



ORIGINAL RESEARCH

Radiographic disease severity in chronic rhinosinusitis patients and health care utilization

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Abstract

Objectives: Chronic rhinosinusitis (CRS) affects approximately 12% of the population and leads to increased health care utilization and indirect costs exceeding \$20 billion annually in the United States. The Lund-Mackay score (LMS) measures radiographic disease severity for CRS but poorly correlates with symptom scores. The association between LMS and health care utilization in CRS patients has not yet been investigated. The study aimed to assess the association between health care utilization and CRS radiographic severity using LMS.

Methods: CRS patients enrolled in a clinical registry were evaluated. Nasal endoscopy findings and LMS were recorded for patients with sinus CT imaging. Patient symptom scores, demographic characteristics, and health care utilization measures were collected. The relationship between these factors and LMS was examined.

Results: A total of 556 patients met inclusion criteria. Mean age was 45.3 years, 53.4% were male, and 41.7% had nasal polyps. There was no difference in sex, smoking history, 22-item Sino-nasal Outcome Test scores, or past medical history factors between patients with high (≥ 8 , $n = 410$) and low (< 8 , $n = 146$) LMS. Among high LMS patients, 73.7% underwent endoscopic sinus surgery (ESS) compared to 55.5% with low LMS ($P < .01$), and a greater percentage of patients had nasal polyps (49.3% vs 20.5%, $P < .01$). On multivariable logistic regression, high LMS patients used fewer antibiotic courses (OR: 0.68 [0.51-0.91]), but were more likely to be managed with ESS (OR: 2.28 [1.41-3.73]), and have nasal polyps (OR: 2.11 [1.16-3.93]) compared to low LMS patients. There was no significant difference in the number of steroid courses, over the counter pill use, provider visits, work/school days missed, or symptom duration between the two LMS groups.

Conclusion: CRS patients with severe radiographic disease are more likely to have nasal polyps, undergo ESS, and take fewer antibiotic courses. However, there is no

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association between radiographic disease severity and other measures of health care utilization.

Level of Evidence: 2b, individual retrospective cohort study.

KEYWORDS

chronic rhinosinusitis, health care utilization, Lund-Mackay score, radiographic disease severity, SNOT-22

1 | INTRODUCTION

Chronic rhinosinusitis (CRS) is an inflammatory condition affecting approximately 12% of the United States population.¹ It is characterized by two or more of the following signs and symptoms: nasal obstruction, nasal discharge, facial pain or pressure, and reduction of smell for 12 or more weeks with findings of inflammation on computed tomography (CT) or nasal endoscopy.² CRS patients have been reported to suffer from increased rates of depression and lower overall quality of life (QOL) with health utility values similar to those of patients with acquired immunodeficiency syndrome (AIDS), asthma, or intermittent claudication.^{3,4}

In addition to affecting QOL, CRS is associated with significant health care costs related to diagnosis and management, ranging from 10 to 13 billion dollars with indirect costs exceeding 20 billion dollars annually in the United States.⁵⁻⁷ Patients with CRS have increased health care utilization, and Bhattacharyya et al showed these patients have significantly more antibiotic prescriptions and clinic visits leading to higher pharmacy and medical costs compared to a reference population without CRS.⁸ Another study demonstrated that CRS patients have greater activity, social, and work limitations relative to non-CRS patients with approximately 11.5 million aggregate workdays missed annually across the United States CRS population.⁹ However, the relationship between CRS patients' radiographic disease severity and health care utilization with regard to antibiotic courses, steroid courses, over the counter (OTC) pill use, health care provider visits, work or school days missed, and symptom duration has not yet been investigated.

CT scans aid in the diagnosis of CRS as well as in assessing disease severity. The Lund-Mackay score (LMS) measures radiographic disease severity for CRS patients using CT images and is a validated scoring system used widely in research and clinical practice with high interobserver reliability.¹⁰ The scoring scale ranges from 0 (complete lucency of all sinuses) to 24 (complete opacity of all sinuses)—a higher score correlates with more severe pathology—and grades the right and left sinuses independently.¹¹ Although the LMS provides valuable objective data, the scale poorly correlates with subjective patient-reported symptom scores at time of presentation.¹² The objective of this investigation was to assess the association between CRS radiographic severity and health care utilization.

