Rhinology, 24, 41-47, 1986

Understanding aerodynamics in the correction of the narrow nose

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SUMMARY

Nasal obstruction can be relieved in the prominent and narrow nose by a nasal widening procedure called the "let out" based on the "en bloc" mobilization used in the "push down" rhinoplasty.

Calculations using measurements made on the cadaver show that widening of the angle of the liminal valve and an increased rigidity of the upper lateral cartilage are responsible for the improved airway rather a presumed increase of the cross section of the valve. The associated increase of intranasal velocity provides an aerodynamic explanation for certain phenomenons observed after cosmetic rhinoplasties.

A clinical case is presented and the principles of "en bloc" mobilization are shown by line drawings.

INTRODUCTION

When respiratory obstruction is caused by a prominent and narrow nose, relief can be obtained by widening the nose and lowering the profile using the "let out", a procedure based on the "en bloc" mobilization of the push down rhinoplasty, as illustrated by the patient in Figure 1.

We thought that the relief of the obstruction was the result of an increase of the cross section of the liminal valve, but measurements on the cadaver and use of appropriate engineering formulas showed that this beneficial effect was rather due to an increase of the angle of the valve, and of the rigidity of the upper lateral cartilages, the cross section being indeed smaller by the procedure.

The principle and various clinical applications of the "en bloc" mobilization of the pyramid will be presented and illustrated by line drawings.

The laboratory findings will be discussed to understand the aerodynamic effects of the let out and the cosmetic rhinoplasty.

Surgical principles

The principle of "en bloc" mobilization of the pyramid, used in the "push down"

Paper presented at the 10th Congress of the European Rhinologic Society and 4th ISIAN, Nancy (France), August 1984.

