Endoscopic Sinus Surgery for Pediatric Patients: Prognostic Factors Related to Revision Surgery

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**Objectives:** In the past two decades, endoscopic sinus surgery (ESS) has been performed frequently in children with medically recalcitrant chronic rhinosinusitis (CRS). However, surgical success rates vary according to age. The causes of failure and prognostic factors for revision ESS remain unclear. The aims of the present study were to evaluate prognostic factors related to revision surgery after ESS, and to determine the most optimal timing for surgery in the pediatric population.

**Methods:** This was a retrospective review in a tertiary medical center. Children who underwent ESS for CRS between 2004 and 2017 were enrolled. Demographics, sinonasal examination findings, previous operation history, laboratory data, comorbidities, and computed tomography (CT) results were collected from medical records. Prognostic factors for revision surgery were analyzed.

**Results:** A total of 188 pediatric patients were enrolled in this study. Twenty-four patients (12.8%) required revision surgery. Multivariate logistic regression analysis identified patients with nasal allergy (OR = 6.258; **P** = .010) and higher Lund-Mackay score on preoperative sinus CT (OR = 1.658; **P** = .043) had worse outcomes, while older age was a positive prognostic factor (OR = 0.702; **P** = .018). A cut-off point of 15.68 years of age and mean Lund-Mackay score of 10.5 showed the best predictive power for revision surgery.

**Conclusion:** ESS is performed with increasing frequency in children, knowledge of prognostic factors for revision surgery is important. In this study, patients with younger age, nasal allergy, and higher Lund-Mackay score on preoperative sinus CT had worse outcomes.

**Key Words:** Pediatric sinusitis, endoscopic sinus surgery, recurrence, revision surgery, chronic rhinosinusitis.

**Level of Evidence:** 4

**Laryngoscope, 00:1–5, 2019**

INTRODUCTION

Chronic rhinosinusitis (CRS) has been defined in the European Position Paper on Rhinosinusitis and Nasal Polyps (EPOS) 2012 as inflammation of the nose and paranasal sinuses that lasts for more than 12 weeks, which is characterized by specific nasal symptoms, endoscopic signs, and/or computed tomography (CT) images. For medically recalcitrant sinus diseases, the logical surgical algorithm for pediatric CRS begins with adenoidectomy with possible antral irrigation or balloon dilation of the maxillary sinuses; endoscopic sinus surgery (ESS) is reserved for treatment failures. For decades, ESS has been proven effective and safe in pediatric patients. Promising results with respect to the improvement of sinus symptoms and quality of life after ESS have been reported in several studies. However, surgical success rates consistently vary according to age among pediatric patients. In addition, considering the impact of surgery on facial growth, poor cooperation with postoperative nasal local treatment, and the immature state of the pediatric immune system, no consensus has formed regarding the optimal time to perform ESS in pediatric patients.

In the present study, we retrospectively evaluated pediatric patients who underwent ESS. The aims of the study were to evaluate prognostic factors related to revision surgery after ESS, and to establish the most optimal timing for surgery in the pediatric population.

**MATERIALS AND METHODS**

**Patients**

Pediatric patients, aged 0 to 18, who presented for ESS due to CRS were identified by automated and manual chart reviews using the following approach. To identify patients who underwent ESS, we conducted an automated search of the histopathology database in Chang Gung Memorial Hospital, using samples taken...
between 2004 and 2017. We then manually reviewed the chart records of the identified patients to confirm the study groups in the present study. A diagnosis of CRS was established in accordance with the EPOS 2012 definition. A total of 188 patients were selected from the database after applying the following exclusion criteria: patients with benign or malignant sinonasal neoplasms; patients with a concomitant diagnosis of cystic fibrosis, primary ciliary dyskinesia, or immunologic complications; no available preoperative CT in the hospital computer network; and a follow-up period of less than 9 months (Fig. 1). Importantly, the electronic medical record system, which was installed in the hospital in 2004, allowed all medical records to be thoroughly reviewed.

**Statistical Analysis**

Statistical analysis was performed with MATLAB 2015b program (MathWorks Inc., Natick, MA, U.S.A.). Patients who underwent ESS were divided into two groups based on whether they underwent revision surgery following ESS; factors related to treatment outcome were compared between groups. Univariate analysis of categorical variables was compared using the $\chi^2$ test or Fisher’s exact test, where appropriate. Univariate analysis of continuous variables was performed using the Mann–Whitney U test. Logistic regression analysis was performed to evaluate the associations of multiple different variables with requirements for revision surgery. For each significant independent variable, the odds ratio (OR) and 95% confidence interval were calculated. To identify cut-off values for prediction of revision surgery, receiver operating characteristic (ROC) curves were analyzed and the area under the ROC curve (AUC) was calculated. A $P$-value of <.05 was considered to be statistically significant.

