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Aerodynamic studies on the effect of nasal septal plasty

K. Togawa and A. Konno, Akita, Japan

THE importance of breathing through the normal nose can never be overstressed. Disturbance in nasal breathing caused by an anomalous configuration of the septum and the turbinates results in the change of respiratory function in varying degrees. This has already shown by Ogura and others (Ogura et al., 1964, 1966, 1968 and 1971; Unno et al., 1968). The purpose of this study is to re-evaluate the relationship between structure and function from the viewpoint of aerodynamics.

VISUAL OBSERVATION OF THE INTRANASAL AIR-FLOW

For this purpose soft silicone negative casts of the nasal cavity including the nasopharynx were obtained from five human subjects under general anesthesia. Then, positive models were duplicated with silicone rubber (Flexicon®) as previously described (Konno, 1969).
Figure 1 shows the cross-sections of the five nasal casts. Two of them had straight, while three had deviated septums.
By emitting smoke or dye solution into the constant flow of air or water passing through the models, the stream-lines were observed and recorded on movie films. In general, the main stream passed through in the middle portion of the common meatus and in the middle meatus with transient local turbulence (Figure 2). Velocity of the flow measured with a Pitot tube was also the greatest in these portions. Such normal course of the intranasal air-streams may be disturbed by the anomalous intranasal configuration. Consequently, the route of the stream is altered in various ways, and more driving pressure is necessary which may result in creation of more turbulence in the flow. As for the site creating the airway resistance in the nasal passage, partitioning of the resistance was attempted, that is, pressure-differences between the nasal opening and the maxillary ostium and between the maxillary ostium and the oropharynx were compared with each other (Figure 3).
In the normal, the value of the posterior half was one forth of the total. Deviation at the anterior portion or enlarged anterior tubercles of the septum adds more stenosis on the anterior half of the nasal passage which is narrow

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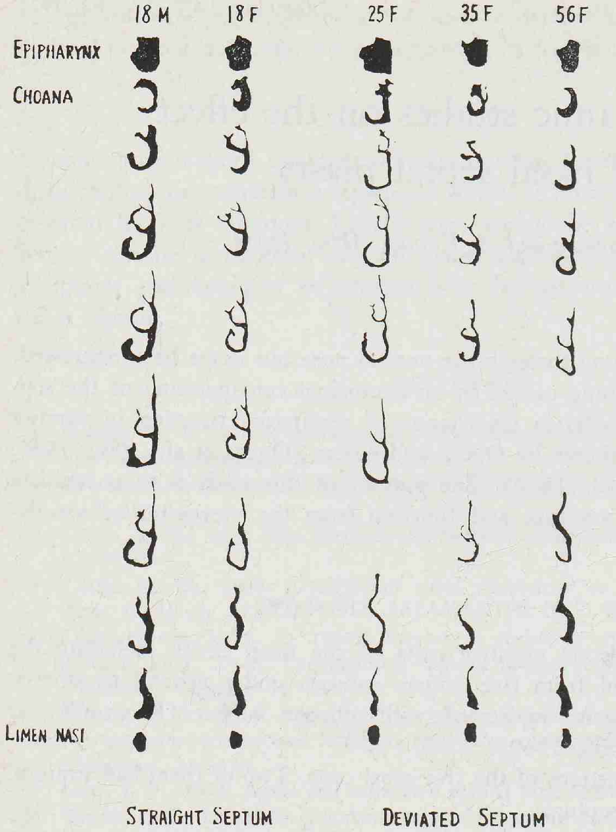


Figure 1. Cross-sections of the nasal cavity casts; two cases with straight, and other three with deviated septums.

even in the normal state. Corrective surgery of the deviated septum and the turbinates recovers the normal course of the air-stream.