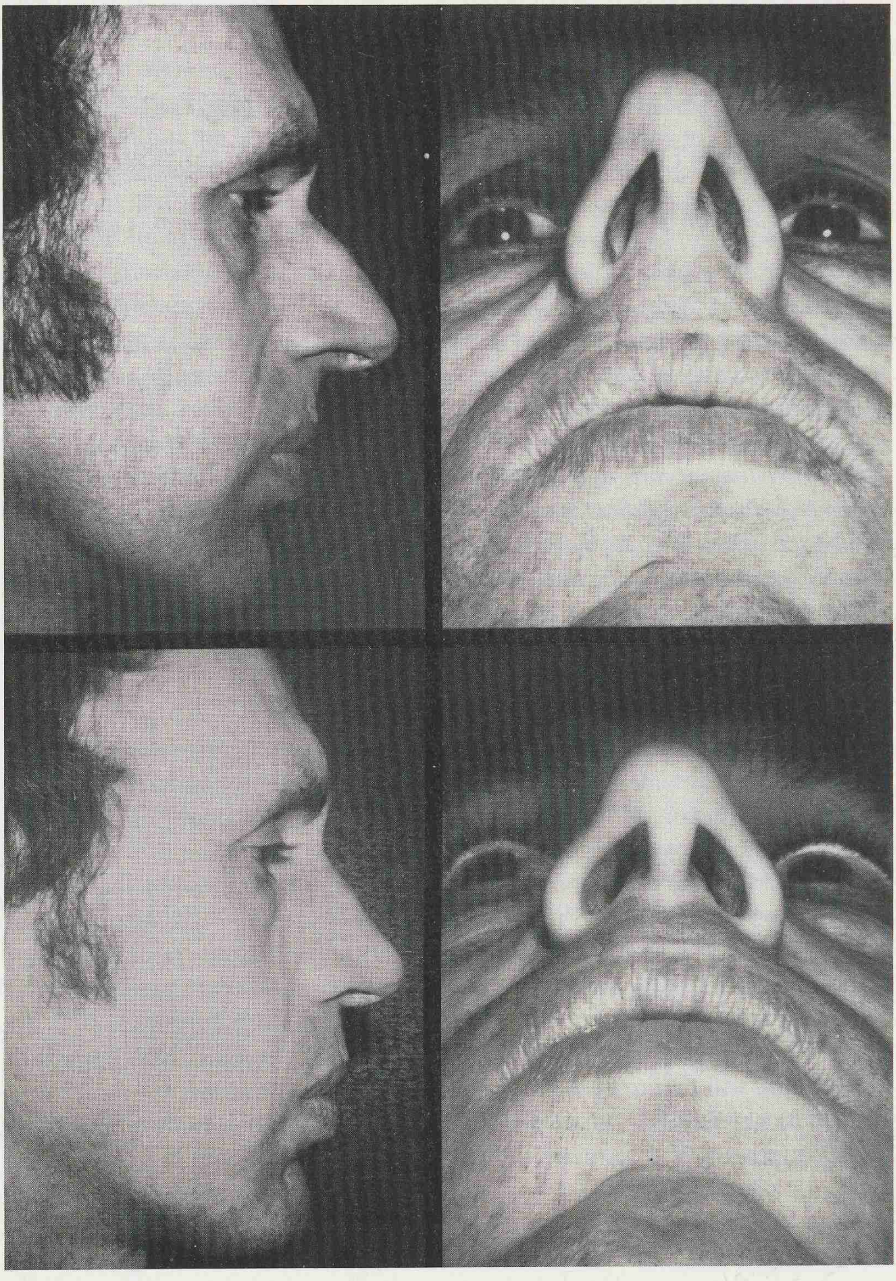

Figure 1. Upper left and right: preoperative profile and base view of patient with a prominent and narrow nose. Lower left and right: profile change and widening of the liminal valve after the "let out" procedure.

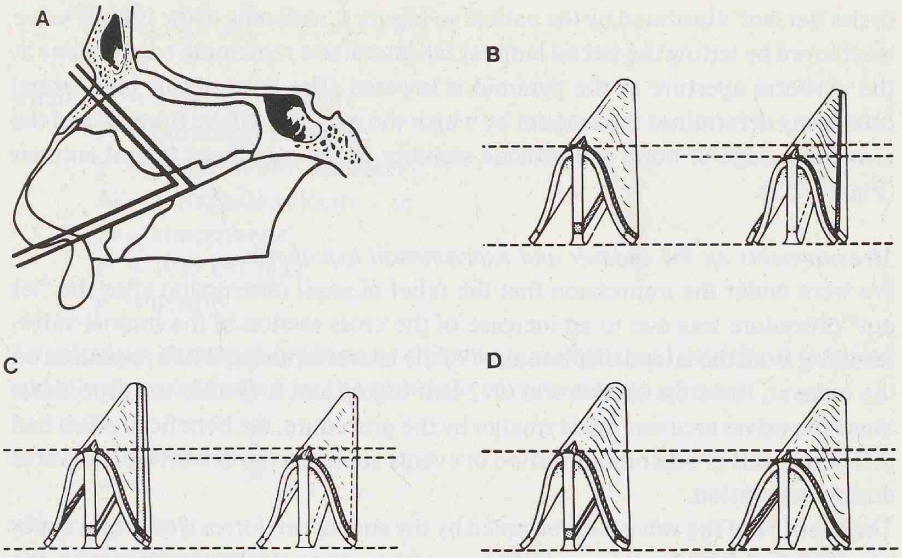

Figure 2. A: double bold lines indicate nasal septum procedures. Changes from B: the "push down". C: the "let down". D: the „let out".

rhinoplasty to lower the profile while preserving the integrity of the dorsum, can be applied to the "let down" and the "let out" to achieve other modifications of the liminal valve. This "en bloc" mobilization is made possible by selective extramucosal exposure of the septum and lateral laminas. Excision of an inferior strip of septal skeleton and vertical osteotomy of the perpendicular plate of the ethmoid will allow vertical displacement of the pyramid, the elevator effect (Figure 2A). Medial, lateral and transverse osteotomies will allow horizontal displacement of the lateral laminas (Figures 2B, C, D).

