Costal Cartilage Lateral Crural Strut Graft vs Cephalic Crural Turn-in for Correction of External Valve Dysfunction

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The nasal valve is the narrowest point for airflow. First described in 1903, it is divided into an internal nasal valve (INV) and an external nasal valve (ENV). The ENV, anterior to the INV, is bound medially by the caudal nasal septum and medial crus of the lower lateral cartilage and laterally by the lateral crus of the lower lateral cartilage and the fibrofatty tissue of the alar rim. The floor of the ENV consists of the nasal sill. In a normal physiological state, the INV is the site of greatest airway resistance. The diameter of the nasal cavity is the most important variable in determining nasal airflow, explained by Poiseuille’s Law \( Q = \frac{\pi Pr^4}{8\eta l} \), as minor radius decreases can have a large effect on flow. Additionally, acceleration of air through the ENV results in a decrease in intranasal pressure, a phenomenon described by Bernoulli.1 The inward force generated by this pressure gradient is balanced by the supporting cartilaginous and fibrous components, maintaining patency of the ENV and allowing air entry into the nose. In cases of ENV dysfunction (EVD), the ENV becomes the restriction point, and the lateral structures are held directly only by the strength of the cartilage and indirectly held by ligamentous attachments to the piriform aperture. External nasal valve dysfunction results when the ENV is narrower and obstructs normal nasal airflow. Reduced airflow leads to symptoms such as congestion, pressure, and fullness in the nose. Classification of EVD may be static or dynamic. Static ENV stenosis causes a constant obstruction that results from a greater intranasal pressure being required to facilitate airflow.4 Dynamic ENV collapse causes more noticeable ob-
Two Procedures for the Correction of External Valve Dysfunction

Figure 1. Lateral Crural Cephalic Turn-in Maneuver

A Preoperative photograph

B Postoperative photograph

Figure 2. Lateral Crural Underlay Strut Graft Using Costal Cartilage

A Preoperative photograph

B Postoperative photograph

Structive symptoms on inspiration at lower transmural pressures. These types of dysfunction are not mutually exclusive; the narrower ENV at baseline may produce a greater Bernoulli effect, which results in ENV collapse. Surgery to correct EVD aims to overcome the intranasal pressure changes and prevent nasal obstruction. Techniques may vary widely but typically either increase rigidity and/or diameter.3,4

The aim of this study was to evaluate the effectiveness of 2 commonly employed techniques of correcting EVD: cephalic crural turn-in maneuver and costal cartilage lateral crural strut grafts.

Methods

A clinical surgical cohort was studied. Patients complaining of nasal obstruction and with clinically diagnosed EVD who were undergoing functional reconstructive rhinoplasty were recruited. The diagnosis of EVD free of rhinitis symptoms or lack of relief of obstruction to intranasal corticosteroid was made clinically by the patients’ clinical history along with an endoscopy and/or anterior rhinoscopy that demonstrated a medially displaced lateral crus with dynamic collapse on mild to moderate inspiratory effort.5 Patients underwent either a lateral crural cephalic turn-in alone (Figure 1) or a lateral crural underlay strut graft using costal cartilage surgery (Figure 2). All surgical interventions were performed by a single surgeon (G.N.M.) and the technique was chosen on clinical grounds and surgeon preference.

The data was collected prospectively as part of routine care for patients undergoing rhinoplasty surgery. All patients provided written informed consent. This study was approved by the St Vincent’s Hospital Human Research Ethics Committee.

Surgical Intervention

Open structured rhinoplasty for correction of clinically diagnosed EVD included concomitant correction of septal deformities6 and concomitant turbinoplasty.7 Cosmetic alteration was always an additional surgical aim.

For the patients undergoing primary surgical intervention, the lateral crura were augmented by a cephalic turn-in maneuver. The procedure requires a scoring incision made parallel to the caudal edge of the lateral crura at approximately the mid cephalic-caudal distance to allow the cephalic portion to fold inwards under the caudal portion. These are then sutured together providing additional support (Figure 1).
For the patients undergoing revision, the lateral crura were augmented or replaced with underlay strut grafts using costal cartilage. Approximately 5 cm of costal cartilage was harvested from the right fifth to eighth rib, and the perichondrium was removed and used to assist in general cosmetic alteration. The harvested cartilage was remodeled and either replaced or provided underlay support to the lateral crus. The lateral crural strut grafts were designed, with some patient variability, to be 1.5 mm thick and 25 mm long with a tapered width (8 mm lateral to 3 mm medial). The lateral edge of the strut graft is inserted into a pocket formed lateral to the piriform aperture in a more caudal orientation. The medial edge lies under the domes for a full bridge of the valve (Figure 2).

