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3-D volumetric computed tomographic scoring as an objective outcome measure for chronic rhinosinusitis: Clinical correlations and comparison to Lund-Mackay scoring

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Abstract

Background—We aimed to test the hypothesis that 3-D volume-based scoring of computed tomographic (CT) images of the paranasal sinuses was superior to Lund-Mackay CT scoring of disease severity in chronic rhinosinusitis (CRS). We determined correlation between changes in CT scores (using each scoring system) with changes in other measures of disease severity

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(symptoms, endoscopic scoring, and quality of life) in patients with CRS treated with triamcinolone.

Methods—The study group comprised 48 adult subjects with CRS. Baseline symptoms and quality of life were assessed. Endoscopy and CT scans were performed. Patients received a single systemic dose of intramuscular triamcinolone and were reevaluated 1 month later. Strengths of the correlations between changes in CT scores and changes in CRS signs and symptoms and quality of life were determined.

Results—We observed some variability in degree of improvement for the different symptom, endoscopic, and quality-of-life parameters after treatment. Improvement of parameters was significantly correlated with improvement in CT disease score using both CT scoring methods. However, volumetric CT scoring had greater correlation with these parameters than Lund-Mackay scoring.

Conclusion—*Volumetric scoring* exhibited higher degree of correlation than Lund-Mackay scoring when comparing improvement in CT score with improvement in score for symptoms, endoscopic exam, and quality of life in this group of patients who received beneficial medical treatment for CRS.

Keywords

computed tomography; computer-assisted image analysis; endoscopy; quality of life; Lund-Mackay

Introduction

For decades, rhinosinusitis has been documented as the most common chronic illness in the United States. It affects a large proportion of the population ¹ and is rising in incidence ². Chronic rhinosinusitis (CRS) is associated with marked socioeconomic impact ³ and detriment to the patient's overall well-being ⁴. It is characterized by chronic inflammation and changes in the nasal and paranasal sinus mucosa that range from inflammatory thickening to gross polyp formation.

Computed tomographic (CT) scanning is useful for assessing changes in paranasal sinus mucosa ⁵. Mucosal thickening on CT currently is considered an objective diagnostic criterion for CRS ⁶. Furthermore, CT scanning is also used to assess efficacy of various medical and surgical treatments for CRS. To perform such efficacy studies, CT findings must be summarized, and various scoring methods have been proposed ⁷, with the goal of improving correlation between CT results and other findings. Improving the diagnostic capability of a tool that can objectively assess changes in disease will aid the ongoing quest to find optimal treatment of CRS.

The Lund-Mackay scoring system ⁸ is most widely used and was recommended by the American Academy of Otolaryngology–Head and Neck Surgery Task Force on Rhinosinusitis for further outcomes research ^{9–11}. Nevertheless, questions have been raised regarding how well existing CT scoring systems correlate with the clinical manifestations of CRS ¹². Zinreich ⁷ noted that the Lund-Mackay system was the most widely accepted, objective, and reproducible of the 4 scoring systems he evaluated, but he also noted that it did not account for the volume of inflammatory disease. He suggested that quantifying disease volume could add clinical value to future classification systems and proposed using magnetic resonance imaging (MRI) to assess the volume of inflammatory mucosa.

Two-dimensional assessment of sinus disease has been used in assessing the effect of medication for CRS ^{13,14}, showing a reduction in disease on the coronal images from a

consistent maxillary sinus location. Savranlar et al¹⁵ reported a statistically significant difference in CT sinus mucosal thickness measurements before and after patients used decongestant spray, but Lund-Mackay scoring results of the same CTs did not show a corresponding difference.

A 3-dimensional (3-D) assessment that can determine the percent volume of disease from CT images would be the most comprehensive and precise information that could be obtained about disease severity on CT images. Sanchez Fernandez et al¹⁶ used CT images to calculate sinus volume, and Deeb et al¹⁷ in 2011 reported measuring mucosal disease and total sinus volume for maxillary sinuses. However, no published reports have described using imaging data (CT or MRI) to score the total percent volume of sinus disease when staging CRS. Here, we compared a scoring system that considered volume percent of sinus disease (hereafter termed *volumetric scoring*) with the Lund-Mackay scoring system for CT assessment of CRS to determine if *volumetric scoring* was superior in correlating with changes from medical treatment that occurred in other measures of disease severity (symptoms, endoscopic findings, and quality of life).