2 | METHODS

2.1 | Participants

A prospective cohort of patients aged 18 to 89 years with a new or existing diagnosis of CRS was enrolled in a clinical registry for the rhinology department at a tertiary medical center after providing written informed consent. Patients who had undergone endoscopic sinus surgery (ESS) within the past 18 months were excluded from the study. Approval from the Northwestern University Institutional Review Board (76987) was granted before study commencement.

2.2 | Data collection

Enrolled patients had a nasal endoscopy performed in the clinic, and those who had CT imaging of the paranasal sinuses had an LMS recorded. Nasal endoscopy findings were recorded by one of the five rhinologists who performed the procedure. The LMS was recorded by one of three members of the research team (M.P.M., C.P.E.P., and K.C.W.). Based on a study with similar methods, patients' raw total LMS were reported as one of two groups: low, LMS <8; high, LMS ≥8.¹³ This limited potential minor differences in scoring and increased interobserver reliability. Moreover, LMS <4 has been shown to be within the normal range of the general population,¹² so a cutoff value greater than that was chosen to distinguish high and low LMS. Additionally, information on patients' treatment course (ie, those who had their CRS symptoms controlled on medical therapy alone vs those recalcitrant to such therapy who required surgical intervention with ESS to manage their CRS symptoms) was recorded.

Registry enrollees also completed a survey that included demographic factors like sex, age, and smoking history. Past medical history including a history of gastroesophageal reflux disease (GERD), allergic rhinitis, obstructive sleep apnea (OSA), or aspirin allergy was obtained. These demographic factors and past medical history were confirmed by electronic medical record chart review. On presentation, study participants completed the 22-item Sino-nasal Outcome Test (SNOT-22), a patient-reported QOL outcomes measure for CRS patients. Self-reported patient health care utilization measures were also collected via the REDCap electronic data capture tool.¹⁴ Importantly, there was no specific temporal relationship between when patients completed their medical history and health care utilization surveys and when

they were told about the results of their CT imaging to limit recall bias between the high and low LMS groups. Patients were asked how often in the past 12 months they had seen a health care provider for their nasal or sinus condition, how many days of work or school they had missed over the past 12 months due to their nasal or sinus condition, and how long they had daily nasal or sinus symptoms. Symptom duration was grouped into the following categories: 1:3 to 6 months; 2:7 to 12 months; 3:1 to 5 years; 4:6 or more years. Additionally, patients were surveyed about their medication usage to manage their CRS over the past 12 months, including the number of oral steroid and antibiotic courses along with how many months they had used nasal steroids and OTC pills. Scoring for the number of courses was categorized as 0:0 courses; 1:1 and 2 courses; 2:3 and 4 courses; 3:5 courses or more. Scoring for the duration of medication use was categorized as 0:0 months; 1:0 to 3 months; 2:4 to 6 months; 3:7 to 12 months.

2.3 | Data analysis

Data analysis was performed using the R programming language (R Project for Statistical Computing; R Foundation). Missing SNOT-22 individual patient survey data was estimated by mean imputation for those who had completed more than 80% of the survey. Age was analyzed as a categorical variable (<40 and ≥40 years of age) based on reported cutoffs described in the CRS literature.¹⁵⁻¹⁷ Demographic data (ie, sex, age, and smoking history), comorbidities (ie, GERD, OSA,

allergic rhinitis, and aspirin allergy), nasal endoscopy findings (ie, normal, non-purulent middle meatal discharge, purulent middle meatal discharge, middle meatal edema, and nasal polyps), and CRS management strategy (ie, medical vs surgical) were stratified by high and low LMS and analyzed using Pearson's chi-squared test with Yates' continuity correction. SNOT-22 scores, age, and the aforementioned health care utilization measures were analyzed as continuous variables compared to LMS using Welch's two-sample *t*-test. All study variables were selected a priori, as potential predictive factors associated with preoperative LMS in a multivariable logistic regression model. Results considered statistically significant were those with a *P* value less than .05.

