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Research Article

Correction of Mouth Breathing Reduces Exercise Induced Bronchospasm in Adults and Children

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Abstract

Introduction: The premise of this study is that conversion from mouth breathing to nasal breathing will reduce or eliminate the symptoms of exercise-induced bronchospasm in most of the affected patients.

Methods: This is a prospective, single arm, non-blinded study involving 50 patients aged 7-64 years who mouth breath during exercise and have symptoms of exercise-induced asthma. All patients underwent nasal surgery to include uncinectomy, anterior ethmoidectomy, bilateral inferior turbinate reduction, nasal swell body reduction and septoplasty and adenoidectomy as indicated. Pre and 3-month post-surgery symptom scores were obtained using NOSE and SNOT-22 scores for Sino-nasal symptoms and the Mini Asthma Quality of Life Questionnaire (Mini-AQLQ) and Exercise-Induced Bronchoconstriction Survey (EIBS) for bronchospasm symptoms scores. The primary outcome measure is the change in the symptom scores of the 4 questionnaires after nasal surgery. Secondary outcome is the correlation between the sino-nasal outcome and bronchospasm symptom scores. Wilcoxon signed rank test and Pearson correlation tests were done using SPSS software.

Results: 33 patients completing the survey; 16 male, 17 female, ages 8-59 (Mean 30 SD 14.8). There is a statistically significant improvement in all 4 metrics after nasal surgery: EIBS ($p < 0.001$), Mini AQLQ ($p < 0.001$), SNOT-22 ($p < 0.001$) and NOSE ($p < 0.001$). Pearson Correlation testing indicated a statistically significant positive correlation of symptom improvement on EIBS and Mini AQLQ scores with the SNOT-22 and NOSE scores.

Conclusions: Surgical correction of mouth breathing can reduce and/or eliminate symptoms of exercise induced bronchospasm in all ages. There is also a statistically significant correlation between mouth breathing due to nasal obstruction and exercised induced bronchospasm.

Keywords: Mouth Breathing; Bronchospasm; Adults; Children

Introduction

Exercise and sport activities are beneficial to maintain a healthy life and are common among many adults and children. During exercise, proper nasal breathing is important for both enjoyment and performance. However, in the presence of nasal obstruction, mouth breathing bypasses the nose and deprives the inspired air from being filtered, warmed and humidified by the nasal mucosa [1]. Therefore, these important nasal functions do not occur when nasal obstruction leads to mouth breathing [2]. This process is exacerbated during exercise and consequently a fair number of people who mouth breath during exercise (both asthmatics and non-asthmatics) develop significant pulmonary symptoms akin to asthma: chest tightness, cough, wheezing, shortness of breath or voice change. This condition is called exercise induced bronchoconstriction or EIB.

Mangla., *et al*. found that nasal breathing is important in preventing exercise induced bronchoconstriction compared to mouth breathing [3], and Izuhara Y., *et al*. found that mouth breathing can independently increase the morbidity of asthma [4]. Nasal obstruction has many causes such as nasal valve narrowing, septal deviation, enlarged turbinates and swell bodies, nasal masses, nasal mucosal disease like chronic sinusitis and allergic rhinitis, and nasal polyps.

EIB is defined as acute airway narrowing occurring because of exercise and can affect chronic asthmatics and non-asthmatics alike.[5.] EIB was recognized in 1960 when it was noticed that some asthmatic patients had reversable decrease of their forced expiratory volume (FEV1) when exercising for 10-15 minutes [6] and was called exercise induced asthma [7]. In 1970 this term was changed to exercise induced bronchoconstriction EIB [8,9]. EIB symptoms can start immediately or 10-15 minutes after starting exercise and subside within approximately 60 minutes [9].

The prevalence of EIB is 5-20% in the general population [10], and it is greater in high-performance athletes than in the general population owing to prolonged inhalation of cold, dry air along with the increase in air pollution [9,11]. EIB affects a patient's ability to exercise and negatively impacts their quality of life [12] by often depriving them from participating in the sport they love. For many patients, EIB is a challenging health issue that compromises their performance, limits their choice of exercise, and often requires the use of bronchodilators during sport. The *osmotic theory* helps explain why inhalation of dry unprepped air triggers EIB and supports our theory that re-establishing nasal breathing will improve EIB.