Materials and Methods

This prospective study, after passing approval by the Radiation Safety Committee, was approved by the Mayo Clinic Institutional Review Board. Patients were screened for any contraindications to therapy with triamcinolone acetonide (e.g. hypertension, diabetes mellitus, ulcers, or osteoporosis) or other exclusion criteria (Box 1). Long-term experience with a single dose of intramuscular triamcinolone has shown that adverse effects are extremely rare. Although long-term adverse effects would not apply to the patients receiving a single dose of triamcinolone in this study, as part of the informed consent process, all subjects were apprised of the possible adverse effects of short-term and long-term treatment with systemic corticosteroid medication.

Box 1

Exclusion Criteria

Upper respiratory infection or acute sinus infection within 2 weeks before the baseline or 1-month follow-up evaluations

Having had oral or parenteral glucocorticoids in the 3 months preceding the baseline study

Women who were pregnant or lactating

Persons younger than 18 years

Immunosuppressed persons

Patients with acute or chronic complications of chronic rhinosinusitis (eg, brain abscess, related problems with eyes or central nervous system)

Patients with hypertension, diabetes mellitus, ulcers, or osteoporosis; other conditions that might preclude safe administration of a single dose of triamcinolone

Study subjects with a diagnosis of CRS were recruited from July 10, 2006 to April 18, 2008 after consultation in the Department of Otorhinolaryngology or the Division of Allergic Diseases at Mayo Clinic (Rochester, Minnesota) All patients provided written informed consent.

Treatment

Although no definitive long-term cure for CRS exists, a consistent and dramatic short-term improvement in symptoms and intranasal examination findings can occur with systemic

glucocorticoid treatment. It is used only intermittently for short-term therapy to avoid potential adverse effects associated with long-term use. For over 4 decades, a common practice in the Mayo Clinic Department of Otorhinolaryngology has been to use intramuscular triamcinolone acetonide for some patients with CRS who have refractory symptoms. Adverse effects have been observed rarely.

All patients underwent clinical evaluation. Patients whose treatment would include a single dose of IM triamcinolone were offered enrollment in the study. Enrollment was refused to any patients in whom screening revealed a contraindication to administration of triamcinolone. For those enrolled, treatment was a single intramuscular dose of triamcinolone acetonide in the gluteus maximus (60 mg for patients less than 70 kg, 80 mg for those greater than or equal to 70 kg).

Study Design

The study design was prospective. Before recruiting patients, a power calculation determined that we needed complete data from 40 subjects (out of 50 enrolled) to adequately power the study. Based on that sample size, it was determined the study would have 80% power to declare an observed correlation of 0.41 as significantly different from zero. This calculation was based on a two-sided Fisher's z test of the null hypothesis that the Pearson correlation coefficient is zero, and a type I error level of 5%. We anticipated that the use of triamcinolone would have a moderate to large effect on chronic rhinosinusitis symptoms, and thus have the best chance of revealing any difference between the scoring systems in assessing patients with CRS using this sample size and the parameters in this study.

Because we aimed to compare the 2 scoring systems in the same group of CRS patients before and after a single treatment, there was no role for randomization, control subjects, or placebo treatment.

To be included in the study, subjects had to fulfill the American Academy of Otorhinolaryngology–Head and Neck Surgery criteria for the diagnosis of CRS (Box 2). In addition, patients were required to have CT findings showing mucosal thickening of at least 5 mm in 2 or more sinuses. In 2007, subsequent to the onset of this study, the diagnostic criteria for adults were revised by the Academy (Box 2)^{6,18}. However, patients in our study still met the new diagnostic criteria.

