Section: Radiology

Original Research Article

CHRONIC RHINOSINUSITIS WITH LOWER AIRWAY INVOLVEMENT: A RADIOCLINICAL CORRELATION

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ABSTRACT

Background: Chronic rhinosinusitis (CRS) is commonly found to co-occur with airway involvement in the lower respiratory tract of a patient, especially in patients with asthma or chronic obstructive pulmonary disease. Understanding the radiological features relative to clinical severity is important for the holistic management of these patients. **Objective:** The aim of this study was to investigate the relationship between sinonasal Computed Tomography (CT) findings and analogously clinical lower airway involvement in patients with CRS.

Materials and Methods: This was a prospective observational study over a period of 18 months with 120 patients diagnosed with CRS by clinically accepted and endoscopically established standardized criteria. All 120 participants underwent sinus CT, pulmonary function tests, and clinical symptom scores for both upper and lower airway involvement. The Lund-Mackay scoring system was used to assess radiological severity, and Pearson/Spearman correlation coefficients were used to assess correlations with clinical lower airways parameters.

Results: Higher Lund- Mackay scores were related to higher severity of lower airway symptoms and lower pulmonary function. Subgroup analysis of patients with asthma demonstrated significantly higher radiological scores compared to non-asthmatic CRS patients with lower airway involvement ($p < 0.05$). Correlation analysis showed a moderate positive correlation between sinus opacification and lower airway obstruction indices ($r = 0.42$).

Conclusion: CRS patients with significant radiological involvement are more likely to also have some degree of lower airway involvement, indicating a need for comprehensive assessment of both the upper and lower airways in the management of CRS.

Keywords: Chronic rhinosinusitis, lower airway involvement, radioclinical correlation, CT scan, Lund-Mackay score, pulmonary function test.

INTRODUCTION

Chronic Rhinosinusitis (CRS): An Overview

Chronic rhinosinusitis (CRS) is a common inflammatory disorder of the sinonasal mucosa, resulting in symptoms lasting for at least 12 weeks. It affects a substantial portion of the world's population, although prevalence varies by geography and demographics.[1] CRS has two main phenotypes: CRS with nasal polyps (CRSwNP) and CRS without nasal polyps (CRSsNP). The pathophysiology of CRS involves various interactions between environmental factors, host immune responses, and microbial effects, leading to mucosal inflammation, impaired mucociliary clearance, and obstruction of sinus cavities.[2]

Lower Airway Involvement in CRS

Accumulating evidence suggests that there is a strong association between CRS and lower airway diseases - and especially eosinophilic asthma and COPD. Most studies have shown that many CRS patients have concurrent lower airway disease - whether overtly or subclinically. In a prospective study of CRS, 60% of patients reported associated lower

airway disease, including 24% of subjects with asthma and 36% of subjects with SAD.[3,4]

The connections between upper and lower airway inflammation appear to be multifactorial. The unified airway theory suggests that the upper and lower airways share common inflammatory pathways, immune responses and anatomical connections, so that inflammation in the upper airway leads to disease activity in the lower airways, creating a continuum of disease.[5] Eosinophilic inflammation, eosinophilic Th2 profile cytokines (IL-4, IL-5, IL-13) and epithelial barrier dysfunction are all important contributors to this process.

Radiological Assessment in CRS

Radiological imaging, most commonly CT of the paranasal sinuses, is an important resource to determine the extent and severity of sinonasal inflammation in CRS patients. While the Lund-Mackay scoring system can be applied to grade the sinus opacification and assess the disease burden[6], the relationship between the radiological findings and clinical status (including the involvement of the lower airways) is an ongoing area of research. There are some studies which have tried to examine preoperative CT findings in relation to pulmonary function parameters. One study showed a negative correlation between CT scan findings of the sinuses and obstructive parameters on pulmonary function tests, in a cohort of patients with small airway disease.[7] This study suggested that more severe evidence of sinonasal inflammation may be associated with greater lower airway impairment.

Rationale for the Study

Although a relationship between CRS (chronic rhinosinusitis) and diseases of the lower airway has been documented, there are few studies that examined an association between radiological sinus severity (Lund-Mackay CT scoring) and clinical measures of lower airway involvement. This relationship is important for total patient care, including risk stratification, treatment selection and prognostication.[8]

The purpose of our study is to analyze the radioclinical correlation between patients with CRS and established lower airway involvement. Particularly, we will analyze the relationship between Lund-Mackay CT scores and clinical metrics of lower airway function to demonstrate the relationship between the airway inflammation in the upper and lower airway. The results may reveal some understanding of the mechanisms underlying united airway disease, as well as providing clinical implications for patients with concurrent CRS and lower airway involvement.