**Ethics**

This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital. All study procedures were performed in accordance with the relevant guidelines and regulations. The requirement for informed consent was waived due to the retrospective nature of the research and anonymity of the data.

**RESULTS**

In total, 188 pediatric patients were enrolled in this study. The average patient age was 15.37 ± 2.24 years. Twenty-four patients (12.8%) received revision surgery. Patients with revision surgery were younger than those without revision surgery ($P = .004$). There was no significant difference in sex or affected side between the two study groups (Table I).

Univariate analysis showed a significantly higher mean Lund-Mackay score on preoperative CT in patients with revision surgery than in those without revision surgery ($P < .001$). Patients with previous adenoidectomy, nasal polyps, or comorbid asthma did not show significantly higher rates of revision surgery. Although nasal allergy did not have a statistically significant impact on ESS outcomes, patients with nasal allergy were more likely to have revision surgery than those without nasal allergy ($P = .072$). Forty-eight patients underwent ESS using an intraoperative navigation system, and none received revision surgery ($P < .001$) (Table I).

Multivariate logistic regression analysis showed that nasal allergy and higher Lund-Mackay score on preoperative CT were negative prognostic factors for revision surgery (OR = 6.258; $P = .010$ and OR = 1.658; $P = .043$, respectively), while older age was a positive prognostic factor (OR = 0.702; $P = .018$) (Table II).

The cut-off points of 15.68 years of age and mean Lund-Mackay score of 10.5 showed the best predictive power for revision surgery after ESS (sensitivity = 0.56 and 0.63, specificity = 0.75 and 0.74, respectively); the respective AUCs were 0.676 and 0.742 (Fig. 2).

**DISCUSSION**

Pediatric CRS is a common disorder that carries significant morbidity. The associated signs and symptoms

**TABLE I.**

<table>
<thead>
<tr>
<th>Clinical Characteristics of Patients With and Without Revision Surgery.</th>
<th>Revision surgery (n = 24)</th>
<th>No revision surgery (n = 164)</th>
<th>$P$ value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>14.16 ± 2.41</td>
<td>15.54 ± 2.17</td>
<td>.004*</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>18/24 (75%)</td>
<td>71/164 (43%)</td>
<td>.760</td>
</tr>
<tr>
<td>Affected side (bilateral)</td>
<td>22/24 (92%)</td>
<td>150/164 (91%)</td>
<td>.973</td>
</tr>
<tr>
<td>Nasal polyps</td>
<td>21/24 (88%)</td>
<td>139/164 (85%)</td>
<td>.724</td>
</tr>
<tr>
<td>History of asthma</td>
<td>0/24 (0%)</td>
<td>3/164 (2%)</td>
<td>1.000</td>
</tr>
<tr>
<td>Phadiatop positive</td>
<td>11/18 (61%)</td>
<td>40/104 (38%)</td>
<td>.072</td>
</tr>
<tr>
<td>Serum IgE (KU/L)</td>
<td>114.57 ± 125.92</td>
<td>176.84 ± 304.19</td>
<td>.413</td>
</tr>
<tr>
<td>History of adenoidectomy</td>
<td>1/24 (4%)</td>
<td>17/164 (10%)</td>
<td>.335</td>
</tr>
<tr>
<td>Lund-Mackay score‡</td>
<td>10.75 ± 1.34</td>
<td>9.17 ± 1.91</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Eosinophilia§</td>
<td>1/24 (4%)</td>
<td>7/155 (5%)</td>
<td>.938</td>
</tr>
<tr>
<td>Navigation assistance</td>
<td>0/24 (0%)</td>
<td>48/164 (29%)</td>
<td>&lt;.001*</td>
</tr>
</tbody>
</table>

Data are represented as mean ± standard deviation.

* $P < .01$
†Mann-Whitney U test for continuous variables; $\chi^2$ test and Fisher’s exact test for categorical variables.
‡Lund-Mackay score was calculated as total score divided by two in the bilateral ESS cases.
§Eosinophilia was defined as eosinophil count for more than 7% of the circulating leukocytes.

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Fig. 1. Algorithm for identifying study cohorts. ESS = endoscopic sinus surgery.