Box 2

Historical and Current Criteria for Diagnosing Chronic Rhinosinusitis, Based on American Academy of Otorhinolaryngology–Head and Neck Surgery Guidelines

Diagnostic Criteria Used Through 2006 (17): Symptoms for >3 mo of 2 or More of the Major Criteria OR 1 Major and 2 Minor Criteria

Major Criteria

- Nasal obstruction or blockage (stuffy nose)
- Postnasal drainage
- Facial (sinus) pressure or pain
- Hyposmia or anosmia
- Cough

Minor criteria

- Headache

Fever
 Halitosis
 Fatigue
 Dental pain
 Ear pain, pressure, or fullness

Diagnostic Criteria Used Since 2007 (7)

12 weeks of 2 symptoms below:

Mucopurulent drainage
 Nasal obstruction
 Facial pain, pressure, or fullness
 Decreased sense of smell

AND at least 1 of the following (evidence of inflammation):

Purulence
 Polyps
 Radiographic evidence of inflammation

Benchmarking

To compare *volumetric scoring* vs. Lund-Mackay scoring using CT images, a benchmark for comparison was needed. Although many studies of CRS use CT as the benchmark, the current study aimed to test CT scoring systems themselves and thus needed an alternative standard.

We selected various parameters and sought to identify those that changed significantly with a therapeutic intervention known to help patients with CRS. We used the symptom questionnaire recommended by the Scoring and Therapy Group⁹ and graded symptoms using a visual analog scale (Box 3). Fiberoptic endoscopic examinations were performed, and outcomes were graded using the system recommended by the Scoring and Therapy Group⁹. Scoring was modified in a backward-compatible fashion to increase the resolution of the results (Table 1). Patients also answered the QOL questionnaire (RhinoQOL or “Rhinosinusitis Quality of Life Questionnaire”) that was developed and validated for the study of patients with CRS^{19,20}. In the QOL survey, questions about the effect of the patient’s nasal symptoms were grouped in 3 categories: “frequency”, “bothersomeness”, and “impact”. CT scanning of the nose and paranasal sinuses was performed using a Siemens Sensation 64 (0.75 mm axial thickness at 0.4 increment and H70 bone kernel) or the Xoran MiniCat (0.4 mm axial slice thickness, contiguous). Phantom data using both scanners showed no significant difference in volume calculations using images from both scanners. The CT protocol used was the same as used for other clinical patients, so there was not any increase in radiation exposure for the protocol CTs. Figure 1 shows the individual parameters assessed during the evaluations.

Box 3

Symptoms Scored Using a Visual Analog Scale^a

Facial pain or pressure

^aPossible scores ranged from 1–10 for each symptom.

Headache
Nasal blockage or congestion
Nasal discharge
Olfactory disturbance
Overall discomfort

CT Scoring

Volumetric scoring and Lund-Mackay scoring of the extent of sinus disease was determined from the CT data at baseline and 1 month after treatment. Most patients with CRS have improvements with triamcinolone treatment that can still be observed 1 month after administration.

The Lund-Mackay scoring system is outlined in Table 2. Lund-Mackay score was determined by neuroradiologists (J.J.O., J.I.L.), an otorhinolaryngologist (J.F.P.), and an allergist (J.B.H.) who were blinded to the clinical data including symptom and endoscopy scores, and QOL data. Scoring differences were reviewed, discussed, and resolved.

Volumetric scoring was done using the software on the Siemens Wizard workstation or Mayo Clinic Analyze (Biomedical Imaging Resource, Mayo Clinic, Rochester, MN) to define the precise volume of each sinus using 0.4-mm spaced images for each patient (Figure 2). A set of heuristics was developed to allow consistent delineation (segmentation), whether patients had previous sinus surgery or not, of the anatomic boundaries of each sinus area on the CT images for each patient. A block of CT image data (multiple slices) is composed of voxels (in this study, cubes of 0.4 mm per edge). A process called segmentation defined which voxels belonged to which sinus (Figure 2). It was necessary to do most of the segmentations using manual methods, since a fully automated method did not exist for paranasal sinuses. Eight authors performed the segmentations (A.C.D., A.S., R.S., N.M.O., K.B.R., N.J., R.D., J.F.P.), and cases were reviewed with the principal investigator (J.F.P.) for accuracy and consistency.