3 | RESULTS

3.1 | Patient characteristics

A total of 556 patients were included in the study, of whom 236 (42.4%) were <40 years old, 268 (48.2%) were female, 380 (68.3%) were never smokers, 173 (31.1%) were managed medically following presentation, and 410 (73.7%) had a high LMS. A summary of patient demographic characteristics and comorbidities is outlined in Table 1. Among CRS patients with a high LMS, 302 (73.7%) underwent ESS compared to 81 (55.5%) of CRS patients with a low LMS (*P* < .01). Moreover, patients ≥40 years were more likely to have a high LMS (60.2% vs 50.0%, *P* = .04). There was no

TABLE 1 Patient demographics

Characteristic	Overall N = 556	Low LMS (<8) N = 146	High LMS (≥8) N = 410	<i>P</i> value
Age group, n (%)				
<40 years	236 (42.4)	73 (50.0)	163 (39.8)	
≥40 years	320 (57.6)	73 (50.0)	247 (60.2)	.04
Sex, n (%)				
Female	268 (48.2)	68 (46.6)	200 (48.8)	
Male	288 (51.8)	78 (53.4)	210 (51.2)	.72
Smoking history, n (%)				
Never smoker	380 (68.3)	104 (71.2)	276 (67.3)	
Past/Current smoker	176 (31.7)	42 (28.8)	134 (32.7)	.44
Past medical history, n (%)				
GERD	179 (32.2)	57 (39.0)	122 (29.8)	.05
OSA	72 (12.9)	14 (9.6)	58 (14.1)	.21
Allergic rhinitis	303 (54.5)	87 (59.6)	216 (52.7)	.18
Aspirin allergy	97 (17.4)	19 (13.0)	78 (19.0)	.13
Disease management, n (%)				
Medically managed	173 (31.1)	65 (44.5)	108 (26.3)	
Surgically managed	383 (68.9)	81 (55.5)	302 (73.7)	<.01

Note: *P* value was calculated using Pearson's chi-squared test with Yates' continuity correction. *P* values < 0.05 are bolded.

Abbreviations: GERD, gastroesophageal reflux disease; LMS, Lund-Mackay score; OSA, obstructive sleep apnea.

significant difference in sex, smoking history, history of GERD, OSA, allergic rhinitis, or aspirin allergy between patients with a low and high LMS.

3.2 | Sinus disease measures

Table 2 reports endoscopy findings and mean SNOT-22 scores among the study population. High LMS patients, when compared to low LMS patients, had a greater percentage of purulent middle meatal discharge (18.3% vs 9.6%, $P = .02$), middle meatal edema (34.4% vs 23.3%, $P = .02$), and nasal polyps (49.3% vs 20.5%, $P < .01$) observed on nasal endoscopy. Furthermore, high LMS participants had a lower percentage of normal nasal endoscopies when compared to low LMS participants (17.8% vs 45.9%, $P < .01$). There was no significant difference observed between low and high LMS patients' SNOT-22 scores.

3.3 | Health care utilization

There was no significant statistical difference on univariate analysis in health care provider visits, work or school days missed, symptom

duration, antibiotic courses, oral steroid courses, months of nasal steroid use, or months of OTC pill use between the two LMS groups. The CRS patients included in this study had a mean of 4.7 provider visits and 3.9 work or school days missed over the past 12 months. On average, they reported daily symptoms lasting between 1 and 5 years. Over the past 12 months, these patients used approximately one to two courses of antibiotics or oral steroids and had used nasal steroids or OTC pills for 4 to 6 months. Table 3 summarizes these findings.

3.4 | Multivariable logistic regression

The findings of multivariable logistic regression analyzing the association of patient demographic characteristics, sinus disease measures, and health care utilization metrics with a high LMS are reported in Table 4. The multivariable odds ratios were determined after adjusting for age group, sex, smoking history, past medical history factors, disease management, endoscopy findings, SNOT-22 score, and health care utilization measures. The number of antibiotic courses used by CRS patients over the past year to manage their nasal or sinus condition was negatively associated with a high LMS (OR: 0.68 [0.51-0.91]). CRS patients who were managed surgically with ESS

