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# Active anterior rhinomanometry in pre- and postoperative evaluation, use of Broms' mathematical model

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SUMMARY

*The authors studied the value of the Broms' mathematical model for active anterior rhinomanometry in a pathological population.*
*They compared all different variables of a pathological group with a normal group and found significant differences for $v_0$, $v_2$ and R.*
*There existed no difference between the means of $v_0$ before and after surgery. There existed, however, a strongly positive correlation between the expiration and inspiration value. The influence of surgery was allways significant for the variables $v_1$, $v_2$, $v_3$ and R.*
*Furthermore, the absolute deviation between the computed values and the recorded values tended to be very small.*
*So, the authors concluded that rhinomanometry is a valuable aid in judging pre- and postoperative results.*

Even today, rhinomanometry has not become a current procedure to ENT physicians in nose surgery and evaluation of the postoperative result. Probably, this is a result of the negative evaluation of these methods, still found in modern publications (Kumlien et al., 1979; Graamans, 1980).
Already as early as 1939, however, Scheideler noticed that nose inspection in itself is not a reliable parameter to discriminate pathological from normal cases. In the same year, Tonndorf reported that a concha cannot be removed for improving nasal passage without there being any repercussions. One of the merits of this author is that he focused attention on Reynolds' number.
Other authors do believe in the value of rhinomanometry for pre- and postoperative measurements (Cottle, 1968; Guillerm et al., 1966). Yet because normal and pathological populations largely overlap, nasal resistance repeatedly proves to be a parameter difficult to handle. Some authors, for that reason, try to introduce other parameters such as forced respiratory resistance (rhino-, revmo-,

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sphygmo-manometry, Cottle, 1968), work of breathing (Guillerm et al., 1967; Cottle, 1968), coefficient of nasal resistance (Von Arentschielt, 1966), and lateralisation percentage (Postema et al., 1980). The disadvantage of these parameters is that they represent only a minor part of the $\Delta P/\mathring{V}$ recording. However, a Swedish group leaded by Broms succeeded in reconstructing the whole recording by making use of polar coordinates.

The authors of this study earlier assessed the applicability of this model in a normal population (Clement et al., 1980). In this paper, its use for pre- and post-operative evaluation is reported.

## MATERIAL AND METHODS

### 1. *Description of the model*

The Broms' mathematical model (Broms et al., 1980) describes the $\Delta P/\mathring{V}$graph as the angle $v$ which the recording makes with the flow axis as a function of the radius, in the following way (Broms et al., 1980): $v(r) = v_0 + c \cdot r$ (Clement et al., 1980); where in normal test subjects the angle $v_0$ is equal for inspiration and expiration.

In this study we concentrated on pathological cases for which it is often observed that the angle $v_0$ differs markedly for inspiration ($i$) and expiration ($e$), while the same holds for the constant $c$.

Therefore, we propose the following generalization:

$$v_i(r) = v_{0i} + c_i \cdot r + \frac{e}{r}$$

$$v_e(r) = v_{ie} + c_e \cdot r - \frac{e}{r} \tag{1}$$

Here $e$ is only a correction constant. In order to estimate the coefficients $v_{0i}$, $v_{0e}$, $c_i$, $c_e$ and $e$, we make use of the measurements $v_{1i}$, $v_{2i}$, $v_{3i}$ and $v_{1e}$, $v_{2e}$, $v_{3e}$. This is done by minimizing the following least square criterion:

$$Q = \sum_{r=1}^{3} r^2 \left(v_i \cdot r - v_{0i} - c_i \cdot r - \frac{e}{r}\right)^2 + \sum_{r=1}^{3} r^2 \left(v_e \cdot r - v_{0e} - c_e \cdot r + \frac{e}{r}\right)^2 \tag{2}$$

The actual calculation can be found in the appendix.

By means of these coefficients, the parameter $R_{2i}$ is determined as

$$R_{2i} = 10 \tan v_{2i} = \frac{\Delta P_{2i}}{\mathring{V}_{2i}}$$

and the same formula is also used for $R_{2e}$. Often, the average value $R = 1/2(R_i +$