Objectives and Study Design

Objectives

Primary Objective:

- To assess the correlation between radiological severity of chronic rhinosinusitis, as measured by the Lund-Mackay CT score, and clinical lower airway involvement, evaluated using pulmonary function tests (PFTs) and symptom scoring.

Secondary Objectives

- To evaluate differences in radiological severity between CRS patients with and without asthma or COPD.
- To determine the prevalence of subclinical lower airway involvement in CRS patients.
- To assess the relationship between symptom severity scores (both upper and lower airway) and CT findings.

Study Design

Type of Study: Prospective observational radioclinical correlation study.

Study Population:

- **Sample Size:** 120 patients, based on prevalence estimates of lower airway involvement in CRS and sufficient power to detect moderate correlations ($r \geq 0.3$) between CT scores and PFT results.

Inclusion Criteria:

- Adults aged 18–65 years with a diagnosis of CRS based on EPOS 2020 criteria (persistent symptoms >12 weeks and endoscopic confirmation).
- Patients willing to undergo CT imaging and pulmonary function testing.

Exclusion Criteria

- History of sinus surgery within the past 12 months.
- Acute upper or lower respiratory infection within 4 weeks.
- Severe comorbidities preventing PFT or CT evaluation.

Study Duration:

- Total duration: 18 months, including:
- Patient recruitment: 12 months.
- Follow-up and data collection: 6 months.

Assessments:

1. Radiological Assessment:

- Paranasal sinus CT scans evaluated using the Lund-Mackay scoring system.
- Assessment of sinus opacification severity and anatomical variations.

2. Lower Airway Assessment:

- Pulmonary function tests including FEV1, FVC, FEV1/FVC ratio, and small airway indices (FEF25–75%).
- Symptom scoring for lower airway involvement using validated questionnaires such as the Asthma Control Test (ACT) or COPD Assessment Test (CAT).

3. Clinical Symptom Scoring for CRS:

- Sinonasal Outcome Test (SNOT-22) for upper airway symptoms.
- Additional scoring for facial pain, nasal obstruction, and olfactory disturbances.

Statistical Analysis:

- Descriptive statistics for demographic and clinical characteristics.
- • Pearson or Spearman correlation to assess the relationship between

Lund-Mackay CT scores and lower airway parameters.
- Subgroup analyses comparing CRS patients with and without asthma or COPD.
- Significance level set at $p < 0.05$.

MATERIALS AND METHODS

Study Setting and Duration

This prospective observational study was conducted at a tertiary care otorhinolaryngology and pulmonology center over **18 months**, from January 2024 to June 2025. The study protocol was approved by the institutional ethics committee, and all participants provided informed written consent prior to enrollment.

Study Population

Sample Size: 120 patients diagnosed with CRS based on EPOS 2020 criteria were recruited consecutively. Sample size estimation was based on achieving 80% power to detect a moderate correlation ($r \geq 0.3$) between CT scores and lower airway parameters at a 5% significance level.

Inclusion Criteria:
- Adults aged 18–65 years.
- Persistent sinonasal symptoms for ≥12 weeks with endoscopic confirmation of mucosal inflammation.
- Willingness to undergo CT imaging and pulmonary function tests.

Exclusion Criteria:
- Prior sinus surgery within the past 12 months.
- Acute upper or lower respiratory tract infection within 4 weeks before enrollment.
- Severe comorbidities that precluded imaging or PFT evaluation.
- Pregnancy or lactation.

Clinical Evaluation

1. **Upper Airway Assessment:**
   - Symptoms were scored using the SNOT-22 questionnaire.
   - Additional assessments included nasal obstruction, facial pain, discharge, and olfactory disturbances.
2. **Lower Airway Assessment:**
   - Detailed history and physical examination for symptoms such as cough, wheezing, dyspnea, and sputum production.
   - Pulmonary function tests (PFTs) were performed according to ATS/ERS guidelines, including FEV1, FVC, FEV1/FVC ratio, and FEF25–75% to assess small airway function.
   - Patients with known asthma or COPD were documented, and severity was classified according to GINA or GOLD criteria.

Radiological Assessment
- **CT Protocol:** Non-contrast high-resolution CT scans of the paranasal sinuses were performed using a multi-slice CT scanner. Axial and coronal images were reconstructed with a 1–2 mm slice thickness.
- **Scoring System:** The Lund-Mackay system was used to quantify sinus opacification. Each sinus was scored 0 (no opacification), 1 (partial opacification), or 2 (complete opacification), yielding a total score ranging from 0 to 24.
- **Reviewer Blinding:** Two experienced radiologists independently scored the scans. Discrepancies were resolved by consensus.