TABLE 2 Measures of sinus disease

	Overall N = 556	Low LMS (<8) N = 146	High LMS (≥8) N = 410	P value
Endoscopy findings, n (%)				
Normal	140 (25.2)	67 (45.9)	73 (17.8)	<.01
Non-purulent middle meatal discharge	89 (16.0)	27 (18.5)	62 (15.1)	.41
Purulent middle meatal discharge	89 (16.0)	14 (9.6)	75 (18.3)	.02
Middle meatal edema	175 (31.5)	34 (23.3)	141 (34.4)	.02
Nasal polyps	232 (41.7)	30 (20.5)	202 (49.3)	<.01
SNOT-22 total, M (SD)	44.1 (18.5)	42.2 (17.6)	44.7 (18.9)	.15

Note: P value was calculated using Pearson's chi-squared test with Yates' continuity correction for Endoscopy findings. P value was calculated using Welch's two-sample t-test for SNOT-22 total. P values < 0.05 are bolded.

Abbreviations: LMS, Lund-Mackay score; M, mean; SNOT-22, 22-item Sino-nasal Outcome Test.

TABLE 3 Health care utilization

Utilization measure, M (SD)	Overall	Low LMS (<8)	High LMS (≥8)	P value
Provider visits	4.7 (4.5)	4.6 (5.1)	4.8 (4.3)	.68
Work/School days missed	3.9 (11.5)	4.4 (13.2)	3.7 (10.9)	.55
Duration of symptoms	3.0 (1.0)	3.1 (1.1)	3.0 (1.0)	.31
Antibiotic courses	1.4 (1.0)	1.5 (1.0)	1.3 (1.0)	.09
Oral steroid courses	0.9 (0.9)	0.9 (0.9)	1.0 (0.9)	.23
Nasal steroids	1.7 (1.2)	1.5 (1.2)	1.7 (1.2)	.07
OTC pills	1.8 (1.2)	1.9 (1.2)	1.8 (1.2)	.46

Note: Provider visits and days missed are reported in days. Duration of symptoms is reported as follows: 1:3 to 6 months; 2:7 to 12 months; 3:1 to 5 years; 4: ≥6 years. Numbers of antibiotic and oral steroid courses are reported as follows: 0:0 courses; 1:1 and 2 courses; 2:3 and 4 courses; 3: ≥5 courses. Duration of nasal steroid and OTC pill use is reported as follows: 0:0 months; 1:0 to 3 months; 2:4 to 6 months; 3:7 to 12 months. P value was calculated using Welch's two-sample t-test.

Abbreviations: LMS, Lund-Mackay score; M, mean; OTC, over the counter.

TABLE 4 Multivariable logistic regression of a high LMS and patient factors

	Odds ratio	95% CI	P value
<i>Demographics</i>			
Age group			
<40 years	REF		
≥40 years	1.53	[0.99-2.38]	.06
Sex			
Female	REF		
Male	0.69	[0.43-1.08]	.11
Smoking history			
Never smoker	REF		
Past/Current smoker	1.15	[0.72-1.87]	.56
Past medical history			
GERD	0.62	[0.39-0.99]	.04
OSA	1.46	[0.72-3.11]	.31
Allergic rhinitis	0.78	[0.49-1.22]	.28
Aspirin allergy	1.39	[0.76-2.65]	.30
Disease management			
Medically managed	REF		
Surgically managed	2.28	[1.41-3.73]	<.01
<i>Sinus disease measures</i>			
Endoscopy findings			
Normal	0.42	[0.21-0.82]	.01
Non-purulent middle meatal discharge	0.51	[0.27-0.98]	.04
Purulent middle meatal discharge	1.38	[0.66-3.02]	.40
Middle meatal edema	1.12	[0.63-2.00]	.70
Nasal polyps	2.11	[1.16-3.93]	.02
SNOT-22 total	1.01	[1.00-1.02]	.14
<i>Health care utilization</i>			
Provider visits	1.03	[0.97-1.10]	.37
Work/School days missed	1.00	[0.98-1.02]	.93
Duration of symptoms	0.85	[0.68-1.04]	.12
Antibiotic courses	0.68	[0.51-0.91]	<.01
Oral steroid courses	1.03	[0.75-1.40]	.87
Nasal steroids	1.21	[0.99-1.49]	.07
OTC pills	0.87	[0.70-1.08]	.22

Note: P values < 0.05 are bolded.