Each voxel had a measure of attenuation (measured in Hounsfield units [HU]; for reference, water has an HU of 0). To assess the paranasal sinuses, the range $-1,024$ to -500 HU was used for air, and disease or mucosal thickening was designated by -499 to $+250$ HU. The software allowed calculation of the volume of disease and air from the segmented voxels. We defined *total volume percentage of disease*, the parameter reported with *volumetric scoring*, as the volume of mucosal thickening in all of a patient's sinuses divided by the total volume in all sinuses (including air and mucosal thickening), multiplied by 100. The bone in the sinus walls or ethmoid partitions was not included in the disease calculations. We were comparing this method to Lund-Mackay scoring which does not include bone.

An additional feature of the Analyze software was its ability to apply segmentations from baseline images to the post-treatment images. By registering both data sets together, objects representing the baseline sinus volumes could be loaded onto the exact space of the sinuses on the post-treatment images. The volume percent of disease could then be calculated using the previously defined anatomic space of each sinus. This saved the time and labor of performing a second segmentation of all sinuses on the post-treatment scans.

Statistical Analysis

Statistical analysis was performed to compare *volumetric scoring* vs Lund-Mackay scoring and determine whether they showed significant differences in correlation with changes in other parameters after a beneficial medical therapeutic intervention. Analysis was done by statisticians of the Mayo Clinic Department of Biostatistics.

The differences (changes from baseline to 1 month post-treatment) were calculated for each evaluation (symptom questionnaire, endoscopic findings, QOL questionnaire, and CT score for each scoring method). The parameters studied included all individual items for each type of evaluation. Additionally, total scores for endoscopic examination, symptoms, and QOL, 3 symptom score (obstruction, discharge, olfactory) and subtotal QOL scores (sub-scores) for frequency, bothersomeness, and impact, were evaluated (Figure 1). The data distribution allowed the use of parametric statistical methods. Analyses were performed using SAS statistical software (version 9.1; SAS Institute, Inc). We determined the correlation between change in CT score (for both scoring methods) compared to change in each parameter score and the composite scores. We determined the level of significance for the correlations and compared the performance graphically (Figure 3).

To look for a statistically significant difference between *volumetric scoring* and Lund-Mackay scoring we used a regression model. This evaluated the relationship between the dependent variable (the scores for symptoms, examination findings, and quality-of-life parameters) and the predictor variables (*volumetric scoring* and Lund-Mackay scoring). First, the regression model was fit between each parameter (change with treatment) and Lund-Mackay scoring (change with treatment) to determine the percent of the total variation in the dependent variable (the parameter) that could be explained by Lund-Mackay scoring (Table 3, column 2). We then determined whether including *volumetric scoring* in that regression model could explain any *additional* variation in the dependent variable (Table 3, column 3). We then showed whether a statistically significant improvement could be obtained with *volumetric scoring* over Lund-Mackay scoring for each parameter (Table 3, column 4, items highlighted in yellow).

Results

Forty-eight subjects with CRS completed this study. Of these, 37 patients had visible nasal polyps. 23 patients had past sinus surgery. No patients reported any clinically significant adverse effects; 2 patients reported transient irritability.

Figure 1 illustrates the mean change in the parameters (symptom scores, endoscopic exam scores, and QOL scores) measured 1 month after treatment with triamcinolone. All of the parameters used for comparison with CT scoring showed a positive change one month after treatment except for “crusting”.

Figure 3 shows correlation coefficients for the relationship between post-treatment changes in individual parameters (shown on the horizontal axis) and 1) changes in *volumetric scoring* (blue bars) and 2) changes in Lund-Mackay scoring (red bars). Correlation coefficients greater than 0.29 were statistically significant at $p < 0.05$ (orange line).

The correlations for *volumetric scoring* (blue bars) were higher than for Lund MacKay scoring (red bars) for all of the Figure 3 parameters except for ‘Crusting’ and ‘Facial pain or pressure’. For 5 of the parameters (‘Exam-Discharge’, ‘Symptoms-Olfactory disturbance’, ‘Symptoms-Blockage-drainage-olfactory’, ‘QOL-Frequency-Sinus headaches, facial pain’, and ‘QOL-Bothersomeness-Postnasal drip’) in Figure 3, only the *volumetric scoring* method yielded statistical significance (bar extending above orange line) while Lund MacKay

scoring did not. Both CT scoring systems showed significant correlation for 5 additional parameters ('Exam-Polyps', 'Symptoms-Cough', 'Symptoms-Total symptom score', 'QOL-Frequency-Postnasal drip', 'QOL-Frequency-Thick nasal drainage') in Figure 3, and the correlation was higher in all cases for *volumetric scoring*. Both CT scoring systems showed positive going correlations for all but 2 of the parameters ('Exam-Scarring', 'Exam-Crusting').

