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Determinants of Outcomes of Sinus Surgery: A Multi-Institutional Prospective Cohort Study

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Abstract

OBJECTIVES—1. To measure the proportion of patients with chronic rhinosinusitis (CRS) who experience clinically significant improvement after endoscopic sinus surgery (ESS) in a prospective, multi-institutional fashion. 2. To identify preoperative characteristics which predict clinically significant improvement in quality of life (QOL) after ESS.

STUDY DESIGN—Prospective, multi-institutional cohort study

SETTING—Academic tertiary care centers

SUBJECTS & METHODS—302 patients with CRS from three centers were enrolled between July 2004 and December 2008 and followed for an average of 17.4 months postoperatively. Preoperative patient characteristics, computed tomography (CT) scan, endoscopy score and pre- and postoperative quality of life (QOL) were collected. Univariate and multivariate analyses were performed.

RESULTS—Patients improved an average of 15.8% (18.9 points) on the Rhinosinusitis Disability Index and 21.2% (21.2 points) on the Chronic Sinusitis Survey (both $p<0.001$). Patients significantly improved on all eight Medical Short Form-36 subscales (all $p<0.001$). Among patients with poor baseline QOL, 71.7% of patients experienced clinically significant improvement on the RSDI and 76.1% on the CSS. Patients undergoing primary surgery were 2.1 times more likely to improve on the RSDI (95% CI: 1.2, 3.4; $p=0.006$) and 1.8 times more likely to improve on the CSS (95% CI: 1.1, 3.1; $p=0.020$) as compared to patients undergoing revision surgery.

CONCLUSION—In this prospective, multi-institutional study, most patients experienced clinically significantly improvement across multiple QOL outcomes after ESS. Specific patient characteristics provided prognostic value with regard to outcomes.

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Keywords

sinusitis; quality of life; outcomes; endoscopic sinus surgery; health-services research

INTRODUCTION

According to The National Health Interview Survey, chronic rhinosinusitis (CRS) affects 14–16% of the U.S. population and has significant socioeconomic implications with annual direct costs of $4.3 billion.[1,2] In addition, the Medical Short Form-36 (SF-36) general quality of life (QOL) instrument has shown that patients with CRS exhibit statistically significant deviations from the general population in several domains.[3] Using this instrument, patients with sinusitis scored lower in measures of bodily pain and social functioning than patients with congestive heart failure, angina, chronic obstructive pulmonary disease, or back pain.[4] Due to the chronicity of the disease, and the relatively poor response of some patients to initial medical therapies, patients with CRS undergo 500,000 surgical procedures annually, with the primary goal of improving QOL. A major goal of our research has been to study patient factors such as standard diagnostic tests or comorbidities that best predict surgical outcomes to aid in preoperative patient counseling and surgical case selection.

Several studies have reported improvement in the large majority of patients undergoing endoscopic sinus surgery (ESS) but have been limited by retrospective data collection or unvalidated outcomes.[5,6] Some prospective studies have reported improvement in mean QOL and symptom scores following ESS but they did not define the proportion of patients that improved, they were largely single institution results, or they had limited sample sizes for analysis.[3,7–11] The goal of this study was to report outcomes of ESS using prospective, multi-institutional data from a large cohort and validated disease-specific and general health-related QOL instruments. In addition, preoperative patient factors were evaluated for their ability to predict clinically significant outcomes so that surgeons can appropriately counsel patients and optimize surgical case selection.

MATERIALS & METHODS

Study Participants and Data Collection

Adult (≥ 18 years) study subjects were enrolled from three performance sites, Oregon Health & Science University (OHSU), the Medical College of Wisconsin (MCW), and Stanford University as part of a multi-institutional prospective cohort study. All patients had a diagnosis of CRS based on the Rhinosinusitis Task Force criteria.[12] Patients were enrolled at the time they elected to undergo endoscopic sinus surgery after failing broad-spectrum or culture directed antibiotics in addition to a trial of oral and topical steroid therapy. All study protocols and informed consent were collected and approved by the Institutional Review Boards at each study site.

Demographic data and social history were self-reported by the patient and included age, gender, race and/or ethnicity, annual household income, education level, cigarette use and alcohol consumption. For the analysis, annual household income was dichotomized in order to approximate the median US household income (< $50,000 or ≥ $50,000). Heavy alcohol consumption was defined as 14 drinks/week for men and 7 drinks/week for women.[13] Presence or absence of clinical characteristics were documented by the physician and included asthma, nasal polyposis, allergies confirmed by testing, acetylsalicylic acid (ASA) intolerance, depression, and history of prior sinus surgery. Preoperative computed tomography (CT) scan and preoperative endoscopy exam were scored by the physician using the Lund-MacKay and Lund-Kennedy scoring systems. Two validated disease-specific instruments, the

Rhinosinusitis Disability Index (RSDI, quality of life) and the Chronic Sinusitis Survey (CSS, symptom and medication use), and one validated general health-related QOL instrument, the Medical Outcomes Study Short Form-36 (SF-36) were administered by an experienced research coordinator pre- and post-operatively.7,14 In this observational study, the extent of surgery was tailored to the patient's disease process as defined by signs, symptoms, CT scan and clinical judgment. Sinus mucosal tissue was collected from the ethmoid cavity at the time of surgery.