$R_e$) for inspiration and expiration is used. In the case of the total nose (left and right nostril), it is possible to obtain a new curve, where the relationship between the pressure gradient scale and the flow scale is 1 to 5.
Therefore, the total $R_{iT}$ there equals:

$$R_{iT} = 5 \tan (v_{2i})_T = \frac{\Delta P_{2iT}}{\mathring{V}_{2iT}}$$

But this measurement is often not performed, and one computes the results for the total nose from those for both nostrils. A first idea would be to calculate the sum of $R_{i\,\text{left}}$ and $R_{i\,\text{right}}$, but this would not be logical. Indeed, one is concerned with the sum of the air flow at the same pressure gradient, and not conversely. Therefore, we have

$$\frac{\mathring{V}_{2T}}{\Delta P_2} = \frac{(\mathring{V}_2)\ \text{left}}{\Delta P_2} + \frac{(\mathring{V}_2)\ \text{right}}{\Delta P_2}$$

so

$$R_{iT} = \frac{1}{\dfrac{1}{R_{i\,\text{left}}} + \dfrac{1}{R_{i\,\text{right}}}}$$

2. *Patients and test subjects*

For the data in a normal population, the results of the preceding article are drawn on (Clement et al., 1980). The normal population in that study consists of 32 subjects (11 males, 21 females) aged 18 to 30 years. None of the subjects showed any abnormalities after anterior rhinoscopic examination performed by an experienced ENT physician.

The pathological population consists of 27 patients (14 males, 13 females) with an average age of 32 years (limits 13 and 43 years). Postoperative rhinomanometry was performed usually 4 months after the surgical procedure (2 weeks–12 months).

All patients were operated following functional complaints, nasal obstruction being the major complaint (85% of all patients). A few patients had to undergo surgery because of a poor tuba function with septum deviation, and one because of postnasal drip.

3. *Material*

Rhinomanometry was performed by means of a Bachmann rhinomanometer (1976): active anterior rhinomanometry with XY writers. The abscisse (pressure/ axis) was calibrated in such manner that 1 cm corresponds with 1 mBar, while on the ordinate (flow axis) 1 cm corresponds with 0.1 litre/second. The inspiration was represented at the right of the flow axis (negative pressure), the expiration at the left of it (positive pressure).

The same as is done in Bachmann's method, the recording of the right nostril is represented from bottom left to top right, that of the left nostril from top left to bottom right (Bachmann 1976).

The rhinomanometric evaluation was done while the patient was sitting and no decongestants were used so as to resemble the natural situation as much as possible.

## RESULTS

### 1. *Comparison of mean and standard deviation of the different variables in normal and pathological groups*

From Table 1a follows that there exists a significant difference in variances, as well as a significant difference in means between normal and pathological values of the different variables $\hat{v}_0$, $\hat{v}_2$ and $R$. For $\hat{c}$ there exists a significant difference in variance, to a lower degree than for the other variables. This goes for inspiration, expiration, left and right nostril.

Table 1a. Comparison healthy – pathological before surgery.

| | healthy (32) | | pathological (26) | | | |
|---|---|---|---|---|---|---|
| | mean | variance | mean | variance | F | T |
| right nostril | | | | | | |
| $\hat{v}_0$ | 3.13 | 3.88 | 27.37 | 782.88 | 201.77 | 4.81 |
| $\hat{c}_e$ | 4.14 | 1.78 | 5.07 | 15.21 | 8.54 | 1.24 |
| $\hat{c}_i$ | 3.90 | 2.09 | 4.37 | 13.84 | 6.62 | 0.64 |
| $\hat{v}_{2e}$ | 12.05 | 13.48 | 34.65 | 717.17 | 53.20 | 4.65 |
| $\hat{v}_{2i}$ | 11.55 | 15.62 | 38.97 | 689.59 | 44.15 | 5.73 |
| $R_e$ | 2.14 | 0.45 | 35.16 | 633.93 | 124.30 | 2.31 |
| $R_i$ | 2.06 | 0.51 | 54.94 | 179.15 | 351.29 | 2.20 |
| left nostril | | | | | | |
| $\hat{v}_0$ | 4.94 | 13.48 | 22.55 | 620.51 | 46.03 | 3.88 |
| $\hat{c}_e$ | 4.17 | 4.65 | 5.04 | 11.83 | 2.54 | 1.15 |
| $\hat{c}_i$ | 4.40 | 7.12 | 4.84 | 15.13 | 2.13 | 0.50 |
| $\hat{v}_{2e}$ | 13.28 | 36.50 | 29.26 | 424.77 | 11.64 | 4.10 |
| $\hat{v}_{2i}$ | 13.75 | 47.64 | 29.28 | 519.38 | 10.90 | 3.60 |
| $R_e$ | 2.40 | 1.32 | 8.44 | 159.52 | 120.85 | 2.65 |
| $R_i$ | 2.50 | 1.80 | 9.64 | 237.47 | 131.93 | 2.57 |

All values of F above 2.18 show a significant difference in variances (two-sided test, 5%).
All values of T above 2.00 show a significant difference in means (two-sided, 5%).