The results of the statistical analysis are shown in Table 3 with significant P values highlighted in yellow in the 4th column. The additional percentage of variation explained by adding *volumetric scoring* to a regression model using *Lund-Mackay scoring* is shown in the third column. *Volumetric scoring* was significantly ($p < 0.05$) better than Lund-Mackay scoring for multiple parameters ('Examination-Polyps', 'Exam-Total examination score', 'Symptoms-Olfactory', 'Symptoms-Sum of 3: blockage, discharge, olfactory', 'Symptoms-Total symptom score', and 'QOL-Frequency sub-score' for nasal symptoms). The 'QOL-Impact sub-score' for nasal symptoms (Table 3, last row, $p=0.4$), which assesses impact of the patient's nasal symptoms on other non-nasal symptoms ('Tired or fatigued', 'Trouble sleeping', 'Harder to concentrate', 'Embarrassed', 'Frustrated', 'Irritable', 'Sad or depressed', 'Think about') did not do as well in distinguishing performance difference between the 2 CT scoring methods.

Discussion

This study demonstrated that *volumetric scoring* calculated from sinus CT image data yielded a useful objective measure that correlated with improvement after medical treatment of CRS. The Lund-Mackay scoring system also showed correlation with clinical improvement after medical therapy in CRS. However, the stronger correlation of *volumetric scoring* with changes in endoscopic findings, symptoms, and QOL in the current study verifies that a precise measurement of the volume of mucosal disease in sinuses is an improvement over an estimate that uses the same grade (e.g., "1") to represent a range of mucosal disease from 1% to 99% for a given sinus. Interestingly, this study demonstrates that the cumulative effect of scoring 0, 1, or 2 for ten different sinus sites still can result in a meaningful and useful score.

It was noted that a control group was not needed for a comparison of 2 CT scoring methods using the same group of CRS patients. Regarding scoring of patients *without* CRS, Lund-Mackay scoring of patients with and without CRS has been performed and showed an average score of 4.26²¹ and 4.3²² for patients without sinusitis, whereas the score was 9.8 for patients with CRS.

Strengths and Limitations of the Study

The conclusions in this study apply only to our group of CRS patients who were all adults, 23 of 48 with history of previous sinus surgery, and 37 of 48 with visible nasal polyps. Consequently, our prospective sequence of patients meeting the definition of CRS would be most representative of CRS "with" nasal polyps. Since this study was evaluating scoring of disease *in* the sinuses, disease and polyps outside the volume of the sinuses were not included in the measurements, and patients with CRS were included whether they had visible nasal polyps or not. It is unknown if the results would be the same for a group in which all patients were "without" visible nasal polyps (see "Future work" below).

Many studies have looked at the correlation (or lack thereof) between CT findings and sinus symptoms, often reporting a poor correlation between symptoms and CT findings^{23–27}, whereas our study found significant correlations between symptoms and CT scores. We suspect that the poor correlation in other studies may be partly attributable to more

heterogeneity of study groups, less comprehensive data availability in retrospective analyses, and the variable nature of subjective parameters such as symptoms and QOL assessments, particularly when measured at a single point in time. By comparison, our study was prospective, allowing a clear definition of included subjects. Also, it looked at change with treatment between 2 points in time rather than a single assessment of parameters, some of which can be quite variable within a given study group. *Change* in one month after successful treatment is a less “noisy” parameter than a single random value, and thus has a better chance for showing the “signal”, revealing the existing correlations.

The significant correlations between changes in CT scoring and nasal symptoms, endoscopic findings, and QOL parameters in our study support the use of CT scoring (volumetric or Lund-Mackay) as an objective measure to evaluate changes with medical therapy, in a similar group of patients with CRS. It also supports the use of the highly correlating clinical parameters for comparison of CT scoring systems. This study does not give evidence regarding whether the results would be the same if the intervention was surgical rather than medical. That would be the subject of a different study.