Statistical Analyses

The objectives of this study were: (1) to measure the proportion of patients who experienced clinically significant improvement after ESS in a prospective, multi-institutional fashion, and (2) identify baseline characteristics that were predictive of clinically significant improvement in QOL after ESS.

Clinically significant improvement was defined for each outcome as a change of ≥ 1/2 standard deviation (SD) of the baseline QOL score.[15] Using this construct, improvement was defined as a decrease of ≥10.35 points on the RSDI and an increase of≥ 9.75 points on the CSS. Improvement was defined for each SF-36 subscale in a similar fashion (Table 1). To address ceiling effects, patients in the top (best) quintile of QOL scores were removed as a reasonable proxy for patients with baseline scores considered too high to achieve clinically significant improvement; the remaining patients were defined as having poor baseline QOL.

Multivariate logistic regression models were created to identify preoperative characteristics that predicted clinically significant improvement after surgery. Baseline variables were first screened to determine potential predictors of QOL improvement. Variables that were predictive on univariate analysis at the $p \leq 0.25$ level were considered candidate variables for logistic regression modeling. Final models were chosen using forward selection and backwards elimination stepwise procedures based on $p = 0.05$ (entry) and $p = 0.10$ (removal) levels of significance after controlling for age and gender.

Post Hoc Analysis of Sinus Mucosa Specimens

A post hoc analysis was performed on a subset of patients with ethmoid sinus mucosal biopsies performed at the time of surgery at a single-institution (OHSU; n=92). Three histological parameters (eosinophil density, basement membrane thickening, subepithelial edema) and their ability to predict QOL outcomes were examined based on preliminary data and previously published methodology.[16]

RESULTS

Baseline Characteristics of the Cohort

Four hundred and thirty-eight patients were enrolled at three sites between July 2004 and December 2008. One hundred and thirty-six patients were lost to follow up because of changes in insurance status, unwillingness to participate, administrative changes, and long-distance travel. Only participants with a minimum of 6 months postoperative follow up were included in this analysis. A total of 302 participants (68.9%) from three sites (OHSU, n=133; MCW, n=101; and Stanford University, n=68) were followed for a mean of 17.4 months (SD 6.9) post-operatively. Baseline characteristics of patients in the cohort are described in Table 2 and were compared to those lost to follow up. Asthma was more prevalent in patients with follow up (43.4% vs 30.4%; p=0.010); there were no other differences detected between those with follow up and those lost to follow up. The frequencies of surgical procedures performed are reported in Table 3.

Disease-Specific and General Health-Related QOL Improvement after ESS

Mean scores significantly improved on the RSDI (18.9 points or 15.8%; $p<0.001$) and on the CSS (21.2 points or 21.2%; $p<0.001$; Table 1) following surgery. SF-36 scores significantly improved across all 8 subscales (all $p<0.001$; Table 1).

Among patients with poor baseline QOL, 71.7% of patients experienced clinically significant improvement on the RSDI and 76.1% of patients experienced clinically significant improvement on the CSS (Figure 1). Among patients with poor baseline QOL, 32.9% to 66.4% of patients improved on each of the SF-36 subscales (Figure 2).

Patient Characteristic Screening for Prediction of QOL Improvement

RSDI—On univariate screening, gender, education level, and the proportion of patients with asthma, ASA intolerance, and a history of prior sinus surgery were significantly different between those who improved and those who did not improve on the RSDI at the $p \leq 0.25$ level (Table 4).

CSS—On univariate screening, age, education level, annual household income, history of prior sinus surgery, and mean preoperative endoscopy score were significantly different between those who improved and those who did not improve on the CSS at the $p \leq 0.25$ level (Table 5).

Sample Size for Construction of the Logistic Regression Models

As part of the initial study design, sample size and power calculations were performed. Logistic regression models of the form:

$$\mathrm{Ln}\,[p/(1-p)] = a_0x_0 + a_1x_1 + a_2x_2 + a_3x_3 + \ldots a_qx_q$$

were used to predict the occurrence of clinically significant improvement where x represented the independent predictor variable and p was the probability of the event. Approximately 10 events were required for each independent variable to assure adequate support for logistic regression modeling. The total sample size, n, was based on the formula $n = 10q/\min(\hat{p}, 1-\hat{p})$, where $\hat{p}$ was an estimate of the probability (p) of the event, and (1−p) was the converse of the probability of the event. Prior to the study, it was estimated that at least 80% of patients would improve on the RSDI and CSS; 300 patients supported the modeling of six predictor variables after univariate screening.