NASAL PATENCY MEASUREMENT

Patency of the nasal passages was evaluated using the following methods:
a) rhinorheography or posterior rhinometry, b) rhinoresistometry, and c) the effective cross-sectional area of the nose measurement (Figure 4).
a) is the recording of the pressure-flow relationship in the nose on a X-Y recorder and subsequent nasal airway resistance or conductance calculation at the certain values of flow velocity or of transnasal pressure difference..
The recorded line showing pressure-flow relationship of the transnasal airstream was curvilinear, which indicates existence of the turbulence in the flow as already shown elsewhere (Konno, 1969; Foxen, 1971). The recorded curve may be called a rhinorheogram.
b) is the direct reading of the value of airway resistance on an oscilloscope using the oscillation method after J. Mead (1960).

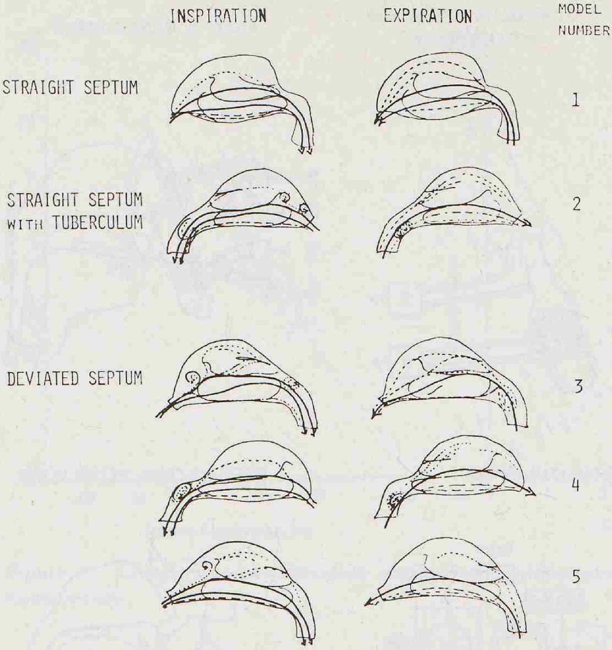


Figure 2. Pattern of the intranasal airflow.

	CASE	16 M	22 M	21 M	22 M	20 M	18 M	38 M	19 M	18 M
INSPIRATION	NOSE MASK TO MESOPHARYNX	5.00	5.68	7.82	3.72	6.90	3.34	5.02	3.58	4.48
	NOSE MASK TO MAXILLARY SINUS	2.84	4.00	6.34	2.92	5.62	2.98	4.96	3.40	5.02
	MAXILLARY SINUS TO MESOPHARYNX	0.60	1.24	2.80	2.80	1.32	0.40	1.10	0.82	0.20
	PERCENTAGE OF POSTERIOR PART	12.7	21.8	35.8	21.5	19.2	13.9	21.9	22.9	4.1
EXPIRATION	NOSE MASK TO MESOPHARYNX	4.24	5.66	5.32	4.20	5.78	3.58	4.52	3.50	5.02
	NOSE MASK TO MAXILLARY SINUS	3.90	5.00	4.78	4.08	5.06	3.44	5.08	3.38	4.80
	MAXILLARY SINUS TO MESOPHARYNX	0.50	0.68	2.32	0.90	0.64	1.00	0.80	0.50	1.00
	PERCENTAGE OF POSTERIOR PART	14.0	12.0	44.3	21.4	14.0	37.9	14.88	14.3	6.5

Figure 3. Partitioning of pressure difference in the nose under constant volume velocity of 6 L/min.