In the "push down", the profile is decreased by literally pushing the mobilized pyramid into the nasal fossa. The loss of height is equal to the size of the excised strip of septal skeleton (Figure 2B). Because of the inevitable narrowing of the liminal valve, this nasal smalling procedure is used only in normal or slightly wide noses.

When a decrease of profile is desired with preservation of an intact dorsum but with a minimum change of the angle of the liminal valve, the "let down" can be used. In this instance, the profile is decreased by removing an inferior strip of cartilage and a matching amount of lateral lamina using a double lateral osteotomy. The pyramid can be "let down" on the pyriform aperture without changing the relationship between the upper lateral cartilages and the septum (Figure 2C). Unilateral or asymmetrical double osteotomy is also one of the technique used to straighten out a leaning nose.

In the "let out" illustrated by the patient in Figure 1, widening of the liminal valve is achieved by letting the lateral laminas fall lateral to a remaining edge of bone at the pyriform aperture as the pyramid is lowered. The level of this high lateral osteotomy determines the amount by which the pyramid will be lowered and the remaining edge of bone will provide stability of the mobilized lateral laminas (Figure 2D).

Measurements on the cadaver and experimental hypothesis

We were under the impression that the relief of nasal obstruction after the "let out" procedure was due to an increase of the cross section of the liminal valve, resulting from the lateral displacement of the lateral laminas. When measured on the cadaver, the cross section was 0.72 cm^2 before and 0.48 after the procedure. Since the valves area was made smaller by the procedure, the beneficial effect had to be the result of other modification or events acting on the dynamic of the valve during inspiration.

The aperture of the valve is determined by the sum of two forces working in opposite direction and by the angle between the upper lateral cartilage and the septum. One force is the inherent rigidity of the cartilage and the strength of the dilator muscles as studied by Van Dishoeck (1965) and Masing (1967), this force tends to keep the valve open. The other force is the negative pressure of the Venturi effect, it tends to close the valve. The angle is also important because it determines the onset of closure of the valve in time, the wider the angle the later the closure takes place.

It was felt that changes of the angle of the valve and of the rigidity of the upper lateral cartilage were responsible for the beneficial effect of the "let out" procedure and they were calculated.

Aerodynamic calculations

The angle of the valve was calculated by trigonometry: it was 24° before the procedure and 34° after, for an increase of 42%.

The rigidity of the upper lateral cartilage, considered as a beam, is measured by the deflection caused by the pressure applied perpendicularly to its length. Deflection is directly proportional to the pressure and to the fourth power of the length of the beam. The following formula will give the change of deflection δ created by the procedure:

$$\frac{\delta \text{ after}}{\delta \text{ before}} = \left(\frac{P \text{ intra after}}{P \text{ intra before}}\right)\left(\frac{\text{length after}}{\text{length before}}\right)^4$$

The length of the free border of the upper lateral cartilage was measured directly on the cadaver, it was 19.7 mm before and 14.4 mm after the procedure.

Intranasal pressure can be calculated by the theorem of Bernouilli:

$$\frac{Vi^2}{2g} + \frac{Pi}{y} = \frac{Ve^2}{2g} + \frac{Pe}{y}$$

where: Vi = intranasal velocity;
Pi = intranasal pressure;
g = gravity = 981 cm/sec^2;
Ve = extranasal velocity - o;
Pe = atmospheric;
P = 1025 cm H_2O;
y = density

To calculate intranasal pressure by this theorem, intranasal velocity is required and it will be calculated by the principle of conservation of mass:

$$q = A \times V \text{ or } V = \frac{q}{A}$$

where: q = flow;
A = cross section;
V = velocity.