Predictors of Disease-Specific Quality of Life Improvement after ESS

The first multivariate logistic regression model examined predictors of clinically significant improvement on the RSDI. After adjustment for age and gender, only a history of prior sinus surgery predicted outcomes: patients undergoing primary sinus surgery were 2.1 times as likely to improve as patients undergoing revision sinus surgery (95% CI: 1.2, 3.4; p=0.006; Table 6). For the variables initially identified on univariate screening, gender, education level, as well as asthma and ASA intolerance, were not significant predictors.

The second multivariate logistic regression model examined predictors of clinically significant improvement on the CSS. After adjustment for age and gender, a history of prior sinus surgery predicted less improvement in QOL after ESS. Patients undergoing primary sinus surgery were 1.8 times as likely to improve as patients undergoing revision sinus surgery (95% CI: 1.1, 3.1; p=0.020; Table 6). For the variables initially identified on univariate screening, age, education level, annual household income, and endoscopy score were not significant predictors.

Preliminary Findings Regarding Histopathologic Predictors of QOL Outcomes

Since our evaluation of various preoperative patient characteristics revealed limited predictive information, we elected to perform a sub-analysis on a portion of our cohort from the OHSU enrollment site (with ethmoid mucosa available for review) to evaluate the predictive value of certain histopathologic features (n=92).[9,16,17] On post-hoc analysis, three histopathologic features were examined as potential predictors of QOL outcomes (Table 7) based on prior findings.[9,16] On univariate screening, 78.7% of patients with <10 eosinophils per high powered field (HPF) improved on the RSDI as compared to 64.4% of patients with ≥10 eosinophils/HPF (p=0.128). 71.7% of patients with <10 eosinophils/HPF improved on the CSS as compared to 55.6% of patients with ≥ 10 eosinophils/HPF (p=0.108). On the CSS, only 58.9% of patients with subepithelial edema improved, whereas 84.2% of patients without subepithelial edema improved (p=0.040).

After adjustment for surgery status (revision vs. primary), patients with <10 eosinophils/HPF were 2.16 times (95% CI: 0.85, 5.45; p=0.105) as likely to improve on the RSDI after surgery and 1.95 times (95% CI: 0.82, 4.64; p=0.133) as likely to improve on the CSS as patients with ≥ 10 eosinophils/HPF. Patients without subepithelial edema were 3.76 (95% CI: 1.00, 14.09; p=0.050) times as likely to improve on the CSS after surgery as patients with subepithelial edema.

DISCUSSION

In this large, multi-institutional, prospective cohort study, 72–76% of patients with CRS and poor baseline QOL experienced clinically significant improvement in disease-specific QOL outcomes after ESS. To help place this within the context of the general medical literature and diverse disease processes, general health-related QOL was also found to significantly improve after sinus surgery. Clinical factors including asthma, ASA intolerance, and prior sinus surgery as well as preoperative diagnostic testing were found to be important potential predictors of outcomes. However, few of these variables were significant predictors of improvement when multiple risk factors were accounted for in the predictive model. Ultimately, primary ESS patients were twice as likely to improve after surgery as patients undergoing revision ESS though a baseline measure of disease severity (endoscopy score) was worse in the revision ESS group. Furthermore, preliminary data suggested that mucosal eosinophilia and subepithelial edema, present at the time of surgery, may be important factors in predicting QOL outcomes.

Prior studies have reported higher proportions of patients improving following ESS as compared to the current study. In 1994, Terris and Davidson combined 10 primarily retrospective case series from single institutions published between 1989–1993.[5] Based on this review of articles, the authors reported a 91% “improvement rate” following ESS in 1713 patients. The primary outcomes were retrospective chart review with abstraction of patient results or unvalidated patient survey responses. Resolution of symptoms or decreased episodes of sinusitis were used as indicators of improvement. There was no standard for categorizing preoperative status, extent of disease, or surgical outcomes. With the introduction of both validated disease-specific QOL and general health-related QOL outcomes instruments, several centers have reported prospective, single institution outcomes primarily utilizing mean pre- and postoperative QOL scores to demonstrate the improvements patients experienced with ESS.[9,10] These studies generally reported improvement in mean QOL scores following ESS but were unable to interpret the clinical relevance of that change or further delineate subgroups of patients who did not experience improvement. Both issues are of critical importance with regard to patient counseling and surgical case selection. In addition, single institution studies have been criticized for the potential lack of generalizability to the population of patients undergoing sinus surgery, an issue at least partially addressed by incorporating a multi-institutional study design. In this study, we attempted to address all of these issues to provide

a framework for the clinical relevance of QOL change following ESS, identify subgroups more likely to improve, and include multi-institutional data in our analyses.