Abbreviations: CI, confidence interval; GERD, gastroesophageal reflux disease; LMS, Lund-Mackay score; OSA, obstructive sleep apnea; OTC, over the counter; SNOT-22, 22-item Sino-nasal Outcome Test.

were more than twice as likely as those managed solely with medication to have a high preoperative LMS (OR: 2.28 [1.41-3.73]). Patients with nasal polyps noted on nasal endoscopy were also more likely than those without nasal polyps to have a high LMS (OR: 2.11 [1.16-3.93]). Those with normal endoscopies (OR: 0.42 [0.21-0.82]), non-purulent middle meatal discharge on nasal endoscopy (OR: 0.51 [0.27-0.98]), or a past or current diagnosis of GERD (OR: 0.62 [0.39-0.99]) were less likely to have a high LMS. All other health care utilization, demographic, and sinus disease measures did not have an association with LMS.

4 | DISCUSSION

To the best of our knowledge, this is the first study analyzing the relationship between radiographic severity and health care utilization in CRS patients. We found that CRS patients with severe radiographic disease were more likely to have nasal polyps and undergo ESS but have also taken fewer antibiotic courses. However, there was no association between radiographic disease severity and provider utilization, work or school days missed, symptom duration, oral steroid courses, or months of nasal steroid and OTC pill use.

The role of antibiotics in the management of CRS is unclear. Multiple studies report that the only well-defined role for antibiotics in this disease process is in treating acute rhinosinusitis exacerbations.^{18,19} In our study, patients with more severe radiographic CRS used fewer antibiotic courses compared to patients with less severe radiographic CRS. One possible contributing factor to using fewer antibiotic courses with higher LMS is the association of higher LMS with eosinophilic inflammation and nasal polyposis. Deosthale et al found that the Lund-Kennedy Endoscopy Score and presence of nasal polyps were significantly correlated with the LMS.²⁰ This study had similar findings with associations between normal endoscopy results and low LMS as well as nasal polyps and high LMS. Min et al reported that nasal tissues and secretions from CRS with nasal polyps (CRSwNP) patients had increased IL-13, eotaxin-2, and eotaxin-3 levels which were positively correlated with tissue eosinophilic cationic protein levels and radiographic scores.²¹ Moreover, Weibman et al observed that LMS was significantly correlated with eosinophilic cation protein in nasal polyp homogenates in CRSwNP patients.²² In CRS patients with eosinophilic inflammation, glucocorticosteroids have well-established roles in reducing inflammatory burden that may be influencing prescribing patterns. Antibiotics such as low-dose long-term macrolides, however, appear to be more effective in neutrophilic rather than eosinophilic inflammation.²³ Therefore, patients with eosinophilic inflammation and nasal polyposis are more likely to have high LMS and may be prescribed fewer courses of antibiotics because there is limited evidence supporting the use of antibiotics in managing these subsets of CRS. Also, patients who use fewer antibiotic courses may have limited access to consistent health care, leading to increased disease severity.

Although the association between radiographic disease severity and health care utilization had not yet been studied, the relationship between CRS and cost to the health care system has been well reported. In a 2019 study by Bhattacharyya et al analyzing cost burden and resource utilization by patients with CRSwNP, they found that annual incremental costs were \$11 507 higher for CRSwNP patients than a reference population without CRS. The CRS patients had significantly more oral steroid and macrolide prescriptions along with increased number of office and ambulatory visits. On a subgroup analysis, CRSwNP patients undergoing ESS had an increase in total costs of \$13 532 relative to CRSwNP patients not undergoing ESS. This difference was mainly driven by higher medical and office costs.⁸ Another study showed that CRS patients are approximately 1.5 times as likely to experience activity, work, and social limitations as reported by the Medical Expenditure Panel Survey relative to a non-CRS reference population.⁹ CRS inflicts a significant disease burden leading to increased health care utilization; however, this study suggests that most metrics of health care utilization are not associated with CRS radiographic severity except for antibiotic use.