The osmotic theory states that increased ventilation of the lower airways by dry, cold and unfiltered air during exercise causes more dehydration and irritation of the lower airways, which in turn creates a hyperosmolar environment. This consequently triggers mast cell degranulation of mediators such as leukotrienes, prostaglandins, histamine, and tryptase which consequently initiate smooth muscle contraction and inflammation of the airway - the hallmark of EIB [13]. Creating a hyperosmolar environment in the lower airways by using hyperosmolar agents such as mannitol can induce EIB without the need for exercise.

EIB is suspected by self-reported bronchoconstriction symptoms during or after exercise and confirmed by objective measures like spirometry during or after exercise and the reversibility of airway obstruction by bronchodilators [13].

Typical symptoms of EIB include wheezing, shortness of breath, dyspnea, cough, or chest tightness during or after exercise. These symptoms usually occur during strenuous exercise and peak about five to 10 minutes after exercise. Additional symptoms include fatigue, feeling out of shape, feeling unable to keep up with peers, and abdominal discomfort [11].

When the patient experiences the previously mentioned symptoms during exercise, EIB should be considered, however a proper diagnosis of EIB should include changes in pulmonary function tests induced by exercise. A greater than 10% reduction in Forced Expiratory Volume in 1 second (FEV1) after exercise compared to their baseline at rest is considered diagnostic of EIB. EIB severity can be graded based on the percent change in FEV1: Minor (>=10% but< 25%), Moderate (>=25% but <50%), and severe (>=50%) [5]. Alternatively, substitutes for exercise such as eucapnic voluntary hyperpnea, hyperventilation, and hyperosmolar aerosols (4.5% saline or dry powder mannitol) can be used to test for EIB in lieu of exercise.

EIB should be differentiated from the following: Exercise-induced laryngeal dysfunction, Exercise-induced hyperventilation, Obstructive/Restrictive lung disease, Exercise-induced anaphylaxis, cardiovascular-pulmonary-gastrointestinal disease-exertional GERD, and psychological causes. The most effective pharmacologic treatment of EIB is Beta-2 agonists before exercise or for relief once the symptoms start. Other treatments include mast cell stabilizers and leukotriene inhibitors. Non-pharmacologic therapy such as warming-up before exercise can help reduce the severity of EIB [13]. However, the best treatment is one that addresses the root cause of EIB, which is to relieve nasal obstruction and eliminate mouth breathing.

This study is the first of its kind to evaluate the reversibility of EIB after relief of nasal obstruction and elimination of mouth breathing in adults and children who exercise regularly. Currently, the main treatment for EIB is the use of bronchodilators before, during, and/or after exercise [13]. This study will confirm the importance of nasal breathing during exercise and minimize the over treatment and misdiagnosis of "asthma" in these patients.

Methods

Study design

Prospective IRB approved non-blinded, non-controlled single arm study involving 50 patients with nasal obstruction and EIB evaluated at our institution who underwent corrective upper airway surgery between 5/2023-6/2023.

Inclusion and exclusion criteria

Inclusion criteria: All willing males and females aged 7-64 years, of all ethnicities, asthmatic or non-asthmatic, diagnosed with EIB or with history of EIB symptoms who also have nasal obstruction and mouth breathing during exercise.

Exclusion criteria: Males and females < 7 years and > 65 years, cognitively impaired patients, pregnant or lactating women, prisoners, and critically ill patients.

Treatment protocol

Patients with nasal obstruction confirmed by history, physical exam, and CT imaging of the sinuses requiring upper airway surgery were screened for symptoms of EIB and were consented in writing for participation in the study.