Defining "clinically significant improvement" with validated QOL instruments is an important means for translating research into meaningful terms that patients can understand and clinicians can factor into shared decision-making. It is also necessary for building models to predict treatment outcomes. The challenge becomes how to discriminate clinically significant improvement. This investigation utilized improvement by at least 1/2 of the standard deviation of the baseline QOL score to indicate clinically significant change. Interestingly, this approximates a patient's ability to detect relevant change in other areas utilizing QOL outcomes and has been described as a "universal" phenomenon in the QOL literature.[15] For comparison with other published literature, we noted that 80.8% of patients experienced at least a 50% reduction in the duration of symptoms and/or medication use on the CSS; this was nearly identical to the 82% reported in a study by Gliklich.[7] In addition, when considering potential changes in QOL score, one must consider that some patients' preoperative QOL scores were high enough that they were unable to experience clinically significant improvement in QOL. Therefore inclusion of those patients in the analyses resulted in a potentially lower proportion of patients with clinically significant improvement following intervention. We addressed this potential ceiling effect by performing one analysis that included all patients and a secondary analysis that excluded patients in the top quintile of preoperative QOL scores. The results from the predictive models were similar. Ultimately, translating data into clinically meaningful terms will assist clinicians in providing realistic expectations to patients, but determining the best definition for reporting clinically significant change continues to be an area of investigation.

Several clinical factors including comorbidities such as asthma or ASA intolerance, prior sinus surgery, and diagnostic testing including endoscopy score were significant in the univariate screening of potential predictors of QOL outcomes. These clinical factors have been studied elsewhere in the literature and have been shown to impact outcomes.[18,19] Demographic characteristics including gender, annual household income, and education level were also important in univariate screening and have been studied by us and others in the general QOL literature.[20] Surprisingly, when we accounted for all of these patient factors (comorbidities, diagnostic tests, and demographic characteristics) in our predictive model, very few patient factors were found to be predictive of outcomes of ESS. Whether patients were undergoing primary or revision surgery was clearly predictive such that the chances of QOL improvement were twice as high for primary surgery as compared to revision surgery. Therefore, patient characteristics discernable on presentation for sinus surgery or "clinical phenotype" did not provide the predictive information we sought. This led us to investigate other factors that may have predictive importance.

Based on several studies, it appears that inflammation is an important factor in determining treatment outcomes.[9,10,18,19] In following this concept of inflammatory status predicting outcomes, we began to examine our cohort for other indicators of inflammation that have been suggested to predict outcomes.[9,16,17] Specifically, markers of inflammation present in the sinus mucosa may provide predictive information regarding outcomes based upon their ability to discriminate the severity of the inflammatory process. In a post hoc analysis, our preliminary focus on histological markers of inflammation in the sinonasal mucosa revealed the finding of heterogeneity within clinical phenotypes (e.g. CRS with polyps) with regard to the presence of inflammatory markers and outcomes of treatment.[16] When evaluated using predictive models, mucosal eosinophil density and sub-epithelial edema appeared to provide predictive information such that patients with lower eosinophil density or less subepitheilial edema were 2 to 4 times more likely to improve with ESS. The observational nature of this study and the routine use of perioperative co-interventions, including systemic steroids that are thought to impact the expression of these markers, should be considered in the context of these results.

Future investigations should continue to evaluate histological and molecular inflammatory markers in a more controlled fashion for their utility in defining disease and predicting treatment outcomes. If found to be an important determinant of outcome, inflammatory marker evaluation through preoperative mucosal sampling might play a role in future patient counseling regarding outcomes of sinus surgery.

CONCLUSION

In this prospective, multi-institutional cohort study, the majority of patients experienced clinically significant improvement in QOL outcomes with ESS. Certain clinical phenotypes, such as CRS associated with asthma, CRS associated with ASA intolerance, and CRS associated with prior sinus surgery, were significant in the univariate screening of predictors of QOL outcomes but among these, history of prior sinus surgery appears to be most predictive. In addition, standard diagnostic tests such as endoscopy were significant in the univariate screening of potential predictors of QOL outcomes, but not significant in the final predictive models. Finally, preliminary analyses suggested that mucosal inflammatory markers provide important predictive information and deserve further investigation.

