Lund-Mackay total scores.

changes in ion channels or intense inflammation or both. Poor paranasal sinus development, intense inflammatory changes, high prevalence of previous surgery, medial bowing of the lateral nasal wall, and demineralization have all been described in patients with CF.^{2,4–14} These previous studies have largely focused on children with CF, with some mixing in some adults with CF as well. No previous study has examined adults alone.

Sphenoid sinus underdevelopment has been described as one of the most constant sinus developmental variations in CF patients while seen only rarely in non-CF patients.^{9,11} Nearly three-quarters of our adult patients had sphenoid sinus aplasia or hypoplasia.

Hypoplasia or aplasia of the sinuses was a common finding in our population. This has been attributed to chronic inflammation by many experts but has recently been proposed to have a genetic basis as well.^{2,9,11} Krzeski *et al.* showed frontal agenesis or hypoplasia in 43% of patients aged 6–26 years.¹⁰ Nishioka *et al.* found 63% of their patients who were >10 years old to have poor frontal sinus development.⁷ The incidence of poor frontal development in our patients ≥ 18 years old (65.9%) is more in agreement with this older age group.

Sinus inflammation is commonly seen in CF patients and has been shown to be higher than non-CF CRS patients, approaching 100% sinus involvement in some patients.^{5,7,12} McMurphy *et al.* found a mean unadjusted Lund-MacKay score of 14.5 in 134 patients with an average age of 12.7 years (range, 2–27 years).¹⁴

Table 2 Distribution of Lund-Mackay scores by sinus

Score	Frontal	Anterior Ethmoid	Maxillary	Ostiomeatal Complex	Posterior Ethmoid	Sphenoid
0	4 (5.1%)	1 (1.1%)	0 (0.0%)	15 (45.4%)	4 (4.4%)	7 (8.0%)
1	26 (33.3%)	58 (64.4%)	70 (77.8%)		68 (75.6%)	47 (53.4%)
2	48 (61.5%)	31 (34.4%)	20 (22.2%)	18 (54.5%)	18 (20%)	34 (38.6%)
NA*	12	0	0	57	0	2

*NA = not assigned (aplastic sinuses or ostiomeatal complexes that had been opened surgically were not assigned a score).

Krzeski found that inflammatory changes were prevalent throughout their CF population ($n = 30$; aged 6–26 years; mean 15.5 years) but there was no correlation between age and progression of inflammatory disease. Becker *et al.* found higher Lund-MacKay scores were associated with a higher likelihood for revision surgery in their CF patients.¹⁵ We used a modified Lund-MacKay scoring system to account for the high incidence of aplasia in this population and found a similar score. The mean unmodified Lund-MacKay score for our sample was 13.5, again similar to that found by Krzeski *et al.*, verifying the finding that inflammation occurs early and does not tend to progress over ensuing years.

Nearly three-quarters of our patients had previous surgery. This is higher compared with previous studies. Eggesbo *et al.* published three studies in 2001 and 2002 where the age of the patients ranged from 3 to 54 years with a median age of 18–20 years.^{11,12,16} Their rate of previous surgery was 42–45%. Our population's mean age was nearly 10 years older than the median age of these studies and the higher rate of surgery is likely related to this older age. It is possible, however, that this may also be related to a higher tendency of surgeons treating our CF patients to intervene surgically than those treating the patients in the Eggesbo *et al.* patients.

Mucocoele formation has not been a common finding in previous studies of CF patients. Poor mucociliary clearance combined with intense inflammation may result in complete sinus obstruction in some cases. As expected, the narrower outflow of the frontal sinus was associated with the majority of mucocoeles affecting our patients.

Sclerosis was a common finding in our patients, especially affecting the maxillary and sphenoid sinuses. Sclerosis has not been evaluated in previous studies. Rather, demineralization of the sinus bones has been found to be prevalent in CF patients.¹⁰ Eggesbo *et al.* did note, however, that thick sclerotic bones were common in the sphenoid area in their patients who were aged 3–54 years.¹¹ New bone formation has been associated with sinus inflammation and the intensity of the osteoneogenesis has correlated with the degree of inflammation.^{17,18} It is likely that the longer-standing inflammation in our adult population has resulted in osteoneogenesis, manifesting grossly as sclerosis on CT. In this cross-sectional study, we can not evaluate this hypothesis. Instead, a longitudinal study evaluating multiple CT scans, preferably multiple scans in the same patients, will need to be performed.

As in any retrospective study, there are other possible pitfalls in the conclusions we have drawn. First, our search methodology ensured that we included only patients with CF in the study group. We did not, however, necessarily include all adult patients with CF treated at the University of Utah.

Our data, therefore, may be skewed toward those with higher levels of sinus inflammation or findings, *i.e.*, patients with sinus complaints that prompted a scan. Nishioka *et al.* performed a prospective study as part of a wellness program in CF patients yet our data are in good agreement with theirs.⁷ In this study we did not compare our sample to non-CF matched controls because this has been done numerous times throughout the last 10 years and has consistently and without exception shown increased pathological changes in CF patients. Such a comparison was not a goal of this study.

CONCLUSION

Our study focused exclusively on adult patients with CF and found similar inflammatory and developmental changes as seen previously in younger patients. Our adult CF patients had a higher rate of previous surgery and were found to have a significant prevalence of frontal mucocoeles. Sclerosis was a prominent finding, especially in the maxillary and sphenoid sinuses and may indicate the evolution of osteoneogenesis in these chronically inflamed patients.

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