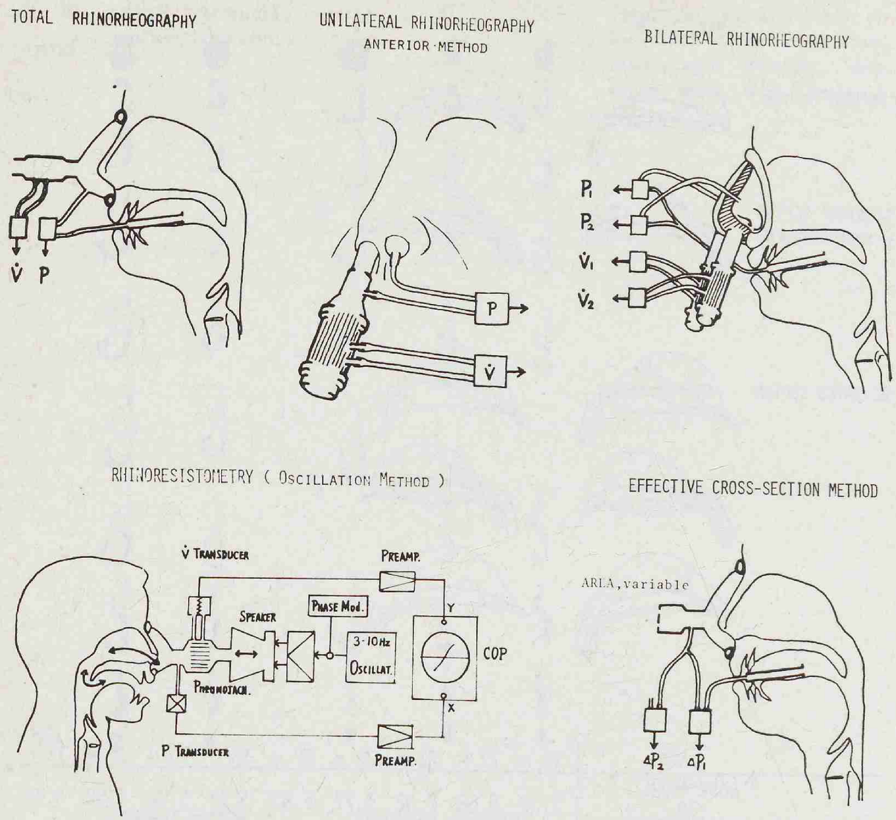


Figure 4. Nasal patency measurement; methods in use.

c) is the direct reading of the value of the effective cross-sectional area in cm^2 on the dial with vernier of the rhinopatency-meter which has specially been made to order.

The values of airway resistance of the nose calculated from a rhinorheogram, those obtained with the oscillation method, and of the effective cross-sectional area were well correlated each other (Figure 5). Border-line value of total nasal airway resistance between the normal and the obstructed was about 1.5 cm H_2O/L/sec., and of the effective cross-sectional area was 0.5 cm^2, respectively. These values may be slightly different due to body height, race etc. We have been using the grading of nasal obstruction which was modified slightly from what has been suggested by Ogura in 1964.

On the patients with nasal airway resistance value of more than 3.5 cm H_2O/L/sec. even after nasal shrinkage, surgical treatment of any choice should be recommended. Successful surgery reduces this value less than 2 cm H_2O/L/sec.

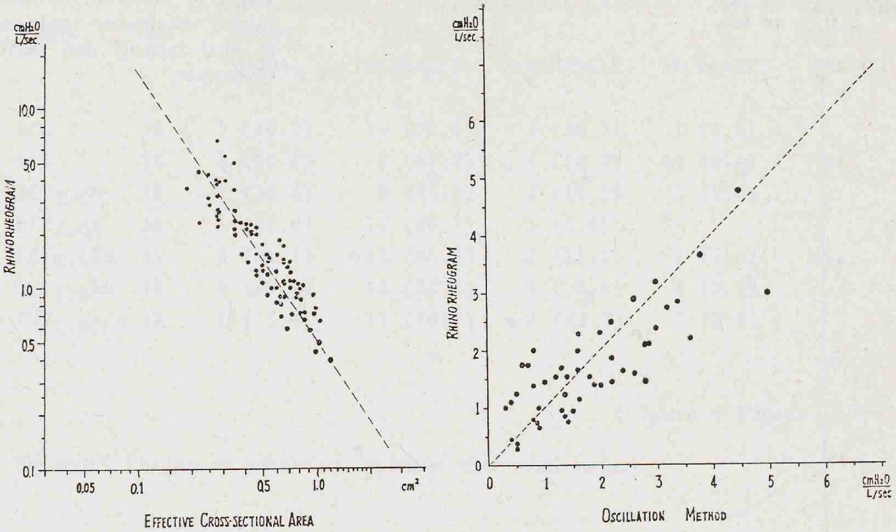


Figure 5. Correlations of the values obtained with different methods of the nasal patency measurement.