**Assessment of Surgical Outcome**

Five tools were used to assess patient-perceived benefit, 3 objective measures of the nasal airway (in the postdecongested state), and a cosmesis score as perceived by the patient were used as assessments of the surgical outcomes. These outcomes were assessed at baseline and then again at least 6 months postoperatively.

**Patient-Reported Nasal Function**

Five tools were used to assess patient-perceived benefit. A visual analog scale (VAS) asked patients to rate ease of breathing on each side on a scale of 0 mm (not blocked) to 100 mm (totally blocked). A number was then obtained from 0 to 100 for severity of nasal obstruction on each side. A 5-point Likert score was used to assess nasal obstruction from no problem (1) to problem as bad as it can be (5). Additionally, a validated Nasal Obstruction Symptom Evaluation (NOSE) Scale and a 22-Item Sinonasal Outcome Test (SNOT-22) were completed by the patient. A global score of nasal function was assessed on a 13-point Likert scale from -6 (terrible) to 0 (neither good nor bad) to +6 (excellent), with 0 representing neither good nor bad.

**Objective Assessment of Airflow**

Three tools were used to assess objective parameters of nasal breathing. The tests were performed 15 minutes after 0.15 mg of oxymetazoline was applied to each nasal cavity topically. This was to ensure that the structure component of the nose was assessed on the testing day and mucosal factors were minimized. This was performed to try to decrease the contribution of vascular mucosal changes before and after surgical intervention. Collapsibility of the airway was assessed with a nasal peak inspiratory flow (NPIF), which was measured with the patient seated using an In-Check Nasal inspiratory flow meter (Clement Clarke International) with an attached anesthetic mask. A tight seal was ensured without compressing the external nares, and the patient was instructed to take a maximal forced inspiratory effort through the nose with the mouth closed. The best recorded result of 3 attempts was used, according to previous studies. Nasal airway resistance (NAR) was measured by active anterior rhinomanometry with an NR6 rhinomanometer (GM Instruments Ltd) using a fixed reference level of 150 Pa as per international standardization of rhinomanometry. The patient was seated and allowed to rest for 15 minutes prior to testing, which was performed in a climate-controlled room. An airtight anesthetic mask was held by the patient over the nose with the nostril opposite to the testing side sealed. The patient was instructed to breathe smoothly and consistently through the nose with the mouth closed while measurements were recorded. The other side was then tested using the same method. Once both sides were tested, the entire process was repeated again until 2 consistent baseline total NAR measurements were produced.

Minimum cross-sectional area (MCA) was measured with an A1 acoustic rhinometer (GM Instruments). Patients were seated upright and the sound tube was applied to the caudal end of the nostril with the appropriately sized nose piece. Once an airtight seal was established, the patient was instructed to breathe in and hold his or her breath. This was repeated at least 3 times until 2 consistent MCA results were obtained. The process was then repeated for the other side.

**Assessment of Cosmesis**

At baseline and 6 months, global score of nasal cosmesis was assessed by patients on a 13-point Likert scale from -6 (terrible) to 0 (neither good nor bad) to +6 (excellent).

**Statistical Analysis**

To perform statistical analysis SPSS version 21 (SPSS Inc, Chicago) was used. A 2-tailed paired sample t test was used to analyze presurgical and postsurgical values for VAS scores, NOSE scores, SNOT-22 scores, NPIF values, NAR values, and MCA values. All continuous data was assessed as parametric and expressed as mean (SD). Global function, cosmesis, and nasal obstruction scores were ordinal scores and assessed by Kendall’s τ-b.

**Results**

Forty-one patients (21 [61%] female) with a mean (SD) age of 35.38 (12.73) years; (range, 16-62 years) were assessed preoperatively and at a minimum 6 months follow up (median, 6.90 months; range, 6-39 months). Sixteen patients underwent costal cartilage lateral crus strut grafts for correction of EVD, and twenty-five underwent cephalic crus turn-in maneuvers. Sixteen (39%) procedures were revision rhinoplasties. The mean (SD) patient body mass index (calculated as weight in kilograms divided by height in meters squared) was 22.81 (3.30); height, 168.44 (10.83) cm; and weight, 65.29 (14.54) kg.