They were provided by 4 baseline questionnaires

- **EIB symptom score:** (A non-validated questionnaire); developed by the research team based on the definition of EIB, and included 5 symptoms, each with the following severity scale: absent, mild, moderate, and severe, and included the type of exercise, the duration the patient can continue exercising after the onset of EIB symptoms, and the average duration of exercise (Figure 1).
- **Sino-nasal outcome test (SNOT-22):** A validated outcome metric to assess sino-nasal symptoms.
- **Nasal Obstruction and Septoplasty Effectiveness Scale (NOSE score):** a validated outcome metric to assess nasal patency.
- **MiniAQLQ (mini asthma quality of life questionnaire):** A validated questionnaire[14] to assess QoL issues related to EIB and asthma.

Questionnaires were filled by the patients or their legal guardian before surgery, and 4-5 months after recovery from surgery. The surgery included a combination of the following: septoplasty, endoscopic sinus surgery, inferior turbinate reduction, cryotherapy, nasal swell body reduction, tonsillectomy and adenoidectomy. (Table 1) After surgery, patients were asked not to use their rescue inhaler before or during exercise unless it was necessary, and to record when doing so.

- **Primary outcomes:** Change in the EIB symptom score and MiniAQLQ score after upper airway surgery compared to baseline.
- **Secondary outcome:** The correlation between the change in EIB symptom score and MiniAQLQ and the change in the SNOT-22 and NOSE scores after upper airway surgery.

Data collected

The following items were assessed: age, gender, type of upper airway surgery, the need to use bronchodilator after or during exercise, type of exercise, the duration the patient can continue exercising after the onset of EIB symptoms, the presence of accompanying atopy, asthma, LPR, and the average daily exercise duration were assessed before and after surgery.

The mean score for all items of MiniAQLQ was calculated and a difference of > 0.5 (range: 0.42-0.58) was considered significant, and it was further subcategorized as follows

- A difference of 0.42-0.58 on the 7-point scale was considered minimal; a difference of 0.77-1.51 is considered moderate; and a difference > 1.5 represented a large change [15,16]. (Table 2)
- The nose surgery was considered successful if the NOSE score dropped >40% after surgery. [20] The minimal clinical important difference in SNOT-22 was 9 [21].

SPSS V29.0.0.0 was used to perform the statistical analysis of the study

- Wilcoxon signed-rank test was used to study statistical significance of change in SNOT-22, NOSE, EIB and total MINIAQLQ before and after surgery. Bivariate correlation between the change in EIB score, MiniAQLQ score, SNOT-22 and NOSE score after surgery was also done.
- Anova test was used to study the differences between subgroups (Adult vs Kids, Asthmatic vs non-Asthmatic, Atopic vs non-atopic, etc.) McNemar Test and Chi-square test were used to analyze inhaler usage before and after surgery.

Results

A total of 50 patients completed the study: there were 14 children (28%), and 36 adults (72%); 27 males (54%) and 23 females (46%); 24 asthmatics (48%) and 26 non-asthmatics (52%). The mean age was 28.48 years (SD 13.9).

Exercise induced asthma questionnaire

Name of patient: DOB:

Who is completing the questionnaire? Please check one of the following:

_____ You are an adult participant.

_____ You are the parent or guardian of a child in this study.

_____ You are the child who underwent the sinus procedure.

Before surgery: 3 months after surgery: 6 months after surgery:

1. Do you get the following symptoms 10-15 minutes after starting your exercise?

Symptoms	Severity of the symptoms			
	None (0)	Mild(1)	Moderate (2)	Severe (3)
Shortness of breath				
Chest tightness				
Cough				
Hoarse voice or stridor/Throat tight				
Wheezing				

2. When do you get these exercise related chest symptoms. *Check all that apply*
   a. all year around ☐
   b. on certain seasons? ☐ Spring ☐ Summer ☐ Fall ☐ Winter
3. What kind of exercise (sport) do you usually do?
4. How long can you continue doing the exercise after these symptoms start in minutes:
5. Do you use any medication, during or immediately after your exercise? Yes/No
6. If Yes: what are the medications, when (during ,or after)do you use them ,and how often ?
7. How long is the duration of you exercise in minutes:

Figure 1: EIB symptom questionnaire.