DISTURBANCE IN NASAL BREATHING AND PULMONARY FUNCTION

Respiratory function tests such as pulmonary volumetry and ventilometry, maximal expiratory flow-volume curve recordings (abriviated as MEFV curve), and the measurement of pulmonary mechanics such as pulmonary resistance and compliance were performed using electronic devices.

When measures during nose breathing, 1 second forced expiratory volume ($FEV_{1.0}$), per cent $FEV_{1.0}$ and the maximal expiratory flow lessened. The value of pulmonary resistance increased correspondingly with the grade of nasal obstruction.

When measured during mouth breathing, these values changed only minimal or unchanged in cases of slight to moderate nasal obstruction. In some cases of so highly obstructed, that breathing through the mouth is forced for most of the time, the value of per cent $FEV_{1.0}$ reduced than normal (Figure 6). High pulmonary resistance and low dynamic compliance obtained in such highly obstructed cases indicate evidence of obstructive change and uneven distribution of air in the lung.

Intranasal corrective surgeries were performed on the cases with moderate or severe nasal obstruction, and these tests were repeated after surgery. Figure 7 shows the differences in pre- and postoperative values in pulmonary mechanics. Improvement of pulmonary resistance measured not only through the nose, but of also through the mouth may be the results of normalization of respiratory mechanism.

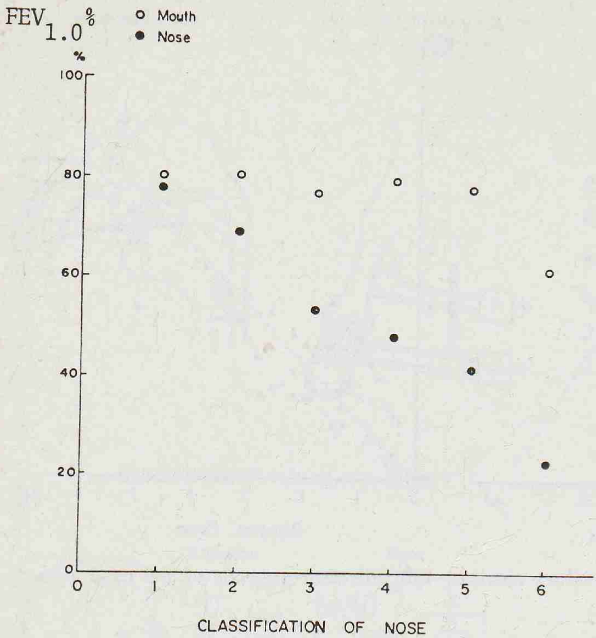


Figure 6. Ratio of 1 second forced expiratory volume to vital capacity and nasal obstruction.

Figure 8 shows the differences in the pre- and postoperative values of the ventilatory tests. These data measured through the nose definitively improved. Those measured through the mouth showed relatively slight change except for $FEV_{1.0}$.

Two cases of the MEFV curves recorded before and after surgery were demonstrated. The difference in shape is well noticed when recorded through the nose which is drawn with a dotted line (Figure 9).

Figure 7. Changes in pulmonary mechanics after nasal surgery.