**Baseline Characteristics Between Groups**

When evaluating the 2 groups at baseline, the costal cartilage lateral crus strut group was older and was made of a greater proportion of males (Table 1). The crus strut group were all undergoing revision rhinoplasty vs all primary rhinoplasty in the cephalic crus turn-in group. The VAS (left), NOSE scores, and the total NAR were higher in the crucual strut group (Table 1).

Nasal obstruction scores were significantly worse in the crus strut group (Kendall’s τ-b = 0.011). Both global scores were also statistically worse in the crus strut group for function (Kendall’s τ-b = 0.006) and cosmesis (Kendall’s τ-b = 0.031).
All patients had significantly improved VAS (both left and right), NOSE, SNOT-22, global function, and cosmesis scores postoperatively (Table 2). The only objective test that statistically improved was NPIF (114.76 [60.48] L/min vs 126.46 [61.17] L/min; \( P = .02 \)).

Effect of Surgical Intervention Between Groups
When evaluating outcomes between the 2 techniques, statistically significant results were found in total NAR and total MCA favoring the crural strut group (Table 3). The nasal obstruction score (Kendall’s \( r \)-b \( P = .18 \)) and global score for function (Kendall’s \( r \)-b \( P = .55 \)) were similar between the 2 groups. Change in global cosmesis score favored the cephalic turn-in group (Kendall’s \( r \)-b \( P = .007 \)). Improved cosmesis was seen in 100% of the cephalic crural turn-in group whereas 75% of the lateral crural strut group reported improvement.

**Discussion**
A variety of surgical options are available to improve nasal airflow in patients with EVD. The underlying pathophysiology is assumed to be resulting from weak or deficient lower lateral crura and their attachment to the piriform aperture. Surgery to correct EVD aims to resist the negative intranasal pressure with subsequent collapse by increasing diameter, rigidity, or both.\(^3,4\) External valve stenosis is often a part of EVD and al-
though the concept of widening the nasal passage to improve patency may appear to be a goal, it may also lead to undesirable cosmesis. Improved rigidity alone may potentially result in the nasal passage becoming stiffer as the primary effect of EVD surgery. A compromise between improving nasal function and preserving or improving cosmesis is often made when performing EVD surgery. Some patients may like an overly narrow or pinched appearance to their lower third, but this may be at the expense of function. In this study, rib or costal cartilage strut reconstruction had a lesser improvement in cosmesis but higher objective improvement in airflow (MCA and NAR). No patient was deemed to have a poor cosmetic result by the authors.

When making the structural components of the ENV more rigid, other components of the lateral nasal wall, such as the internal valve, may be affected. There is no way to isolate the effects of the interventions described, and it is highly likely that the surgical maneuvers affect components of both the internal and external valve. Murakami et al described the cephalic turn-in flap technique, and the need to combine this technique with other maneuvers, such as spreader grafts, has been emphasized by surgeons. Multiple maneuvers is commonplace in rhinoplasty surgery, as patients, especially those undergoing revision, present with a number of problems, and more than 1 surgical technique is applied. It is difficult to isolate improvements due to a single technique, an aspect of rhinoplasty research that is often acknowledged. In this study, the impact of correcting any residual septal deformity or revision of turbinate hypertrophy cannot be isolated. However, these patients were deemed to have EVD as their primary cause of their nasal obstruction on clinical assessment by 2 experienced rhinoplasty surgeons in line with consensus statements, and the correction of septal abnormalities and turbinate reduction was applied consistently across both groups.

Objective outcomes following surgical management of EVD have historically been lacking in the literature and have actually been discouraged or dismissed due to poor correlation with subjective measures. This is in contrast to patient-reported outcomes, which have been deemed more important and correlate well with patient satisfaction. However, improvements in subjective results can align with improved airway outcomes in EVD patients with NPIF being the most robust tool to assess improvement in collapsibility. In this study, we found value in both subjective and some objective airflow measures. Nasal peak inspiratory flow was improved across the entire group as seen in prior study. However, it was only the revision patients in the costal strut group that demonstrated an improvement in MCA (1.10 [0.40] to 1.31 [0.39], P = .02). Previous observation by us has not found that MCA improvements have been a feature of successful interventions but improved resistance to collapsibility (as defined by NPIF). This increase in MCA, while improving function, may come at a cosmesis compromise. The 6-month follow-up was chosen on the clinical assessment that all corrections are structurally sound by 6 months, although some soft-tissue settling may continue to occur and affect the overall results. The postoperative duration was consistent for both groups.