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Laryngoscope 00: 2019

Wu et al.: Outcomes of Pediatric CRS Underwent ESS
and their levels of severity may vary according to patient age. Notably, CRS has a great impact on the quality of life and results in psychological burdens on patients’ parents, as well as substantial economic costs. ESS is reserved for treatment of medically recalcitrant CRS. Although ESS has shown promising results with respect to improvement in sinonasal symptoms, the recurrence rate and necessity for revision surgery are unclear. Ramadan reported that revision sinus surgery was performed in 13.1% (23/176) of pediatric patients who had previously undergone primary ESS at a tertiary children’s referral center between 1993 and 2005. We also conducted a search for revision ESS in pediatric patients in the Taiwan National Health Insurance Research Database. Between 2000 and 2013, 9.7% (39/401) children had undergone ≥2 ESS procedures (Suppl. I). This slightly lower revision rate is reasonable, since the data were retrieved from all health care units nationwide. In the present study, revision surgery was performed in 12.8% (24/188) of the patients. These results were similar to those of prior studies, which suggests that our results represent the real-world status of children in Taiwan.

As patient age increases, the need for revision surgery decreases. In ROC analysis, a cut-off point of 15.68 years of age showed the best predictive power for revision surgery after ESS (sensitivity = 0.56, specificity = 0.75). This could be explained in several ways. All paranasal sinuses are present in some form in a newborn, but different sinuses undergo growth during specific periods. Older children demonstrate more mature sinus growth and better surgical

**TABLE II. Multivariate Logistic Regression Analysis of the Factors Associated With Revision Surgery of Pediatric Chronic Rhinosinusitis.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>β</th>
<th>SE (β)</th>
<th>Wald χ²</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>0.702</td>
<td>0.523–0.942</td>
<td>-0.354</td>
<td>0.150</td>
<td>5.573</td>
<td>.018*</td>
</tr>
<tr>
<td>Gender</td>
<td>1.431</td>
<td>0.409–5.008</td>
<td>0.359</td>
<td>0.639</td>
<td>0.315</td>
<td>.575</td>
</tr>
<tr>
<td>Polyps</td>
<td>1.877</td>
<td>0.156–22.630</td>
<td>0.630</td>
<td>1.270</td>
<td>0.246</td>
<td>.620</td>
</tr>
<tr>
<td>Phadiotop</td>
<td>6.258</td>
<td>1.558–25.136</td>
<td>1.834</td>
<td>0.709</td>
<td>6.682</td>
<td>.010*</td>
</tr>
<tr>
<td>Serum IgE</td>
<td>0.997</td>
<td>0.992–1.002</td>
<td>-0.003</td>
<td>0.002</td>
<td>1.547</td>
<td>.214</td>
</tr>
<tr>
<td>Adenoidectomy</td>
<td>0.280</td>
<td>0.017–4.543</td>
<td>-1.274</td>
<td>1.422</td>
<td>0.803</td>
<td>.370</td>
</tr>
<tr>
<td>Lund-Mackay score</td>
<td>1.658</td>
<td>1.016–2.705</td>
<td>0.506</td>
<td>0.250</td>
<td>4.098</td>
<td>.043*</td>
</tr>
<tr>
<td>Eosinophilia</td>
<td>0.429</td>
<td>0.023–8.145</td>
<td>-0.846</td>
<td>1.502</td>
<td>0.317</td>
<td>.573</td>
</tr>
<tr>
<td>Constant</td>
<td>0.055</td>
<td>-2.909–3.744</td>
<td>-2.909</td>
<td>3.744</td>
<td>0.604</td>
<td>.437</td>
</tr>
</tbody>
</table>

*P < .05
CI = confidence interval.

![Fig. 2. The cut-off points of 15.68 years of age (A) and mean Lund-Mackay score of 10.5 (B) showed the best predictive power for revision surgery after ESS (sensitivity = 0.56 and 0.63, specificity = 0.75 and 0.74, respectively); the respective AUCs were 0.676 and 0.742. AUC = area under the curve; ESS = endoscopic sinus surgery.](http://www.laryngoscope.com)
field visibility during the operation. In addition, they cooperate better during postoperative wound care, including debridement of the nasal wound crust and cleansing of operative wounds in the outpatient department, as well as sinus irrigation at home. In the 1990s, animal studies in piglets suggested that ESS could lead to interruption of facial growth.