We acknowledge that the correlation coefficients in this study were not extremely high, but they were comparable to those associated with clinical significance in other CRS studies^{12,26,28,29}. Until further refinements in phenotypic selection can be made, statistical significance is an important result, given the heterogeneity of patients in CRS studies.

We further acknowledge possible limitations in using CT for investigating the effectiveness of CRS therapy. In this study, we performed 2 CT scans to evaluate change, noting that a single CT scan provides only a static picture of a sometimes dynamically changing condition. Nevertheless, in addition to doubled cost, radiation exposure from 2 CT scans must be considered. This study was reviewed for radiation safety before institutional review board approval was obtained. All of our enrollees in this study were adults, but radiation exposure remains an area of general concern, particularly for children. MRI is a non-radiographic option. However, a CT scan is considerably easier for a patient (much faster to perform), offers greater compliance without medication, and often is less expensive than an MRI. Also, MR imaging has artifacts at air/tissue interfaces which can be impede accurate segmentation.

This study required significant manual intervention for the segmentation of the sinus volumes. Software development is expected to reduce the effort needed. As of manuscript preparation, the method for *volumetric scoring* has not yet been fully automated. The lack of automation currently limits wide application. Using the heuristics we employed, automated segmentation is feasible and could provide an optimized, objective assessment of CT sinus disease for potential use in CRS for research and clinical application (See Future Work below).

Future Work

Further investigations using these data could compare the relative strength of *volumetric scoring* in patients “with” vs. “without” visible nasal polyps or in patients with “less” vs. “more” disease, or in patients having surgical intervention rather than medical. Other CT scoring systems could also be evaluated to determine their relative strength against *volumetric scoring*.

Future work could also look at the impact of osteitic changes or bony thickening on correlation. This study compared volumetric scoring to a scoring method (Lund-Mackay) that assessed soft tissue in the sinuses and not bone. Therefore, bone was not included in the calculations. The ethmoid sinuses (and minimally in the other sinuses) have bony partitions

that are ignored in the same way that the sinus walls are not included in the volume assessment. This methods accepts some possible minimal computational error in 2 ways; some ethmoids have more partitions than others in the demarcated space, and the “normal” mucosal thickness is included in the measured mucosal thickening that is designated as disease.

If volumetric scoring was used for assessment of change with surgery (though it is not in our study), the volume of bone in the ethmoid sinuses would decrease after ethmoid surgery. This would allow more space for mucosa or air. Theoretically this should not change the metric of interest, which is the ratio of mucosa to mucosa plus air. A different study would be needed to assess whether volumetric scoring would perform as well for non-medical interventions.

Since bone is not included, neither of the scoring methods includes assessment of osteitis. Deeb et al ¹⁷, Kim et al ³⁰ and Cho et al ³¹ have found that bone thickness in the maxillary sinus was greater in CRS patients compared to normal subjects. These studies do not tell if there is any change in bone thickness in CRS patients with medical therapy, such that it should be included in scoring methods used to assess change. Bhandarkar et al ³² noted that there was no difference in baseline QOL scores between patients with and without osteitis, but that patients without osteitis were more likely to have QOL improvement with surgery. It is not possible to tell from these observations whether there would be change in osteitis corresponding to a treatment, and whether such a change, if present, would add further to the clinical correlation with change in mucosal disease shown in our study.

This study substantiates the usefulness of *volumetric scoring* and supports pursuit of an automated process to calculate percent of disease volume from sinus CTs. We anticipate that after further automation of the process, future studies could use this tool for optimal objective assessment of medical therapeutic interventions for a similar mix of patients with CRS.

Conclusion

To determine whether a therapeutic intervention is useful in CRS, tools with maximal capability to show significant changes are necessary. This study demonstrated that the objective tool of CT *volumetric scoring* of sinus disease correlated better than the Lund-Mackay scoring system with changes in symptom, examination and QOL measures for patients (37 of 48 with visible nasal polyps) treated medically for CRS. This is a further step toward finding the ultimate objective outcome tool for assessing change in CRS.