There was an inherent allocation bias in this study. The costal or rib struts were performed on the revision patients with both worse nasal obstruction and cosmesis. This skews the results against the costal strut group, but the results show that costal struts are at least as good as equally even in a more difficult setting. These results are important in the decision-making process, and we now maintain a low threshold for the use of costal cartilage lateral crus strut grafts even in primary cases.

Conclusions

Cephalic crus turn-in and costal cartilage crus strut grafts to correct EVD resulted in reduced collapsibility of the airway as demonstrated by improvements in NPIF and patient-reported benefit. Costal cartilage strut grafts can increase the size of the airway and improve collapsibility but may come with a perceived cosmetic compromise for some patients. Both cephalic crus turn-in and costal cartilage crus strut grafts provide rigidity to the ENV, in primary and revision patients, respectively, and are functionally and cosmetically acceptable options for correction of EVD.
Comparing Methods for Repair of the External Valve
One More Step Toward a Unified View of Lateral Wall Insufficiency

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In the current issue, Barham and colleagues1 present data comparing 2 techniques for repair of external valve dysfunction (EVD). These data represent the latest in a line of new studies designed to examine treatments for EVD using various quality-of-life (QOL) instruments, objective measurements of the nasal airway, physician-derived measurements, or some combination thereof.2 In particular, this study is the latest to include the Nasal Obstruction Symptom Evaluation (NOSE) questionnaire as part of its analysis of patient-reported outcomes.3 Over the past 10 years, the NOSE scale has been a mainstay of many studies of functional rhinoplasty maneuvers.2-5 Barham and colleagues are correct that correlation between objection measures of the nasal airway, clinician findings, and patient-reported findings often do not correlate, as pointed out nicely by Lam et al.6 To that end, they note similar findings in the current study.

The authors point out that static and dynamic EVD are distinct entities that can coexist. Treatment for static EVD involves, first and foremost, expansion of the nasal airway. Treatment of dynamic EVD involves strengthening the wall against the negative pressure generated due to the Bernoulli effect. In addition, improvement of the intranasal space (ie, septolasty, turbinate reduction) will reduce the negative pressure generated. Thus, a 2-pronged approach is recommended for dynamic collapse, aimed at the 2 root causes of collapse: a weak lateral wall structure and negative pressure generated due to a narrow tube.

In the current study, an array of qualitative and quantitative measures were used to compare use of autologous rib for lateral crural grafting with the cephalic turn-in technique in patients undergoing primary rhinoplasty. The comparison of efficacy between the 2 is problematic when the patient groups (primary vs secondary) are so different. Still, the present study adds to our library of studies that examine methods to augment the lateral nasal wall. While multiple authors have studied methods to strengthen the lateral nasal wall, the only consistent measure that we have for comparison across studies is the NOSE questionnaire. The utility of the NOSE questionnaire in evaluation of nasal obstruction is well established, but it lacks any domains for measurement of aesthetic outcome. As noted by the authors, changes in aesthetics of the nose are a very real consequence of functional nasal surgery.

Barham and colleagues7 have used nasal peak inspiratory flow (NPIF) to measure efficacy of treatment of EVD. Given the dynamic nature of the airway in patients with weak lateral nasal walls, static measures of the nasal airway may not give an accurate representation of airway status. A consistent physician-derived evaluation would be of paramount importance for better comparison between studies going forward. One requirement for the creation of a physician-derived scale is a consistent, descriptive nomenclature for the disease process. At Stanford, we have found a newer, more descriptive nomenclature for the EVD to be useful.8 First, we now use the term dynamic lateral wall insufficiency (LWI) rather than “external valve collapse” to unambiguously localize the area at issue. Second, since movement of the soft tissue of the lateral nasal wall can occur anywhere between the nasal bones (fixed structure) and the most inferior soft tissue extent of the lateral nasal wall (the alar rim), we note 2 distinct zones of dynamic LWI. Specifically, we characterize movement of the lateral nasal wall...