Data Collection and Management
- Demographic data, comorbidities, symptom scores, PFT results, and CT scores were entered into a secured database.
- Data quality checks and double entry were performed to minimize errors.

Statistical Analysis
- Descriptive statistics: mean ± SD for continuous variables, frequencies, and percentages for categorical variables.
- Correlation analysis: Pearson or Spearman correlation coefficients were used to assess the relationship between Lund-Mackay scores and lower airway parameters.
- Subgroup analyses: Comparison of CT scores and PFT results between CRS patients with and without asthma or COPD using t-tests or Mann-Whitney U tests.
- Statistical significance: $p < 0.05$.
- All analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY).

Ethical Considerations
- Study conducted in accordance with the Declaration of Helsinki.
- Institutional ethics committee approval obtained.
- Informed consent obtained from all participants.

Patient confidentiality was maintained throughout the study.

RESULTS

Patient Demographics and Clinical Characteristics

A total of 120 patients with chronic rhinosinusitis (CRS) were enrolled. The mean age was 42.5 ± 12.3 years, with a male-to-female ratio of 1.2:1. Comorbidities included asthma in 38 patients (31.7%), COPD in 15 patients (12.5%), and allergic rhinitis in 27 patients (22.5%). The mean duration of CRS symptoms was 5.6 ± 3.2 years.

Upper airway symptom severity was moderate-to-severe, with a mean SNOT-22 score of 45.8 ± 12.5. Nasal obstruction was reported by 98 patients (81.7%), facial pain/pressure by 72 patients (60%), and hyposmia/anosmia by 55 patients (45.8%).

Lower airway symptoms included chronic cough in 52 patients (43.3%), wheezing in 38 patients (31.7%), and dyspnea on exertion in 47 patients (39.2%). Among patients with asthma, 62% had uncontrolled or partially controlled symptoms according to ACT scores.

Table 1: Demographic and Clinical Characteristics of CRS Patients

Parameter	Total (n=120)	CRS with Asthma (n=38)	CRS without Asthma (n=82)
Age (years, mean ± SD)	42.5 ± 12.3	44.1 ± 11.8	41.6 ± 12.6
Male:Female	1.2:1	1.1:1	1.2:1
Duration of CRS symptoms (years, mean ± SD)	5.6 ± 3.2	6.1 ± 3.4	5.3 ± 3.1
Nasal obstruction (%)	81.7	89.5	78.0
Facial pain/pressure (%)	60.0	65.8	57.3
Hyposmia/anosmia (%)	45.8	50.0	43.9
Chronic cough (%)	43.3	55.3	37.8
Wheezing (%)	31.7	50.0	22.0

Radiological and Pulmonary Function Findings

CT Scan Assessment (Lund-Mackay Score):

- Mean total Lund-Mackay score: 12.8 ± 4.5 (range 3–22).
- The maxillary and ethmoid sinuses were most frequently involved (90% and 85%, respectively).
- Bilateral sinus involvement was observed in 78 patients (65%).

Pulmonary Function Tests (PFTs):

- Mean FEV1: 78.4 ± 14.2% predicted
- Mean FVC: 82.1 ± 12.8% predicted
- Mean FEV1/FVC ratio: 0.72 ± 0.08
- Mean FEF25–75% (small airway index): 65.3 ± 18.7% predicted
- Asthmatic patients had significantly lower FEV1 and FEF25–75% values compared to non-asthmatic CRS patients ($p < 0.01$).

Table 2: Radiological and Pulmonary Function Findings

Parameter	Total (n=120)	CRS with Asthma (n=38)	CRS without Asthma (n=82)	p-value
Lund-Mackay score (mean ± SD)	12.8 ± 4.5	15.2 ± 4.1	11.8 ± 4.2	<0.01
FEV1% predicted	78.4 ± 14.2	71.3 ± 12.6	81.5 ± 13.5	<0.01
FVC% predicted	82.1 ± 12.8	78.5 ± 11.9	84.0 ± 13.0	0.02
FEV1/FVC ratio	0.72 ± 0.08	0.69 ± 0.07	0.73 ± 0.08	0.03
FEF25–75% predicted	65.3 ± 18.7	58.6 ± 15.4	68.9 ± 19.2	<0.01
SNOT-22 score	45.8 ± 12.5	49.2 ± 11.6	44.1 ± 12.3	0.03

Radioclinical Correlation

- Pearson correlation analysis demonstrated a moderate positive correlation between total Lund-Mackay score and lower airway symptom severity ($r = 0.42$, $p < 0.001$).
- FEV1% predicted showed a negative correlation with Lund-Mackay score ($r = -0.38$, $p < 0.01$), indicating more severe sinus disease is associated with reduced pulmonary function.
- FEF25–75% also negatively correlated with CT scores ($r = -0.35$, $p < 0.01$), reflecting small airway impairment in patients with extensive sinus opacification.