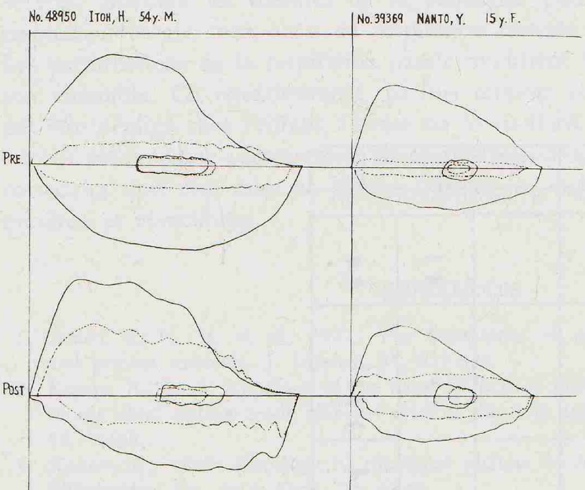
PARAM.	No.	INCREASED BEYOND NORMAL	WITHIN NORMAL RANGE INCREASED	WITHIN NORMAL RANGE UNCHANGED	WITHIN NORMAL RANGE DECREASED	DECREASED BEYOND NORMAL
C_{dy} m.	19	14 (73.7)	4 (21.0)	1 (5.3)	-	-
C_{dy} n.	19	16 (84.2)	1 (5.3)	2 (10.5)	-	-
R_p m.	19	-	1 (5.3)	4 (21.0)	4 (21.0)	10 (52.7)
R_p n.	19	-	-	-	1 (5.3)	18 (94.7)
FRC	17	2 (11.8)	6 (35.3)	5 (29.4)	3 (17.6)	1 (5.9)
SP.C m.	17	4 (23.5)	8 (47.0)	2 (11.8)	1 (5.9)	2 (11.8)

(Ogura & Togawa, 1965)

PARAM.	No.	INCREASED BEYOND NORMAL	WITHIN NORMAL RANGE INCREASED	UNCHANGED	DECREASED	DECREASED BEYOND NORMAL
VCm	18	3 (16.7)	11 (61.1)	3 (16.7)	1 (5.6)	-
VCn	18	9 (50.0)	4 (22.2)	4 (22.2)	1 (5.6)	-
$FEV_{1.0}m$	18	7 (38.9)	8 (44.4)	2 (11.1)	1 (5.6)	-
$FEV_{1.0}n$	18	5 (27.8)	12 (66.7)	1 (5.6)	-	-
$FEV_{1.0}\%m$	18	3 (16.7)	12 (66.7)	2 (11.1)	1 (5.6)	-
$FEV_{1.0}\%n$	18	3 (16.7)	13 (72.2)	1 (5.6)	1 (5.6)	-
$FEV_{1.0}n/m$	18	1 (5.6)	12 (66.7)	4 (22.2)	1 (5.6)	-

(Ogura & Togawa, 1965)

Figure 8. Changes in ventilatory capacities after nasal surgery.



GRADE OF OBSTR.		PREOP. (4)	POSTOP. (2)	PREOP. (5)	POSTOP. (3)
MOUTH	VC	4.40	4.40	3.12	3.04
	PF	9.2	9.6	6.8	5.9
	$\dot{V}_{50}$	8.4	8.3	5.4	4.4
	$\dot{V}_{25}$	1.9	1.9	3.4	2.0
	$\dot{V}_{50}/_{25}$	4.4	4.36	1.6	2.2
	RR.	2.4	2.3	3.4	4.3
NOSE	VC	4.00	4.02	2.80	3.00
	PF	2.0	6.0	0.8	1.8
	$\dot{V}_{50}$	1.8	4.2	0.5	1.7
	$\dot{V}_{25}$	1.7	2.8	0.4	1.5
	$\dot{V}_{50}/_{25}$	1.06	1.5	1.25	1.13
	RR	6.8	4.4	12.0	5.9

Figure 9. Maximal expiratory flow-volume curves recorded before and after surgery.

CONCLUSIVE COMMENTS

Changes in respiratory function due to disturbance in normal nasal breathing are summarized schematically on figure 10. The arrows pointing upward indicate the increase in the values and vice versa.

Patients with nasal obstruction due to intranasal anomalous configuration and other causes are forced to do more work of breathing than in the normal. In severely obstructed cases, the patients are forced to continue uncomfortable mouth breathing day and night. In healthy young adults the influence of disturbance in nasal breathing may be minimal, however, it can not be overlooked in infants, the obese and in the senile (Togawa, 1976).

During sleep, infants with nasal obstruction try unsuccessful nasal breathing with occasional compensatory mouth breaths, snoring and arousal movements. The EEG also showed arousal waves frequently (Konno and Togawa, 1977).