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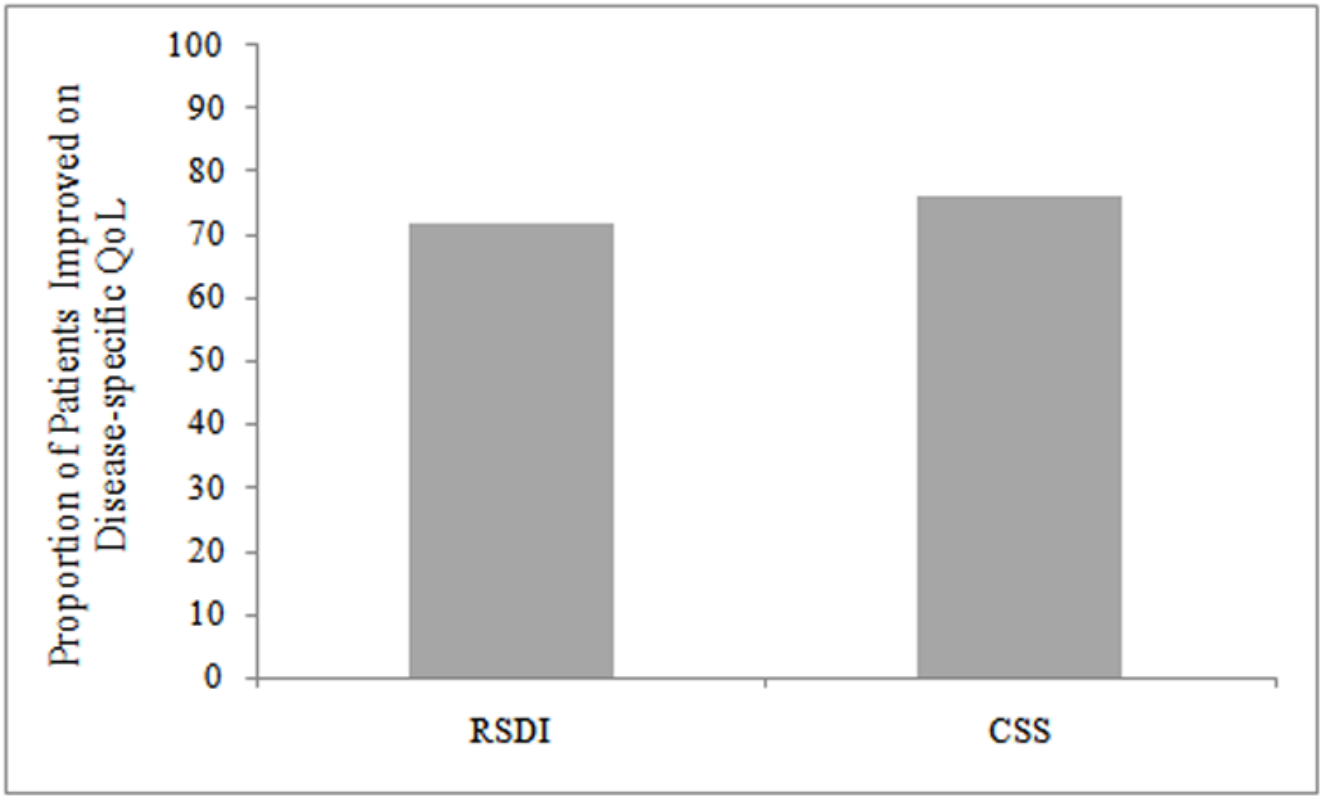

Figure 1.
Proportion of patients with poor baseline quality of life (QOL) who experience clinically significant improvement in disease-specific quality of life after endoscopic sinus surgery. RSDI = Rhinosinusitis Disability Index. CSS = Chronic Sinusitis Survey.

