Endoscopic Sinus Surgery Improves Sleep Quality in Chronic Rhinosinusitis: A Systematic Review and Meta-analysis

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Abstract

Objective. Up to 75% of patients with chronic rhinosinusitis (CRS) suffer with poor sleep quality and reduced quality of life. Endoscopic sinus surgery has demonstrated encouraging results in improving sleep function. The aim of this systematic review is to assess the change in sleep quality after surgery for CRS.

Data Sources. PubMed, Web of Science, EMBASE.

Review Methods. An electronic search was conducted with the keywords “sinusitis” or “rhinosinusitis” and “sleep.” Studies were included only when adults underwent endoscopic sinus surgery and were evaluated pre- and postoperatively by the Epworth Sleepiness Scale (ESS), the Pittsburgh Sleep Quality Index (PSQI), the Apnea-Hypopnea Index (AHI), the sleep domain of Sino-Nasal Outcome Test–22, or the sleep domain of Rhinosinusitis Disability Index.

Results. The database search yielded 1939 studies, of which 7 remained after dual-investigator screening. The standardized mean differences (95% CI) for the ESS, PSQI, and AHI were $-0.94$ ($-1.63$ to $-0.26$), $-0.80$ ($-1.46$ to $-0.14$), and $-0.20$ ($-0.32$ to $-0.07$), indicating large, moderate to large, and small improvements, respectively. All analyses displayed high heterogeneity ($I^2$ = 95%-99%).

Conclusion. Sleep quality, as measured by the ESS and PSQI surveys, shows substantial improvement after surgery for CRS, with smaller improvement seen for AHI. Generalizability of our results is limited by high heterogeneity among studies and by broad confidence intervals that cannot exclude small to trivial changes. The findings of this meta-analysis provide insight into the effect of CRS-related endoscopic sinus surgery on sleep quality, which should guide future research direction and counseling of patients in the clinical setting.

Keywords

sleep quality, sleep impairment, quality-of-life, chronic rhinosinusitis, chronic sinusitis, endoscopic sinus surgery, Epworth Sleepiness Scale, Pittsburgh Sleep Quality Index, Apnea-Hypopnea Index, Sino-Nasal Outcome Test–22, Rhinosinusitis Disability Index

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Chronic rhinosinusitis (CRS) is a common disease that can afflict up to 5% of the population.¹ The level of debilitation in CRS can rival other chronic conditions, such as congestive heart failure, coronary artery disease, neurodegenerative disabilities, end-stage renal dysfunction, and chronic liver disease.² Moreover, up to 75% of patients will suffer with poor sleep quality and reduced quality of life (QOL).³,⁴ Persistent sleep impairment can cause long-term physical and mental health problems, including depressive symptoms, cardiovascular morbidity, and increased mortality.⁵,⁶

Given the vital impact of sleep on health and QOL,⁷,⁸ it is not surprising that sleep-related impairment in CRS can influence a patient’s decision to pursue endoscopic sinus surgery.⁹ In some studies, endoscopic sinus surgery has demonstrated encouraging results in reducing sleep dysfunction¹⁰⁻²³ but conclusions are difficult to reach because of high variability in research design, conduct, and choice of outcome measure. Furthermore, the results remain inconclusive, with some outcomes failing to achieve statistical significance.¹⁴,¹⁵ Due to the high economic, social, and physical burden of impaired sleep,⁸,²⁴⁻²⁶ it is imperative to perform a systematic review of the effect of surgical intervention on sinusitis-related sleep disability.

The objective of this systematic review is to evaluate the change in sleep quality of patients ≥18 years old who underwent endoscopic sinus surgery for CRS. We used meta-analysis to quantitatively pool and synthesize data on...
the effect of CRS-related endoscopic sinus surgery on scores based on the Epworth Sleepiness Scale (ESS), the Pittsburgh Sleep Quality Index (PSQI), the Apnea-Hypopnea Index (AHI), the sleep domain of Sino-Nasal Outcome Test–22 (sdSNOT-22), and the sleep domain of Rhinosinusitis Disability Index (sdRSDI). To our knowledge, this is the first review to provide aggregate quantitative data on the effect of surgical intervention on multiple validated sleep quality instruments among cohorts of patients with CRS.

Materials and Methods

We framed the research question in the PICO format (population, intervention, comparison, outcomes). For patients with medically refractory CRS, does endoscopic sinus surgery improve sleep outcomes? This systematic review was conducted with an a priori protocol, and the resulting article was composed in adherence to PRISMA standards (Preferred Reporting Items for Systematic Reviews and Meta-analyses).