Table 1b shows that there exists no important difference in the mean value and standard deviation of $v_0$ for the right and left nostril. There exists, however, a clear-cut decrease of the $v_0$ balue after surgery. Furthermore, one can see that the $v_{0e}$ value is smaller than the $v_{0i}$ value before surgery.

Table 1b. Comparison of left and right nostril.

| | | mean | standard deviation |
|---|---|---|---|
| before surgery | $\hat{v}_{0i}$ (right) | 30.2 | 29.3 |
| | (left) | 22.8 | 27.6 |
| | $\hat{v}_{0e}$ (right) | 24.5 | 30.8 |
| | (left) | 22.3 | 26.9 |
| after surgery | $\hat{v}_{0i}$ (right) | 16.6 | 16.8 |
| | (left) | 10.6 | 9.3 |
| | $\hat{v}_{0e}$ (right) | 17.4 | 19.9 |
| | (left) | 11.0 | 12.3 |

Table 1c confirms the smaller values of $v_{0e}$ as well as those of $v_{1e}$, $v_{2e}$ and $v_{3e}$. This difference decreases clearly arter surgery.

Table 1c. Comparison inspiration/expiration.

| | before surgery | | after surgery | |
|---|---|---|---|---|
| | mean | standard deviation | mean | standard deviation |
| $v_{1i}$ | 30.9 | 26.8 | 18.2 | 13.7 |
| $v_{1e}$ | 28.4 | 26.4 | 18.0 | 16.6 |
| $v_{2i}$ | 35.8 | 25.9 | 22.6 | 13.6 |
| $v_{2e}$ | 33.6 | 25.1 | 21.7 | 17.7 |
| $v_{3i}$ | 40.3 | 25.1 | 27.2 | 14.3 |
| $v_{3e}$ | 38.6 | 23.6 | 25.5 | 18.4 |
| $\hat{v}_{0i}$ | 26.5 | 28.4 | 13.6 | 13.8 |
| $\hat{v}_{0e}$ | 23.4 | 28.6 | 14.2 | 16.7 |
| $\hat{c}_i$ | 4.60 | 3.77 | 4.45 | 2.71 |
| $\hat{c}_e$ | 5.06 | 3.64 | 3.77 | 2.50 |

## 2. *Comparison of the left and right nostril before and after surgery*

Table 2.

| | | means | $P$ value ($t$ test) | correlation | $P$ value |
|---|---|---|---|---|---|
| before surgery | $v_{0i}$ (right) | 30.2 | 0.22 | .439 | 0.02 |
| | (left) | 22.8 | | | |
| | $v_{0e}$ (right) | 24.5 | 0.73 | .386 | 0.05 |
| | (left) | 22.3 | | | |
| after surgery | $v_{0i}$ (right) | 16.6 | 0.11 | .080 | 0.70 |
| | (left) | 10.6 | | | |
| | $v_{0e}$ (right) | 17.4 | 0.07 | .482 | 0.01 |
| | (left) | 11.0 | | | |

From Table 2 follows that there exists:

1. no significant difference between the means of the right and left side;
2. a weak correlation between the variables of the left and right nostril in the same patient.

3. *Comparison of inspiration and expiration variables before and after surgery*

Table 3.

| | | means | significance ($t$ test) | correlation | significance |
|---|---|---|---|---|---|
| before surgery | $v_{1i}$<br>$v_{1e}$ | 30.9<br>28.4 | 0.35 | .75 | 0.00 |
| | $v_{2i}$<br>$v_{2e}$ | 35.8<br>33.6 | 0.37 | .75 | 0.00 |
| | $v_{3i}$<br>$v_{3e}$ | 40.3<br>38.6 | 0.47 | .77 | 0.00 |
| | $\hat{v}_{0i}$<br>$\hat{v}_{0e}$ | 26.5<br>23.4 | 0.31 | .71 | 0.00 |
| | $\hat{c}_i$<br>$\hat{c}_e$ | 4.60<br>5.06 | 0.44 | .35 | 0.01 |
| after surgery | $v_{1i}$<br>$v_{1e}$ | 18.2<br>18.0 | 0.86 | .80 | 0.00 |
| | $v_{2i}$<br>$v_{2e}$ | 22.6<br>21.7 | 0.60 | .74 | 0.00 |
| | $v_{3i}$<br>$v_{3e}$ | 27.2<br>25.5 | 0.31 | .76 | 0.00 |
| | $\hat{v}_{0i}$<br>$\hat{v}_{0e}$ | 13.6<br>14.2 | 0.68 | .75 | 0.00 |
| | $\hat{c}_i$<br>$\hat{c}_e$ | 4.54<br>3.77 | 0.005 | .73 | 0.00 |

N.B.: $t$ test: two-tailed test for difference in means.