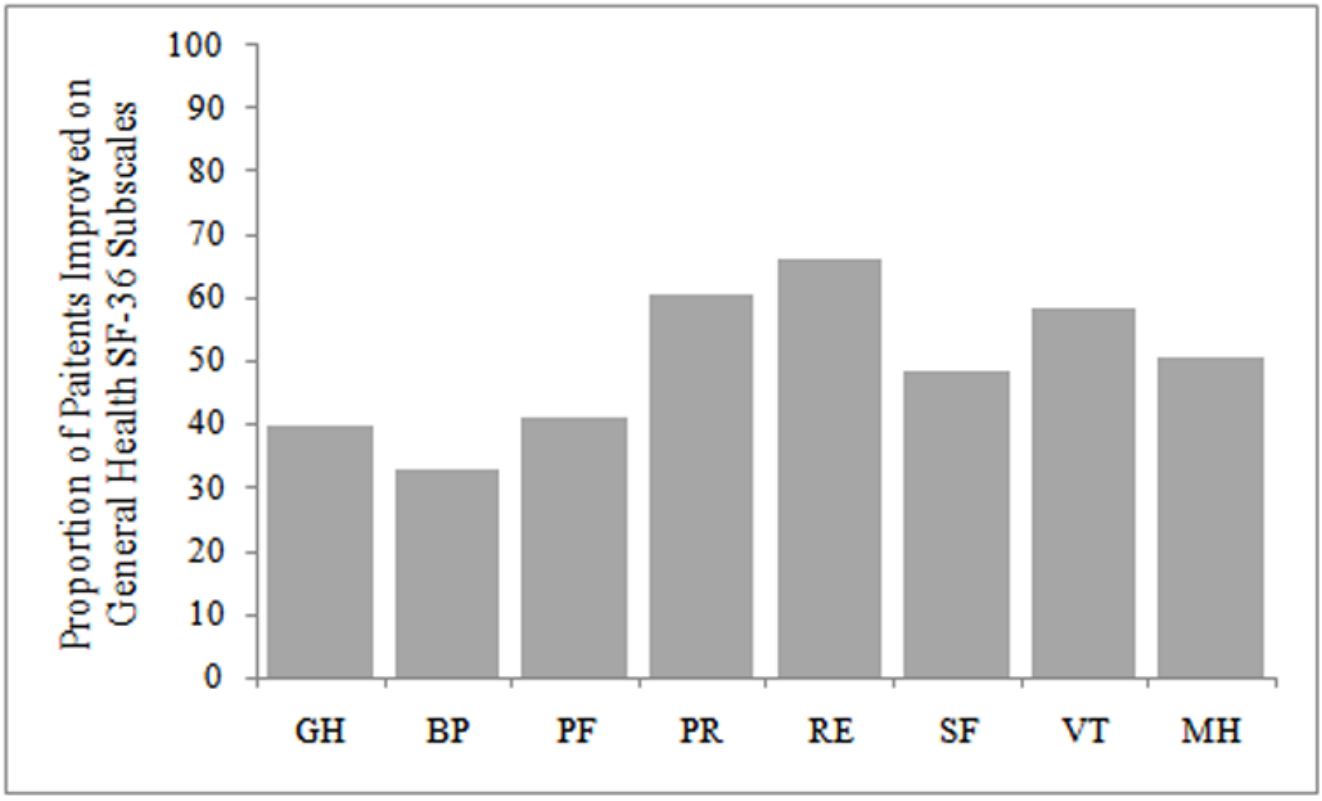

Figure 2.
Proportion of patients with poor baseline quality of life who experience clinically significant improvement in general health-related quality of life after endoscopic sinus surgery. SF-36 = Medical Outcomes Short Form-36. GH = general health subscale. PF = physical functioning subscale. RP = role-physical subscale. RE = role-emotional subscale. SF = social functioning subscale. BP = bodily pain subscale. VT = vitality subscale. MH = mental health subscale.

TABLE 1

Mean change in disease-specific and general health-related QOL after endoscopic sinus surgery

	Preoperative	Postoperative	Absolute Δ*
Disease specific QOL:	(mean ± SD)	(mean ± SD)	(mean ± SD)
RSDI total	46.9 ± 20.7	28.1 ± 22.4	18.9 ± 19.6
Physical	18.7 ± 7.6	11.5 ± 8.2	7.2 ± 7.5
Functional	15.3 ± 7.3	8.7 ± 7.7	6.6 ± 7.3
Emotional	13.0 ± 8.4	7.9 ± 7.9	5.1 ± 7.6
CSS total	37.8 ± 19.5	59.0 ± 21.4	21.2 ± 22.6
Symptom	29.1 ± 26.5	59.6 ± 29.3	30.6 ± 32.0
Medication	46.3 ± 25.2	58.2 ± 24.5	11.9 ± 26.2
General health QOL:			
SF-36 subscale			
GH	53.2 ± 23.9	58.6 ± 24.5	5.5 ± 19.8
PF	74.9 ± 24.5	81.6 ± 23.1	6.7 ± 18.5
RP	44.3 ± 42.3	65.6 ± 41.7	21.3 ± 43.2
RE	67.3 ± 40.0	79.9 ± 34.3	12.6 ± 39.6
SF	65.1 ± 26.1	72.9 ± 27.3	7.8 ± 28.7
BP	56.9 ± 24.2	63.9 ± 25.7	7.0 ± 22.6
VT	36.8 ± 23.3	51.9 ± 24.8	15.1 ± 22.7
MH	66.9 ± 20.3	74.7 ± 18.5	7.8 ± 16.3

Δ denotes absolute change values of quality of life measures.

* designates that all changes are statistically significant with p-values < 0.001. QOL = quality of life. RSDI = Rhinosinusitis Disability Index. CSS = Chronic Sinusitis Survey. SF-36 = Medical Outcomes Short Form-36. GH = general health subscale. PF = physical functioning subscale. RP = role-physical subscale. RE = role-emotional subscale. SF = social functioning subscale. BP = bodily pain subscale. VT = vitality subscale. MH = mental health subscale.