An electronic search of PubMed, Web of Science, and EMBASE databases was conducted. The inquiry was performed with the keywords “sinusitis” or “rhinosinusitis” and “sleep.” An information specialist at our institution performed the search, which was limited to English-only articles and articles in foreign languages that were translated to English. Book chapters, textbooks, and published oral or poster conference abstracts were excluded. Abstracts were removed from analysis if they evaluated patients with acute sinusitis, examined outcomes of medical treatment, consisted of primarily pediatric populations, did not report postoperative sleep survey and QOL measures. The studies were included in the final analysis (n = 7). Characteristics of the studies are summarized in Table 1. Among the 7 studies, 4 were from the United States, 1 from Canada, and 2 from Turkey. The sample sizes ranged from 27 to 291. The most common type of study encountered was prospective (n = 5), followed by case series with chart reviews (n = 2). The range of follow-up periods varied from about 3 to 13.5 months. Notably, 5 studies had statements of follow-up timelines but no calculated mean and standard deviation of follow-up times. Endoscopic sinus surgery was performed in all studies, which may have included unilateral or bilateral maxillary antrostomy, partial or total ethmoidectomy, sphenoidotomy, or frontal sinusotomy and adjunctive procedures such as septoplasty, inferior turbinate reductions, or polypectomies. Four studies included revision cases as well.

After the search was conducted, 2 independent investigators (D.C.S. and J.M.A.) reviewed and screened abstracts and full-text articles using the aforementioned inclusion and exclusion criteria. The 2 reviewers then extracted data using a standardized form, specifically looking at demographic variables, sample size, follow-up, interventions, and pre- and postoperative sleep survey and QOL measures. The methodological quality of the studies and analyses of bias were assessed with the MINORS criteria (Methodological Index for Non-randomized Studies). Any discrepancies encountered during the dual-investigator review were resolved through re-review and a mutual discussion between the 2 investigators with the senior-most author (R.M.R.).

Statistical analysis was performed with meta-analysis software to pool outcomes across studies for the change in ESS, PSQI, sdSNOT-22, or AHI scores from baseline to after endoscopic sinus surgery. Effect size is reported as the standardized mean difference (SMD), calculated as the mean group outcome after surgery minus the mean group outcome at baseline, divided by the standard deviation within the groups. An advantage of the SMD is that it is comparable across studies, with zero indicating no difference and higher numbers reflecting larger differences. The SMD is comparable to Cohen’s effect size and can be interpreted as trivial if <0.20, small if 0.20 to 0.49, moderate if 0.50 to 0.79, and large if ≥0.80. All data were pooled via random effects meta-analysis, which does not assume a common effect size across studies and results in wider 95% CIs versus a fixed effects approach. Heterogeneity was assessed with I² statistics, with values of 25%, 50%, and 75% corresponding to low, moderate, and high heterogeneity, respectively. All comparisons were assessed for significance with a type I error probability (P value) threshold of 0.05.

Results

The database search yielded 1939 studies, of which 1641 remained after duplicates were removed. After dual-investigator screening of abstracts and full-text articles, 7 studies were included in the final analysis (Figure 1). Characteristics of the studies are summarized in Table 1. Among the 7 studies, 4 were from the United States, 1 from Canada, and 2 from Turkey. The sample sizes ranged from 27 to 291. The most common type of study encountered was prospective (n = 5), followed by case series with chart reviews (n = 2). The range of follow-up periods varied from about 3 to 13.5 months. Notably, 5 studies had statements of follow-up timelines but no calculated mean and standard deviation of follow-up times. Endoscopic sinus surgery was performed in all studies, which may have included unilateral or bilateral maxillary antrostomy, partial or total ethmoidectomy, sphenoidotomy, or frontal sinusotomy and adjunctive procedures such as septoplasty, inferior turbinate reductions, or polypectomies. Four studies included revision cases as well.