Name of procedure	Number of patients	Percentage of patients
Bilateral inferior turbinate reduction	50	100%
Endoscopic sinus surgery	49	98%
Septoplasty	49	98%
Nasal swell body reduction using radiofrequency ablation	33	66%
Cryotherapy of posterior nasal nerve	19	38%
Adenoidectomy	8	16%
Tonsillectomy	2	4%
Nasal valve repair	2	4%

Table 1: Breakdown of surgical procedures.

Change of mean AQLQ	Category	Number of patients	Percentage
-	Worse	5	10%
0.42<	no change	13	26%
0.42-0.58	minimal significant change	5	10%
0.77-1.51	Moderate significant change	16	32%
>1.5	large significant change	11	22%
Total		50	100%

Table 2: Changes in Mini-AQLQ after nasal surgery.

Based on the mean AQLQ[15], the percentage and degree of improvement is shown in table 2.

When comparing the improvement in EIB after surgery regarding age groups: 66.7% of adults and 64.3% of minors improved, and there was no statistical difference in the ANOVA test between the 2 age groups.

The percentage of patients who had improved with Cryotherapy was greater than the number of patients who improved and did not receive Cryotherapy (Table 3). This difference was statistically significant via ANOVA ($p < .05$).

EIB Improvent * underwent Cryotherapy Crosstabulation

			underwent Cryotherapy NO	underwent Cryotherapy YES	Total
EIB Improvent	worsened	Count	4	1	5
		% within underwent Cryotherapy	11.4%	6.7%	10.0%
	No change	Count	10	2	12
		% within underwent Cryotherapy	28.6%	13.3%	24.0%
	improved	Count	21	12	33
		% within underwent Cryotherapy	60.0%	80.0%	66.0%
Total		Count	35	15	50
		% within underwent Cryotherapy	100.0%	100.0%	100.0%

Table 3: Improvement after Cryotherapy.

In addition, there is a significant difference in post-op NOSE score improvement between patients receiving Cryotherapy and those who did not ($p < .002$). (Table 4) This did not hold true for SNOT-22 scores.

Interestingly, patients with LPR had less improvement in their EIB questionnaire compared to patients without LPR (Table 5) and this difference between groups was statistically significant per ANOVA testing ($p < .05$).

ANOVA

underwent Cryotherapy

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.921	14	.423	3.232	.002
Within Groups	4.579	35	.131		
Total	10.500	49			

Table 4: ANOVA test of NOSE scores between those receiving Cryotherapy and those who did not.

EIB Improvent * LPR Crosstabulation

			LPR		
			No LPR	Has LPR	Total
EIB Improvent	worsened	Count	1	4	5
		% within LPR	2.8%	28.6%	10.0%
	No change	Count	10	2	12
		% within LPR	27.8%	14.3%	24.0%
	improved	Count	25	8	33
		% within LPR	69.4%	57.1%	66.0%
Total		Count	36	14	50
		% within LPR	100.0%	100.0%	100.0%

Table 5: EIB Improvement with and without the presence of LPR.

By using Wilcoxon Signed Rank Test (a nonparametric test), the changes in mean MiniAQLQ score, total MiniAQLQ score, EIB symptom score, SNOT-22, and NOSE scores before and after nasal surgery were statistically significant ($p < 0.001$). (Table 6-10).

MeanMINIAQLQbefore, MeanMINIAQLQafter

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	50
Test Statistic	1039.500
Standard Error	91.510
Standardized Test Statistic	5.453
Asymptotic Sig.(2-sided test)	<.001

Table 6: Mean Mini-AQLQ.

totalMINIAQLQbefore, totalMINIAQLQafter

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	50
Test Statistic	1041.000
Standard Error	91.501
Standardized Test Statistic	5.470
Asymptotic Sig.(2-sided test)	<.001

Table 7: Total Mini-AQLQ.

EIB Before Surgery, EIB After Surgery

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	50
Test Statistic	74.000
Standard Error	100.226
Standardized Test Statistic	-5.373
Asymptotic Sig.(2-sided test)	<.001

Table 8: EIB questionnaire.