Longstanding mouth breathing results in not only dessiccative change in the lower airway, but also obstructive change in the peripheral bronchioli (so-called small airway) in the lung. Recovery of normal patency of the nose by corrective surgery lessened airway resistance and pulmonary resistance to the normal level, which is the optimal condition to keep the respiratory function normal. In time while these respiratory changes are minimal and reversible, surgical correction of the anomalous configuration of septum disturbing normal nasal breathing is strongly recommended.

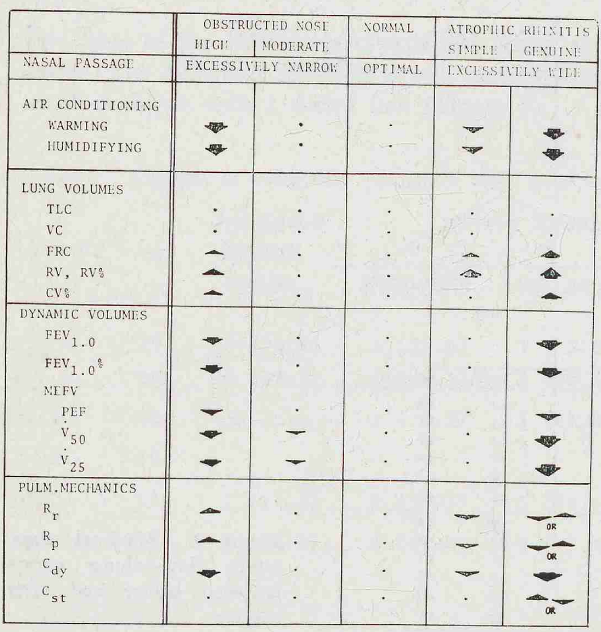


Figure 10. Changes in respiratory function caused by disturbance in normal nasal breathing.

RÉSUMÉ

Le but de ce travail est l'évaluation des relations entre structures et fonctions nasales sur le plan aérodynamique.

L'observation visuelle du courant aérien intranasal est faite sur des modèles à débit constant de fumée dans l'air ou d'encre dans l'eau. Normalement la résistance de la moitié postérieure de la fosse nasale représente le ¼ de la résistance totale. Les déformations de la partie antérieure ont davantage de conséquences respiratoires.

Les mesures de la perméabilité nasale utilisent toutes les méthodes connues. Il y a corrélation entre le rhinorrhéogramme, l'enregistrement oscilloscopique et la mesure des sections. Les valeurs limites de la normalité et de l'obstruction sont environ 1,5 cm H_2O / L / Sec et 0,5 cm^2. L'obstruction nasale totale persistant après rétraction de la muqueuse fait apparaître des valeurs supérieures à 3,5 cm H_2O / L / sec.

Les perturbations fonctionnelles des respirations nasales et pulmonaires sont étudiées comparativement durant la respiration buccale et la respiration nasale. En respiration buccale, les valeurs varient peu ou pas dans les cas d'obstruction nasale modérée. Dans quelques cas d'obstruction importante, une résistance pulmonaire élevée indique des modifications obstructives bronchopulmonaires.

La chirurgie correctrice intra-nasale, effectuée sur des obstructions modérées ou sévères, améliore les mesures de la résistance pulmonaire, non seulement en respiration nasale, mais aussi en respiration buccale.

Les perturbations de la respiration nasale modifient la fonction respiratoire dans son ensemble. Ce retentissement, parfois minime chez l'adulte jeune, ne peut pas être négligé chez l'enfant, l'obèse ou le vieillard. A la longue, la respiration buccale entraine une augmentation de la résistance bronchopulmonaire. La chirurgie correctrice doit être mise en oeuvre lorsque les modifications respiratoires sont minimes et réversibles.

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Kiyoshi Togawa and Akiyoshi Konno,
Department of Otorhinolaryngology,
Akita University School of Medicine,
Hondo 1-1-1, Akita, 010, Japan.