The definition of CRS varied throughout the included studies. Three studies classified CRS in accordance to the 2007 American Academy of Otolaryngology—Head and Neck Surgery Foundation’s adult sinusitis clinical guideline. Benninger and Senior included patients with signs and symptoms consistent with the 2003 Rhinosinusitis Task Force guideline. Tosun et al defined CRS as at least 6 months of symptoms with >50% obstruction in each nasal passage, while Gunhan et al specified no duration but defined their criteria as polyps on CT or endoscopy and having at least 2 of the following symptoms: nasal obstruction, rhinorrhea with anterior/posterior nasal drip, hyposmia, or anosmia. Notably, Yalamanchali et al did not include a specific definition for CRS.
The methodological quality of each study was evaluated with the MINORS criteria (Tables 1 and 2). The MINORS scores ranged from 11 to 15, with 16 being a perfect score. The mean and median MINORS scores were 12.6 and 12, respectively. Studies with scores >11 were considered to have low risk of bias. Most studies were deficient in categories of power calculation and blinded evaluations. The majority of these studies also lost >5% of their sample size at follow-up. All of the studies had clearly stated aims and consecutive sampling. Given that the studies aimed to evaluate QOL and sleep quality, all had validated end points appropriate to their objectives. Two studies were case series with chart reviews or were retrospective in nature, but all studies involved prospective collection of data.

**Epworth Sleepiness Scale**

Three studies evaluated sleep outcomes with the ESS (Table 3). A forest plot is displayed in Figure 2, which demonstrates a random effects meta-analysis for the change in ESS scores after surgery. An SMD of −0.94 (diamond) was obtained for the pooled result, which indicated a large and statistically significant (P = .007) improvement. However, the clinical significance may be lower because the broad 95% CI was not able to rule out a small effect size (SMD, −0.26). The I² of 99% was consistent with high heterogeneity among studies.

Two studies included patients with nasal polyposis, while 1 study specifically evaluated patients without nasal polyps. A study had to be excluded from the meta-analysis due to the use of median and interquartile range, as opposed to mean and standard deviation.

**Pittsburgh Sleep Quality Index**

The PSQI was utilized as the outcome instrument in 2 studies (Table 3). The forest plot shown in Figure 3 demonstrates a random effects meta-analysis for the change in the PSQI. The SMD of the pooled result was −0.80 (diamond), which was consistent with a large and statistically significant (P = .017) improvement. The clinical significance was uncertain because the broad 95% CI could rule out a trivial effect size (SMD, −0.14). The I² of 99% indicated high heterogeneity among studies.

Rotenberg and Pang excluded patients with nasal polyposis, while Alt et al included patients suffering from nasal polyposis.
Three studies \(^1^4\)–\(^1^6\) evaluated the change in AHI after surgery (Table 3). Figure 4 shows a random effects meta-analysis for AHI. The SMD of the pooled result was \(-0.20\) (diamond), which indicated a small improvement after surgery. The 95% CI ranged from a trivial (\(-0.07\)) to a small (\(-0.32\)) effect size. The \(I^2\) of 95% was consistent with high heterogeneity among studies.

Notably, Yalamanchali et al \(^1^6\) included only patients with obstructive sleep apnea (OSA), while Gunhan et al \(^1^5\) specifically excluded them. Patient with nasal polyps were included in all 3 studies.

**Sleep Domain of Sino-Nasal Outcome Test–22**

The sdSNOT-22 was utilized by multiple studies to evaluate sleep quality. \(^9\)–\(^1^2\),\(^2^0\),\(^2^1\),\(^4^1\)–\(^4^3\) These studies had overlapping cohorts of patients from 4 academic tertiary care institutions (Oregon Health & Science University, Medical University of South Carolina, Stanford University, and University of Calgary). Among these studies, DeConde et al \(^9\) was evaluated to have the highest MINORS score (Tables 1 and 2) and was included in the final data set (Figure 1). This study involved 291 patients who underwent endoscopic sinus surgery for CRS, as defined by the 2007 American Academy of Otolaryngology—Head and Neck Surgery Foundation’s adult sinusitis clinical guideline.\(^3^9\) Patient comorbidities included asthma (33%), allergies (11.1%), depression (16.7%), and smoking (14%). Nasal polyps were present in about 39% of the study population. The average follow-up was 13.5 months (SD, 5.7 months). The sdSNOT-22 improved by 5.7 (SD, 7.0), with a statistically significant \(P\) value <.001. Other related studies involving this cohort supported the finding that the sdSNOT-22 significantly improved after endoscopic sinus surgery.

**Sleep Domain of Rhinosinusitis Disability Index**

Only 1 study measured sleep quality with the sdRSDI.\(^1^7\) The study had a MINORS score of 12 and was a case series with chart review involving 113 adult patients with CRS. CRS was defined in this study by the 2003 Rhinosinusitis Task Force guideline.\(^4^0\) Patient comorbidities included asthma (42.5%), smoking (9.7%), and allergies (38.1%).
About 35% of patients had nasal polyposis. The average patient follow-up was 12.7 months (SD, 2.4 months). The mean preoperative sdRSDI was 2.4 (SD, 1), and the mean postoperative sdRSDI was 1.5 (SD, 1.1). This improvement was statistically significant at a $P$ value <.001.