SNOT-22 Before surgery, SNOT-22 After surgery

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	50
Test Statistic	62.000
Standard Error	103.571
Standardized Test Statistic	-5.557
Asymptotic Sig.(2-sided test)	<.001

Table 9: SNOT-22 Scores.

NOSE Before Surgery, NOSE After Surgery

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	50
Test Statistic	15.500
Standard Error	100.453
Standardized Test Statistic	-5.943
Asymptotic Sig.(2-sided test)	<.001

Table 10: NOSE scores.

The duration the patient could continue exercising after the onset of EIB symptoms was increased after surgery and this increase was statistically significant ($p < .001$): (Tables 11 and 12).

Duration of ability to exercise after EIB onset	Number of patients	Percentage
Increased	26	52%
No change	16	32%
Decreased	8	16%

Table 11: Change in exercise tolerance after surgery.

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	50
Test Statistic	469.000
Standard Error	58.457
Standardized Test Statistic	2.934
Asymptotic Sig.(2-sided test)	.003

Table 12: Statistical difference in exercise tolerance.

Inhaler usage during exercise

Based on McNemar Test and Chi-square Test Number of patients requiring a rescue inhaler during exercise before surgery dropped from 22 (44%) to 7 (%14) after surgery (Table 13) and this difference was highly statistically significant (p < .001).

ANOVA showed that children had a statically significant improvement in the average duration of exercise after surgery compared to adults (p < .05); however, there was no difference between the 2 age groups regarding improvement in mean MiniAQLQ, total MiniAQLQ score, and the ability to continue exercise after onset of EIB symptoms after surgery.

Inhaler Usage Before Surgery * Inhaler Usage After Surgery Crosstabulation

			Inhaler Usage After Surgery		
			NO	YES	Total
Inhaler Usage Before Surgery	NO	Count	28	0	28
		% of Total	56.0%	0.0%	56.0%
	YES	Count	15	7	22
		% of Total	30.0%	14.0%	44.0%
Total		Count	43	7	50
		% of Total	86.0%	14.0%	100.0%

Table 13: Inhaler use after nasal surgery.

Both asthmatic and non-asthmatic patients improved equally with respect to Mini AQLQ, EIB symptom score, duration of exercise, and time to onset of symptoms. There was also no difference in outcomes with respect to atopics and non-atopics for each of the same metrics.

Lastly, we compared the average change in NOSE scores between those with an improvement in EIB vs those who did not improve in EIB. We made the same comparison using NOSE scores vs AQLQ scores. In both comparisons, the average NOSE scores for those showing improvement in EIB or AQLQ were statistically better than those who did not show improvement (p < .05).

Discussion

This study evaluated the effects of corrective upper airway surgery on patients with symptoms of EIB; a health issue affecting the quality of life of many patients and preventing them from engaging in the sports they love and achieving their exercise goals.

Our results show that exercise tolerance and EIB symptoms were improved in both adults and children after nasal surgery to a similar degree (p>.05) therefore correcting nasal obstruction is effective in all ages. Most of the outcome metrics we reviewed showed a statistically significant improvement after nasal surgery. These include:

- We found a statistically significant improvement (p < .001) in EIB symptom scores, mean Mini AQLQ scores, and total Mini-AQLQ scores after nasal surgery which supports our premise that treating nasal blockage and eliminating mouth breathing can reduce and improve symptoms of EIB.
- When studying the change in mean AQLQ alone we found 30 patients (60%) had significant improvement, 13 patients (26%) had no impact, and 5 patients (10%) scored worse. These results demonstrate that correcting nasal obstruction and mouth breathing is beneficial for most patients with EIB.
- The increase in the time a patient could continue to exercise after the onset of EIB symptoms was statistically significant overall (p<.05), increasing in 27 patients (52%), remained unchanged in 16 patients (32%) and decreased in 8 patients (16%) after surgery.
- The number of patients with EIB requiring an inhaler during exercise dropped from 22 (44%) before surgery to 7 (14%) after surgery. Thus, 15 patients (30%) no longer needed bronchodilators and after surgery.
- Patients requiring cryotherapy had better outcomes than those not receiving cryotherapy. This suggests that treating allergic and non-allergic rhinitis is an important component of improving the nasal airway, especially in athletic patients.
- NOSE scores, a validated subjective metric of nasal obstruction, improved most in patients who had better exercise tolerance after surgery. While all NOSE scores improved after surgery, those with a better nasal airway (better NOSE scores) after surgery had better exercise tolerance.
- The average duration of daily exercise for patient before and after surgery increased in 17 patients (34%), did not change in 22 patients (44%), and decreased in 11 patients (22%) after surgery. However, this difference was not statistically significant.