TABLE 2

Characteristics of cohort of patients with CRS (n=302)

	mean ± SD	n (%)
Age (years)	48.6 ± 13.8	
Education (years)	14.9 ± 2.7	
Gender:		
Male		155 (51.3)
Female		147 (48.7)
Race/ethnicity:		
White		267 (88.4)
Asian		13 (4.3)
Black or African American		9 (3.0)
Hispanic/Latino		6 (2.0)
American Indian/Alaskan Native		4 (1.3)
Native Hawaiian/Pacific Islander		2 (0.7)
Other		1 (0.3)
Annual household income:		
$0–25,000		39 (12.9)
$26–50,000		63 (20.9)
$51–75,000		55 (18.2)
$76–100,000		54 (17.9)
$100,000+		90 (29.8)
Clinical characteristics:		
Asthma		131 (43.4)
Nasal polyposis		125 (41.4)
Allergy		93 (30.8)
Aspirin intolerance		39 (12.9)
Depression		48 (15.9)
Prior sinus surgery		185 (61.3)
Social history:		
Tobacco use (packs/day)	0.3 ± 0.1	16 (5.3)
Alcohol consumption (grams/week)	22.8 ± 52.8	126 (41.7)
Preoperative diagnostic testing:		
Lund-Kennedy endoscopy score	6.9 ± 4.8	
Lund-MacKay CT score	13.0 ± 6.4	

CRS = chronic rhinosinusitis. SD = standard deviation. CT = computed tomography.

TABLE 3

Frequency of surgical procedures performed (n=302)

	Left side n(%)	Right side n(%)
Maxillary antrostomy	240 (79.5)	252 (83.4)
Ethmoidectomy:		
Partial	43 (14.2)	49 (16.2)
Total	220 (72.8)	222 (73.5)
Sphenoidotomy	162 (53.6)	171 (56.6)
Frontal sinusotomy	172 (56.9)	150 (49.7)
Septoplasty	92 (30.5)	
Image guidance	193 (63.9)	

TABLE 4

Univariate screening for predictive variables on the RSDI

	Total Cohort (n=302)			Poor Baseline QoL (n=240)		
Variables:	**Improved**	**Did not improve**	**p-value**	**Improved**	**Did not improve**	**p-value**
Age (mean ± SD)	48.3 ± 13.6	49.2 ± 14.3	0.561	47.9 ± 13.6	48.2 ± 12.7	0.890
Education (mean yrs.)	15.2 ± 2.6	14.6 ± 2.9	0.113*	15.2 ± 2.5	14.5 ± 3.0	0.094*
Gender (%)						
Male	60.6	39.4		68.5	31.5	
Female	68.0	32.0	0.181*	75.0	25.0	0.268
Race						
White	65.2	34.8		72.0	28.0	
Non-white	57.1	42.9	0.352	69.0	31.0	0.731
Annual household income						
< $50,000/year	62.7	37.3		67.1	32.9	
≥ $50,000/year	65.3	34.7	0.658	74.2	25.8	0.241*
Nasal polyposis						
Present	64.0	36.0		72.7	27.3	
Absent	64.4	35.6	0.942	70.9	29.1	0.760
Asthma						
Present	59.5	40.5		66.7	33.3	
Absent	67.8	32.2	0.136*	75.4	24.6	0.139*
ASA Intolerance						
Present	51.3	48.7		62.1	37.9	
Absent	66.2	33.8	0.070*	73.0	27.0	0.221
Allergies by testing						
Present	61.3	38.7		73.5	26.5	
Absent	65.5	34.5	0.476	70.9	29.1	0.687
Depression						
Present	70.8	29.2		78.6	21.4	
Absent	63.0	37.0	0.299	70.2	29.8	0.274
History of sinus surgery						

	Total Cohort (n=302)			Poor Baseline QoL (n=240)		
Variables:	**Improved**	**Did not improve**	**p-value**	**Improved**	**Did not improve**	**p-value**
Primary	74.4	25.6		83.5	16.5	
Revision	57.8	42.2	0.004*	64.4	35.6	0.001*
Current smoker						
Smokers	75.0	25.0		71.4	28.6	
Non-smokers	63.6	36.4	0.356	71.7	28.3	0.984
Alcohol consumption						
Not heavy	64.0	36.0		72.2	27.8	
Heavy	68.4	31.6	0.694	61.5	38.5	0.405
Preoperative diagnostic testing: (mean ± SD)						
Lund-Kennedy endoscopy	6.8 ± 4.8	7.2 ± 4.8	0.547	6.8 ± 4.7	7.2 ± 4.4	0.462
Lund-MacKay CT	13.2 ± 6.3	12.7 ± 6.7	0.558	13.4 ± 6.2	12.5 ± 6.3	0.325

RSDI = Rhinosinusitis Disability Index. QOL = quality of life. SD = standard deviation. CT = computed tomography.

*denotes statistically significant candidate variables for final outcome models at the $p \leq 0.25$ level for both total cohort and candidates with poor baseline QOL.