Table 3: Correlation Between Lund-Mackay CT Scores and Lower Airway Parameters

Parameter	Correlation Coefficient (r)	p-value
FEV1% predicted	-0.38	<0.01
FEF25–75% predicted	-0.35	<0.01
Lower airway symptom severity	0.42	<0.001

Summary of Results

- Patients with higher Lund-Mackay CT scores exhibited greater lower airway symptom burden and reduced pulmonary function.
- Presence of asthma or COPD significantly accentuated these correlations.
- Radiological severity correlated moderately with clinical measures, supporting the concept of united airway disease.
- Integrated upper and lower airway assessment is recommended for comprehensive management of CRS patients.

DISCUSSION

Overview and Key Findings

This systematic review evaluated the radioclinical correlation in patients with chronic rhinosinusitis (CRS) and lower respiratory involvement. Of the 120 patients, higher Lund-Mackay CT scores were clinically related to higher lower airway symptom burden and worse pulmonary function (FEV1, FEF25–75%, and FEV1/FVC). Additionally, patients with asthma or COPD, as a comorbidity, had more significant sinus opacification, symptom scores, and pulmonary function impairment [9,10].

The findings support the strong evidence behind the "united airway" hypothesis, emphasizing the shared pathophysiology of the upper and lower respiratory tract, providing a broader view of the disease. Radiological severity in the sinonasal region may be used as a surrogate for the risk of lower airway involvement, which is relevant to the overall management of CRS patients [11].

Comparison with Prior Studies

Several studies have explored the association between CRS and lower airway diseases:

1. Bachert et al., 2010 described patients with CRS and nasal polyps commonly having asthma, and higher eosinophilic inflammation in their upper and lower airways[12].
2. Ciprandi et al., 2012 found that CRS with asthma patients had higher Lund-Mackay scores than non-asthmatic patients, which coordinated with our findings[13].
3. Tan et al., 2015 stated that pulmonary function values, specifically small airway indices (FEF25–75%), are inversely related to CT scores in patients with CRS, emphasizing sinonasal inflammation-induced dysfunction in the lower airways[14].

Our study expands upon these findings by including both CRSwNP and CRSsNP phenotypes, employing a comprehensive radiological and functional assessment, and quantifying correlations between upper and lower airway parameters. The moderate correlation coefficients observed (r = 0.35–0.42) suggest a clinically relevant, though not absolute, relationship, reflecting the multifactorial nature of airway disease.[15]

Clinical Implications

1. **Integrated Airway Assessment:** CRS patients, especially those with asthma or COPD, should undergo both sinonasal imaging and pulmonary function evaluation to identify subclinical lower airway involvement.
2. **Personalized Management:** Higher CT scores may indicate the need for more aggressive medical therapy or surgical intervention, as these patients are at higher risk for lower airway morbidity.
3. **Monitoring and Prognostication:** Lund-Mackay scores could serve as a marker for monitoring disease progression and predicting lower airway outcomes, particularly in patients with comorbid asthma.

Strengths of the Study

- Prospective design with standardized imaging and pulmonary assessment protocols.
- Moderate sample size (n=120) providing adequate power for correlation analyses.
- Comprehensive inclusion of both upper and lower airway clinical parameters.
- Inclusion of a subgroup analysis for patients with asthma and COPD, enhancing the clinical relevance of findings.

Limitations

- Single-center study, which may limit generalizability to other populations.
- Cross-sectional correlation analysis; causal relationships cannot be definitively established.
- Limited COPD subgroup (n=15), reducing the statistical power for this specific population.
- PFTs may not capture all forms of lower airway inflammation; additional biomarkers (e.g., FeNO, sputum eosinophils) were not assessed.

Future Directions

- Longitudinal studies to evaluate whether changes in sinus radiological severity predict progression of lower airway disease.
- Integration of biomarker analysis (e.g., systemic and local eosinophilia, cytokine profiling) to better understand the pathophysiological mechanisms of united airway disease.
- Larger multicenter studies to validate findings across diverse populations and CRS phenotypes.

CONCLUSION

In patients with chronic rhinosinusitis, radiological severity of sinus disease correlates moderately with lower airway involvement, including symptom burden and pulmonary function impairment. Comorbid asthma or COPD amplifies this correlation. These findings support the concept of a united airway and underscore the importance of integrated evaluation and management of upper and lower airways in CRS patients. Clinicians should consider routine lower airway assessment, particularly in patients with severe radiological disease, to optimize outcomes and prevent long-term respiratory complications.

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