In addition to demonstrating new findings, the study supported prior reports related to LMS and CRS. Multiple studies have showed that LMS is not significantly correlated with symptom scores when measured with scales like the SNOT-22 or Sinonasal Assessment Questionnaire (SNAQ-11).^{3,12} This study also demonstrated no significant association between radiographic severity and patient-reported

symptoms. Findings from Hopkins et al highlighted that patients with higher LMS were more likely to undergo surgery and specifically noted that higher LMS correlated with more extensive surgery.¹² The current study also suggested that patients who undergo ESS were more likely to have a high LMS. Indications for ESS are multi-faceted relying on factors like LMS, history of medical therapy trials, patient-reported symptomatic severity, and disease complications.²⁴ Therefore, the decision to proceed with ESS is a complex one that goes beyond radiographic disease severity and is heavily driven by patient-centered decision-making. Although there was no significant correlation between LMS and SNOT-22 scores, the association between high LMS and patients who underwent ESS may be due to multiple factors. One factor could be that, because high LMS is associated with increased eosinophilic inflammation which is less likely to respond to antibiotics,²³ these patients may have been considered refractory to medical therapy and were then referred for surgery. Other potential contributing factors include surgeon bias on observing CRS with significant radiographic severity or patients' feeling that surgery is necessary after being referred to a tertiary care center for severe CRS based on imaging.

When considering the association between medical history and LMS, the CRS literature is still developing. The current study identified that patients with a past or current diagnosis of GERD were less likely to have a high LMS; however, there is no consistent evidence of a relationship between CRS and GERD in adults. As both diseases are highly prevalent in society, it is common for them to coexist independently.²⁵ A 2017 systematic review by Sella et al showed that GERD may be associated with refractory CRS in adults, but their team was unable to determine a clear relationship between GERD and general CRS.²⁶ Other studies have produced evidence supporting an involvement of GERD in the development of CRSsNP.^{27,28} If GERD may contribute to the development of CRSsNP rather than CRSwNP, then it would likely be associated with a lower LMS based on how the score is calculated. Although Lal et al reported females had a lower preoperative LMS than males,²⁹ the current study found no significant difference between LMS for females and males. Kilty et al showed no association between daily smoking and LMS,³ and the current study showed no association between being a former or current smoker and LMS. Although smoking and comorbid OSA are associated with the severity of symptoms experienced by CRS patients,³⁰⁻³² neither factor was found to be significantly related to radiographic severity in this study. Koskinen et al demonstrated no significant difference in LMS between CRS patients with and without allergic rhinitis as exhibited in this study as well.³³ An epidemiologic study done in the United Kingdom by Philpott et al showed that aspirin sensitivity is strongly associated with CRSwNP³⁴; however, other studies have not considered the association between aspirin sensitivity and LMS which was shown not to be significant in the current study.

4.1 | Limitations

There are limitations to consider when interpreting the findings of this study. With the primary outcome being health care utilization, one

limitation is that the difference in barriers to health care access was not measured but could serve as a confounding variable. The patient population was restricted to a tertiary care center causing possible sampling biases by selecting for increased disease severity relative to the general CRS population. This also may have allowed for referral bias as described above in that patients referred to a tertiary care center for CRS with significant radiographic disease severity may be more likely to feel that surgery is necessary. Furthermore, patients with less severe disease are less likely to have a sinus CT, meaning they would have been excluded from this study. A majority of patients in the study population had a high LMS, but it would have been desirable to have a sample of patients with more equivalent baseline characteristics in terms of their LMS. Also, while supported by another study with similar methods,¹³ the dichotomization of low and high LMS is somewhat arbitrary. Patients completed their surveys at variable times, most commonly either at the time of diagnosis or at the time of sinus surgery. We recognize this as a limitation that may have influenced how patients answered certain questions, but it should not necessarily impact the comparison between the groups as the survey timing was random among the study sample. Further study would involve improving on these factors and incorporating a longitudinal component to assess the association between changes in LMS and health care utilization following treatment. This would lead to a more robust analysis of radiographic disease severity and health care utilization.

5 | CONCLUSION

Radiographic severity of CRS is associated with decreased antibiotic use, presence of nasal polyps, and undergoing ESS. However, similar to its association with subjective patient-reported symptom scores, LMS is a poor indicator of overall health care utilization. Also, while associated with higher likelihood of undergoing ESS, LMS should not be used as the sole basis upon which to proceed with surgery. To our knowledge, this is the first study examining the relationship between CRS radiographic severity and health care consumption measures. Although CRS patients may objectively have a more severe phenotype of CRS, they do not appear to utilize more medications or provider visits.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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