Asthmatics and non-asthmatics both showed similar improvement after nasal surgery suggesting a similarity between the etiology of asthma and EIB.

Tonsillectomy and adenoidectomy were rarely performed (<8%) demonstrating that most of the upper airway resistance lies within the nasal cavity and this area should be the main target of surgery for EIB.

We questioned why more patients did not improve after nasal surgery and if there is something unique about this group? When reviewing those patients who did not improve as much in EIB or AQLQ as the others, we noted a few potential explanations.

Most of the patients showing less improvement in EIB and/or AQLQ also reported laryngopharyngeal reflux disease (LPR). We then reviewed the data between those patients with LPR and those without and found that more patients with LPR had less improvement in EIB, and more of these patients also had their EIB symptoms worsen after surgery when compared to patients without LPR. This difference was statistically significant as shown in Table 5 and implies there may be a significant role for LPR in the etiology of EIB. Improving the nasal airway allows more air to reach the lower airway. However, if the lower airway (from the larynx to the carina) is irritated from gastric acid, this increased airstream may cause more irritation to the lower airway mucosa triggering EIB. The patients in our study who reported LPR were under treatment for it, but the effectiveness of their treatment was unknown. Weiler et al.[18] mentioned in their paper that LPR can be a cause of EIB and is consistent with our findings as well.

Another important factor causing persistence of EIB and mouth breathing after nasal surgery is the fact that mouth breathing can become habitual for some. Thus, despite a great nasal airway after corrective surgery, some patients must relearn how to breathe through their nose again. The incidence of habitual mouth breathing after proper nasal surgery is not known. This is primarily because this issue has never been studied before. With a more contemporary emphasis on the correction of mouth breathing because of the adverse effects it has on many other health concerns, we should be able to determine the incidence of habitual mouth breathing in the near future.

Another potential explanation is the finding that the average NOSE scores for those who improved their EIB and/or AQLQ was significantly better than those who did not improve. This supports our clinical experience and the importance of obtaining a great airway via surgery. However, some patients have very challenging nasal issues such as extreme narrow lateral nasal walls, vasomotor rhinitis and/or allergic rhinitis. These conditions, alone or in combination, usually results in a lower post-op NOSE score. R Bronstein et al found that 47% of children with EIB had allergic rhinitis and only 5% did not, which again emphasizes the challenges one faces when trying to improve the nasal airway in these patients [17].

As shown in the study by Mangla[3] there is a beneficial effect from nasal breathing in preventing EIB symptoms compared to mouth breathing. Our study fully supports this finding and furthermore shows that if you can improve nasal breathing in these patients, most of them will show a reduction or elimination of the symptoms of EIB.

The weakness of the study is that it was based primarily on subjective questionnaires rather than objective measures (such as FEV1 before and after exercise). The logistics and resources required for the latter are overwhelming and not within our scope. Yet our study shines significant light on the clinical nature of EIB and provides a path for future studies combining both objective and subjective data in defining the role of upper airway nasal surgery in treating EIB.

Conclusions

Surgical correction of mouth breathing during exercise can reduce and/or eliminate symptoms of exercise induced bronchospasm in all ages. There is a statistically significant correlation between mouth breathing due to nasal obstruction and exercised induced bronchospasm. The likelihood of improvement correlates with the patient's improvement in NOSE scores.

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