**Discussion**

Our meta-analysis supports the current trend in the literature demonstrating that sleep quality, as measured by multiple validated instruments, significantly improves after endoscopic sinus surgery for CRS. Based on random effects meta-analysis, the SMDs for the ESS, PSQI, and AHI were $-0.94$, $-0.80$, and $-0.20$, respectively. This indicates a large and statistically significant effect size for the ESS and PSQI and a small but statistically significant effect size for AHI.

Early studies demonstrated that intranasal obstruction is associated with polysomnographic apneas, hypopneas, loss of deep sleep, and cortical arousals. This is further exacerbated in the setting of prolonged sinus disease. Similar to various chronic inflammatory conditions, CRS is associated with upregulation of proinflammatory cytokines IL-1β and TNF-α, which are signaling proteins involved in pathways of sleep regulation and non-rapid eye movement sleep. The current clinical evidence parallels this molecular observation, with the majority of patients with CRS reporting deficits in sleep. Recent studies have demonstrated the positive effect of surgical intervention on CRS-related sleep quality. However, these studies exhibit high heterogeneity and inconsistent utilization of outcome instruments.

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**Table 3. Summary of Meta-analysis for the ESS, PSQI, and AHI.**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Studies</th>
<th>Patients</th>
<th>SMD (95% CI)</th>
<th>$P$ Value</th>
<th>$I^2$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS</td>
<td>3</td>
<td>109</td>
<td>$-0.94$ (–1.63 to –0.26)</td>
<td>.007</td>
<td>99</td>
</tr>
<tr>
<td>PSQI</td>
<td>2</td>
<td>272</td>
<td>$-0.80$ (–1.46 to –0.14)</td>
<td>.017</td>
<td>99</td>
</tr>
<tr>
<td>AHI</td>
<td>3</td>
<td>112</td>
<td>$-0.20$ (–0.32 to –0.07)</td>
<td>.002</td>
<td>95</td>
</tr>
</tbody>
</table>

*Abbreviations: AHI, Apnea-Hypopnea Index; ESS, Epworth Sleepiness Scale; PSQI, Pittsburgh Sleep Quality Index; SMD, standardized mean difference.*
and health, a systematic quantitative analysis is necessary to evaluate the available evidence.

The ESS was shown to significantly correlate with the respiratory disturbance index and minimum oxygen saturation in overnight polysomnography among patients with OSA. A meta-analysis further showed a statistically significant improvement of pooled ESS results in nasal surgery for OSA. Recently published literature showed that patients with CRS have increased baseline ESS scores and that endoscopic sinus surgery yields favorable results. Our pooled SMD supports this with a statistically significant large effect size.

An alternative to the ESS, the PSQI is a 19-item questionnaire that measures sleep quality and disturbances over a 1-month period. A score >5 suggests poor sleep, as observed in populations of patients with CRS. Recent studies have shown sleep improvement after endoscopic sinus surgery, and the pooled SMD of this meta-analysis concurs with this trend.

AHI, as the primary measure of OSA severity, is also extensively utilized as a validated outcome instrument for sleep quality. The improvement in AHI after nasal surgery has been controversial, with several prospective studies and a recent meta-analysis failing to display statistical significance in OSA patients. However, in the setting of CRS, the pooled SMD of our analysis showed a statistically significant but modest effect size.

In contrast to the ESS, PSQI, and AHI, the change in the sdSNOT-22 cannot be assessed by meta-analysis due to the uncertainty of sample overlap in multiple related studies. The Sino-Nasal Outcome Test–22 is a modification of the Sino-Nasal Outcome Test–20, a patient-reported outcome measure designed to evaluate QOL in the setting of rhinosinusitis. A component of both tests is the sleep domain, which functions as a metric of sleep quality. Based on multiple related studies, the sdSNOT-22 improved after CRS-related endoscopic sinus surgery, which agrees with this review’s overall findings. Given its MINORS score of 14 and large sample size, the study by DeConde et al was selected to be in the final data set.

Only 1 study in our data evaluated sleep quality with the sdRSDI. The Rhinosinusitis Disability Index, developed in 1997, is a validated questionnaire that measures the physical, functional, and emotional impact of rhinosinusitis on QOL. Benninger and Senior found an overall decrease in sleep-related Rhinosinusitis Disability Index score after CRS-related endoscopic sinus surgery. Given that only 1 study utilized this instrument, a meta-analysis was unable to be performed on this outcome measure.