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Abbreviations

3-D three-dimensional

CRS	chronic rhinosinusitis
CT	computed tomographic
MRI	magnetic resonance imaging
QOL	quality of life

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Figure 1. Change in scores for endoscopic findings, nasal symptoms, and quality-of-life parameters, 1 month after treatment with triamcinolone acetonide.

Figure 2.

Sinus images from a patient before treatment. Left, Three-dimensional view of the segmented sinus volumes. Right, The corresponding axial view through the ethmoid and sphenoid sinuses (in the plane shown by the green rectangle in the left frame).

Figure 3.

Correlation coefficients for relationship between individual parameters and volumetric staging (blue) or Lund-Mackay staging (red). Individual parameters included endoscopic findings, symptoms, and quality-of-life scores. The orange line ($r = 0.29$) shows the threshold for statistical significance ($p < .05$) for a correlation between the changes for each staging method and that parameter.

Table 1

Endoscopic Scoring System

Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H
Parameter being graded	Endoscopic grading system	Score right	Score left	Backwards compatible endoscopic grading system used	Score	Score right	Score left
Polyps	Absent	0	0	Absence of polyps	0	0	0
	Middle Meatus Only	1	1	Polyps barely visible	1A	1	1
				polyps extend part way along height of middle turbinate	1B	2	2
				polyps extend to inferior edge of middle turbinate	1C	3	3
	Polyps Beyond The Middle Meatus	2	2	polyps extend to top of inferior turbinate	2A	4	4
				polyps extend along the side of inferior turbinate	2B	5	5
Edema	Absent	0	0	polyps extend to or beyond inferior edge of inferior turbinate	2C	6	6
	Mild	1	1	Absent		0	0
				Barely perceptible		1	1
				Mild		2	2
	Severe	2	2	Moderate		3	3
				Severe		4	4
Discharge	None	0	0	None		0	0
	Clear, Thin	1	1	Slight, clear		1	1
				Clear, Thin		2	2
				Thicker, gray		3	3
	Thick or Purulent	2	2	Thick or Purulent		4	4
				Absent		0	0
Scarring	Absent	0	0	Limited		1	1
	Mild	1	1	Mild		2	2
				Moderate		3	3
				Severe		4	4
	Absent	0	0	Absent		0	0
				Minimal		1	1
Crusting	Mild	1	1	Mild		2	2

Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H
Parameter being graded	Endoscopic grading system	Score right	Score left	Backwards compatible endoscopic grading system used	Score	Score right	Score left
				Moderate		3	3
	Severe	2	2	Severe		4	4

Table 2**Lund-Mackay Scoring System**

Anatomic Location	Scoring Criteria^a
Maxillary sinuses	0: No abnormality
	1: Partial opacification
	2: Total opacification
Anterior ethmoid sinuses	0: No abnormality
	1: Partial opacification
	2: Total opacification
Posterior ethmoid sinuses	0: No abnormality
	1: Partial opacification
	2: Total opacification
Sphenoid sinuses	0: No abnormality
	1: Partial opacification
	2: Total opacification
Frontal sinuses	0: No abnormality
	1: Partial opacification
	2: Total opacification
Ostiomeatal complex	0: Not occluded
	2: Occluded

^aLeft and right sides are scored separately. Total score can range from 0–24.

Table 3

shows the additional percent of variation explained by adding *Volumetric scoring* to Lund-MacKay scoring using the statistical approach described in the Methods and Results sections.

Column 1	Column 2	Column 3	Column 4
Dependent variable	Percent of variation: Lund-Mackay scoring	Percent of variation: adding <i>volumetric</i> <i>scoring</i>	P-value for: Is the additional variation explained by <i>volumetric</i> <i>scoring</i> significant
Examination			
Polyp	16.5	23.8	0.044
Discharge	4.0	9.2	0.11
Total examination score	5.9	15.4	0.03
Symptom			
Nasal blockage	0.7	5.0	0.16
Olfactory	1.7	20.6	0.002
Sum of 3: blockage, discharge, olfactory	2.9	16.3	0.01
Total symptom score	6.6	18.6	0.014
Quality of life (QOL)			
Frequency subscore	12.7	22.7	0.02
Bothersomeness subscore	5.5	10.5	0.12
Impact subscore	8.4	9.8	0.4