TABLE 5

Univariate screening for predictive variables on the CSS

	Total Cohort (n=302)			Poor Baseline QoL (n=236)		
Variables:	**Improved**	**Did not improve**	**p-value**	**Improved**	**Did not improve**	**p-value**
Age (mean ± SD)	47.9 ± 13.7	50.2 ± 13.8	0.163*	48.0 ± 13.5	47.6 ± 12.0	0.858
Education (mean yrs.)	15.1 ± 2.7	14.7 ± 2.6	0.208*	15.2 ± 2.7	14.4 ± 2.6	0.054*
Gender (%)						
Male	65.8	34.2		72.0	28.0	
Female	65.5	34.5	0.958	80.2	19.8	0.145*
Race						
White	66.4	33.6		76.8	23.2	
Non-white	60.0	40.0	0.453	70.4	29.6	0.461
Annual household income						
< $50,000/year	61.0	39.0		70.7	29.3	
≥ $50,000/year	67.8	32.2	0.240*	78.5	21.5	0.192*
Nasal polyposis						
Present	63.2	36.8		73.5	26.5	
Absent	67.4	32.6	0.447	77.9	22.1	0.429
Asthma						
Present	64.9	35.1		73.1	26.9	
Absent	66.3	33.7	0.802	78.6	21.4	0.332
ASA Intolerance						
Present	66.7	33.3		77.4	22.6	
Absent	65.5	34.5	0.888	75.9	24.1	0.850
Allergies by testing						
Present	63.0	37.0		73.3	26.7	
Absent	66.8	33.2	0.525	77.4	22.6	0.501
Depression						
Present	66.0	34.0		76.3	23.7	
Absent	65.6	34.4	0.964	76.0	24.0	0.969
History of sinus surgery						

	Total Cohort (n=302)			Poor Baseline QoL (n=236)		
Variables:	**Improved**	**Did not improve**	**p-value**	**Improved**	**Did not improve**	**p-value**
Primary	74.1	25.9		85.7	14.3	
Revision	60.3	39.7	0.014*	69.9	30.1	0.006*
Current smoker						
Smokers	62.5	37.5		64.3	35.7	
Non-smokers	65.8	34.2	0.784	76.8	23.2	0.287
Alcohol consumption						
Not heavy	65.5	34.5		81.2	18.8	
Heavy	68.4	31.6	0.794	75.7	24.3	0.615
Preoperative diagnostic testing: (mean ± SD)						
Lund-Kennedy endoscopy	6.5 ± 4.8	7.8 ± 4.5	0.018*	6.6 ± 4.9	8.6 ± 4.1	0.006*
Lund-MacKay CT	12.9 ± 6.4	13.4 ± 6.5	0.449	13.1 ± 6.3	15.0 ± 5.8	0.054*

CSS = Chronic Sinusitis Survey. QOL = quality of life. SD = standard deviation. CT = computed tomography.

*denotes statistically significant candidate variables for final outcome models at the $p \leq 0.25$ level for both total cohort and candidates with poor baseline QOL.

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TABLE 6

Predictors of disease-specific QOL improvement after ESS (n=302).

Models:	Independent predictors:	OR	(95% CI)	p-value
RSDI	Age (years)	1.0	(0.9, 1.1)	0.815
	Gender	1.4	(0.8, 2.2)	0.196
	Primary surgery	2.1	(1.2, 3.4)	0.006
CSS	Age (years)	1.0	(0.9, 1.1)	0.221
	Gender	1.0	(0.6, 1.6)	0.936
	Primary surgery	1.8	(1.1, 3.1)	0.020

ESS = endoscopic sinus surgery. QOL = quality of life. OR = odds ratio. CI = confidence intervals. RSDI = Rhinosinusitis Disability Index. CSS = Chronic Sinusitis Survey. Gender was controlled using males as the reference group. Odds ratios for primary surgery are compared to patients undergoing revision sinus surgery.

Table 7

Proportion of patients who experience clinically significant improvement in QOL after ESS related to eosinophil density, basement membrane thickening, and subepithelial edema (n=92).

	RSDI	p-value	CSS	p-value
Eosinophilia	(%)		(%)	
0–10 count/HPF	(78.7)		(71.7)	
≥10 count/HPF	(64.4)	0.128	(55.6)	0.108
BM thickening				
< 5 microns	(77.5)		(64.1)	
5–10 microns	(65.8)		(57.9)	
10–15 microns	(76.9)		(76.9)	
15+ microns	(0.0)	0.204	(100.0)	0.550
Subepithelial edema				
Absent	(68.4)		(84.2)	
Present	(73.6)	0.507	(58.9)	0.040

QOL = quality of life. RSDI = Rhinosinusitis Disability Index. CSS = Chronic Sinusitis Survey. HPF = high power field (400×). BM = basement membrane.