There are several limitations with our review. The first stems from the design of individual studies in the final data set. For a comparison study, the ideal design involves a concurrent randomized control group. The majority of studies included are noncomparative and prospective, with subjects serving as their own preoperative controls. Without a control group, it is difficult to distinguish the true change in sleep quality after sinus surgery from spontaneous improvement or regression to a mean symptom state. Furthermore, the inherent biases present in observational studies conducted as part of routine clinical care cannot be excluded. This limitation is somewhat tempered by using validated outcomes measures and by the high quality of the studies involved, with all MINORS scores having values ≥11 and an average of 12.6 out of 16.

Another limitation is the lack of consensus in CRS definitions among included studies. As previously discussed, CRS was defined by different guidelines with 2 studies utilizing their own criteria and 1 study lacking a stated definition. In addition, the presence of comorbidities is inconsistent among the studies’ inclusion and exclusion criteria, with a wide discrepancy in the frequency of smoking, depression, OSA, allergies, and nasal polyposis. Depressive symptoms, tobacco smoking, OSA, and allergies are known risk factors for poor sleep quality. Furthermore, the presence of nasal polyps is associated with a 2-fold higher risk of sleep disturbance as compared with patients without nasal polyposis. Additionally, the extent of surgical intervention in these studies was ultimately dependent on surgeon preference. The array of procedures may have involved standard functional endoscopic sinus surgery with unilateral or bilateral maxillary antrostomy, partial or total

<table>
<thead>
<tr>
<th>Study name</th>
<th>Outcome</th>
<th>Std diff in means</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>p-Value</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tosun 2009</td>
<td>AHI</td>
<td>-0.086</td>
<td>-0.140</td>
<td>-0.033</td>
<td>0.002</td>
<td>27</td>
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<tr>
<td>Gunhan 2011</td>
<td>AHI</td>
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<td>-0.381</td>
<td>-0.275</td>
<td>0.000</td>
<td>29</td>
</tr>
<tr>
<td>Yalamanch 2014</td>
<td>AHI</td>
<td>-0.178</td>
<td>-0.215</td>
<td>-0.141</td>
<td>0.000</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.197</td>
<td>-0.322</td>
<td>-0.073</td>
<td>0.002</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Forest plot showing random effects meta-analysis for the Apnea-Hypopnea Index (AHI). The standardized mean difference of −0.20 (diamond) indicates a small improvement, but the broad 95% CI cannot rule out a small to trivial effect size.
ethmoidectomy, sphenoidotomy, or frontal sinusotomy, with or without septoplasty, inferior turbinate reductions, and polypectomy as adjuncts. With imprecise follow-up times in the final data, our confidence in calculated effect sizes is also attenuated, as short- versus long-term changes are not clearly distinguished.

These inherent variabilities are reflected in the high heterogeneity parameter of the final data set. The I² statistics, a derivative of Cochran’s $Q$, is a percentage measure of variance that is attributable to study heterogeneity instead of chance. Although the I² value is high among the studies in this review (95%-99%), this is partially addressed by a random effects meta-analysis, which assumes that a distribution of effect sizes exists, not a single mean common effect among studies. Moreover, the random effects model gives more relative weight to small studies (vs a fixed effects analysis) and has wider 95% CIs, consistent with the additional uncertainty that accompanies high heterogeneity.

In summary, our meta-analysis provides insight into the effect of CRS-related endoscopic sinus surgery on sleep quality. As an important contributing parameter to QOL and health, restful sleep is a priority among many patients, and an honest discussion regarding the effect of endoscopic sinus surgery on sleep disturbance is paramount in the clinical setting. Our results show a large and statistically significant effect of endoscopic sinus surgery on 2 validated sleep instruments—namely, the ESS and PSQI. Smaller improvements in AHI were found after CRS-related endoscopic sinus surgery, suggesting that nasal surgery may be a useful adjunct in controlling obstructive apneas in patients with concurrent CRS. Further studies are required to elucidate the effects on the sdSNOT-22 and sdRSDI, as a meta-analysis could not be performed on these outcome measures.

**Author Contributions**

Daniel C. Sukato, lead author, study design, data collection, data interpretation, final approval; Jason M. Abramowicz, contributing author, study design and conception, data collection, data interpretation, final approval; Marina Boruk, contributing author, data interpretation, manuscript editor, final approval; Nira A. Goldstein, contributing author, data interpretation, manuscript editor, final approval; Richard M. Rosenfeld, principal investigator, study design, statistical analysis, data interpretation, manuscript editor, final approval.

**Disclosures**

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**References**