Although there was insufficient evidence that ESS actually affected facial growth in children, surgeons tended to be more conservative in performing ESS in younger children. Moreover, younger children have more immature immune systems and are likely to experience upper respiratory tract infections, which could result in recurrent and chronic sinusitis. In a prospective study of pediatric patients with upper respiratory tract symptoms, Nguyen et al. noted that younger age was the single most important risk factor associated with chronic sinusitis. These factors could lead to the increased rate of revision surgery in younger children who underwent ESS.

Patients with positive aeroallergen tests had higher rates of CRS recurrence after ESS and required revision surgery in our study. This result was reasonable and consistent with the previous literature. Inhalant allergies contribute to many comorbidities, including allergic asthma, atopic dermatitis, allergic conjunctivitis, rhinosinusitis, allergic ear diseases, and allergic laryngeal manifestations. There is evidence that allergic rhinitis is an inflammatory instigator or exacerbating factor for CRS. In addition, allergic rhinitis has a negative impact on recovery from surgery (ESS). Children with a family history of atopy or asthma who attend daycare in the first year of life have a 2.2-fold increased odds of physician-diagnosed sinusitis, compared to that in children who do not attend daycare. This evidence emphasizes the importance of controlling allergic rhinitis after ESS; thus, long-term follow-up care is necessary in these patients.

The Lund-Mackay staging system was developed to quantify the extent of inflammation present in the sinus mucosa and to act as an inclusion criterion for research studies. Importantly, the score is not meant to be used as a cut-off point for surgery, but rather as a tool that can be paired with physical examination findings and symptom severity to make treatment decisions. Increased Lund-Mackay score has been correlated with the need for revision surgery in adult patients with CRS. Similarly, the revision rate after initial ESS was significantly higher in pediatric patients with increased Lund-Mackay scores in the present study. Notably, the Lund-Mackay score increased with increasing grade of polyposis and multiple sinus involvement, which may both increase the difficulty and complexity of the operation. This correlation could serve as helpful information in preoperative counseling with respect to the possibility of revision surgery.

There was no correlation between asthma and revision surgery in the present study. Furthermore, there were no significant differences in the occurrence of eosinophilia or total serum IgE level between the two study groups. This suggests that infection and type 1 inflammation, rather than type 2 inflammation, may be predominant in Asian pediatric patients with CRS. Zhang et al. noted that, although Western nations exhibit a type 2 signature in approximately 80% of nasal polyps, this might be between 20% and 60% in China and Korea or Thailand, respectively. These differences may greatly influence postoperative treatment. Future studies on endotypes of pediatric CRS are needed.

There are several limitations that warrant consideration in this study. First, it was a retrospective study; thus, missing data, loss to follow-up, inclusion of different surgeons, and lack of clinical history were unavoidable complicating factors. Second, an intraoperative navigation system was installed in 2009, but did not become popular until 2011 in our institute. Although none of the 48 patients who underwent operation with the assistance of intraoperative navigation system had revision surgery, the sample size was small. Therefore, the role of an intraoperative navigation system in preventing disease recurrence and revision surgery remains unsettled. Third, information regarding clinical microbiology was not available for most patients in this study. Preoperative long-term use of antibiotics could lead to the false-negative results in microbial analyses. Further investigations regarding the impact of microbes with post-ESS disease recurrence are needed. Finally, this study was a retrospective case-control design. A large-scale prospective study is thus needed for more information.

**CONCLUSION**

Our study analyzed prognostic factors related to revision surgery in 188 pediatric patients with ESS, the largest cohort to date. With improvements in surgical techniques and equipment of ESS, more procedures are performed in children. Knowledge of the risk for revision surgery is important. We found that patients with younger age, nasal allergy, and higher Lund-Mackay score on preoperative sinus CT had worse outcomes. These patients may need longer follow-up periods after surgery. During preoperative consultation, the increased possibility of recurrence and potential for revision surgery should be addressed.

**ACKNOWLEDGMENTS**

The authors thank the statistical assistance and wish to acknowledge the support of the Maintenance Project of the Biostatistical Consultation Center at Chang Gung Memorial Hospital for study design and monitoring, as well as data analysis and interpretation. Funding for this project was provided by grants from Chang Gung Memorial Hospital, Taiwan (CMRPG3G0671, CLRPG2G0082).

**AUTHOR CONTRIBUTIONS**

PWW and TJL designed the study. Chien-Chia Huang, YH, Chi-Che Huang, and PHC contributed to collection of data. Chien-Chia Huang and YSL analyzed the data. PWW and SWY wrote the paper with input from all authors.

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