A flow rate of 196 cm^3/sec was used for uninasal respiration (calculated from a total nasal flow of 11.76 L/min). The cross section of the valve was measured directly on the cadaver, it was 0.72 cm^2 before and 0.48 cm^2 after the procedure. These figures are introduced in the equation and the intranasal velocity is calculated:

$$Vi \text{ before} = \frac{196}{.72} \text{ cm}^2 = 272 \text{ cm/sec}$$

$$Vi \text{ after} = \frac{196}{.48} \text{ cm}^2 = 408 \text{ cm/sec}$$

The intranasal velocity before and after the procedure can be introduced in the theorem of Bernouilli and intranasal pressure is calculated. It is 0.42 mm H_2O before 1.03 mm H_2O after the procedure.
Finally by introducing the length of the upper lateral cartilage and the intranasal pressure before and after the procedure in the formula for deflection, the effect of the procedure on the rigidity of the upper lateral cartilages can be calculated:

$$\frac{\delta \text{ after}}{\delta \text{ before}} = \left(\frac{1.03}{0.46}\right)\left(\frac{14.4}{19.7}\right)^4$$

The deflection after the procedure is found to be only 64 percent of the deflection before, which means that the let out procedure has in fact increased the rigidity of the upper lateral cartilages by 36%.

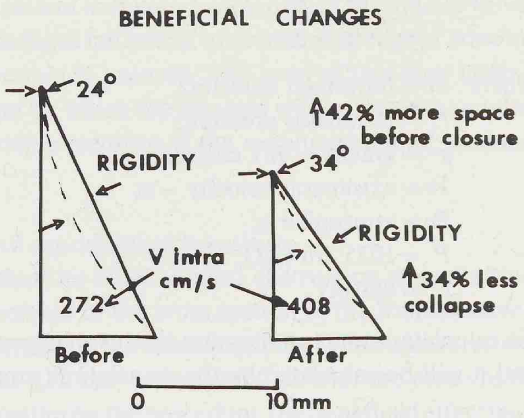

Figure 3.
Schematic representation of the liminal valve area showing measurements and calculations before and after the "let out".

DISCUSSION AND CONCLUSION

According to measurements on the cadaver and by using appropriate formulas, summarized in Figure 3, the beneficial effect of the "let out" observed clinically is not due to an increase of the cross section of the liminal valve, but it is the result of an increased rigidity of the upper lateral cartilage and a widening of the angle of the valve. Shortening the upper lateral cartilage makes it more rigid so that, in spite of a decrease of the intranasal pressure (greater Venturi effect) created by the small crosses section, it will have little deflection during inspiration. Widening the angle of the valve will keep the upper lateral cartilage away from the septum, thus keeping the airway open.

In this functional procedure there is a trade off between early collapsus and a tolerable increase of resistance. Therefore the "let out" can only be used in a nose large enough that, when it is made smaller, it does not cause a fixed mechanical obstruction, as seen in stenosis of the vestibule.

Had the cross section been increased by the procedure, as we had presumed, airway patency would have been maintained with the secondary benefit of a smaller intranasal velocity. In the "let out", the decrease of the cross section creates an increased intranasal velocity with its undesirable drying action on the mucosa and change of the proprioceptive sensation.

Although this experimental study has not been done after a conventional rhinoplasty, these findings can be extrapolated to say that cosmetic rhinoplasties usually do not cause nasal obstruction because the anatomical changes are counterbalanced by increased rigidity of the upper lateral cartilages. On the other hand, the sniffing frequently observed after rhinoplasties, is probably due to the increased intranasal velocity caused by a decrease of the cross section of the valve area.

RÉSUMÉ

A l'aide de mesures chez le cadavre et diverses équations, on a demontré que la descente extranasale (let out) corrige l'obstruction chez le nez aquilin et très étroit, par une augmentation de l'angle de la valve et par une rigidité accrue des cartilages latéraux plutôt que par une augmentation de l'aire de la valve. L'analyse des phénomènes à la suite de cette procédure, nous permet également d'apporter une explication aérodynamique a d'autres phénomènes après une rhinoplastie esthétique.

Un cas illustre cette entité clinique. A l'aide de desseins, on montre comment on se sert du principe de la mobilization "en bloc" de la pyramide, pour corriger l'étroitesse du nez.

ACKNOWLEDGEMENT

This research was made possible by a grant from the Canadian Medical Research Council MRC MA 5416. It was done at Ecole Polytechnique Université de Montreal, Canada.

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