From Table 3 follows that there exists:

1. a strongly positive correlation (significantly different from zero) between the expiration and inspiration values of the different variables $v_1$, $v_2$, $v_3$, $v_0$ and $c$;
2. no significant difference in the inspiration and expiration mean values of the different variables $v_1$, $v_2$, $v_3$ and $v_0$, except for the coefficient $c$ where there exists a significant difference after.

4. *Comparison of variables before and after surgery*

The most important question, of course, is that of the effect of surgery.

Table 4.

| | | means | significance ($t$ test) | correlation | significance |
|---|---|---|---|---|---|
| $v_{1i}$ | before | 30.9 | 0.00 | .402 | 0.00 |
| | after | 18.2 | | | |
| $v_{1e}$ | before | 28.4 | 0.00 | .442 | 0.00 |
| | after | 18.0 | | | |
| $v_{2i}$ | before | 35.8 | 0.00 | .333 | 0.02 |
| | after | 22.6 | | | |
| $v_{2e}$ | before | 33.6 | 0.00 | .444 | 0.00 |
| | after | 21.7 | | | |
| $v_{3i}$ | before | 40.3 | 0.00 | .265 | 0.06 |
| | after | 27.2 | | | |
| $v_{3e}$ | before | 38.6 | 0.00 | .444 | 0.00 |
| | after | 25.5 | | | |
| $\hat{v}_{0i}$ | before | 26.5 | 0.00 | .418 | 0.00 |
| | after | 13.6 | | | |
| $\hat{v}_{0e}$ | before | 23.4 | 0.01 | .435 | 0.00 |
| | after | 14.2 | | | |
| $\hat{c}_i$ | before | 4.60 | 0.92 | −.089 | 0.53 |
| | after | 4.54 | | | |
| $\hat{c}_e$ | before | 5.06 | 0.02 | .207 | 0.14 |
| | after | 3.77 | | | |
| $R_i$ | before | 32.3 | 0.04 | .394 | 0.00 |
| | after | 4.73 | | | |
| $R_e$ | before | 21.8 | 0.03 | .579 | 0.00 |
| | after | 5.07 | | | |

N.B.: $t$ test: two tailed $t$ test.

From Table 4 follows that:

1. the effect of surgery is always significant for the variables $v_1$, $v_2$, $v_3$, $v_0$ and $R$, both for expiration and for inspiration, except for $c_i$;
2. the correlation is usually positive except for $\hat{c}_i$, and mostly this positive correlation is significant, except for $\hat{c}_i$, $\hat{c}_e$ and $\hat{v}_3$, where it is almost significant.

5. *Quality of the mathematical model*

In order to study the quality of the fit, the authors compared the estimated values (values computed by means of the mathematical model) with the measured values (values measured directly on the recording) of $v$. In fact the measured values of $v_1$, $v_2$ and $v_3$ for inspiration and expiration were used to compute the coefficients $\hat{v}_0$ and $\hat{c}$ of the mathematical model. Then the estimated values $\hat{v}_{0.5}$, $\hat{v}_{1.5}$ and $\hat{v}_{2.5}$ (computed with the mathematical model at the radii 0.5, 1.5, 2.5) were compared with the measured values of the same variables on the recording, which were not used in the previous calculation. In order to measure the discrepancy, the average absolute deviation was calculated, for example, the average value of $|v_{0.5i} - \hat{v}_{0.5i}|$. In this investigation this led to the following values in degrees (Table 6).

Table 6. Average values of the absolute differences in degrees between the measured and computed values of $v$.

| | | inspiration | | | expiration | | |
|---|---|---|---|---|---|---|---|
| | | .5 | 1.5 | 2.5 | .5 | 1.5 | 2.5 |
| pre | right | 2.29 | 0.64 | 0.61 | 3.09 | 0.68 | 0.72 |
| | left | 1.93 | 0.43 | 0.47 | 2.74 | 0.49 | 0.60 |
| post | right | 2.57 | 0.44 | 0.55 | 1.98 | 0.47 | 0.37 |
| | left | 1.10 | 0.52 | 0.36 | 1.64 | 0.43 | 0.47 |

The main conclusion is that:

1. the absolute deviation tends to be very small;
2. there exists a marked difference between the absolute deviation at radius 0.5 on the one hand, and the other two radii on the other.

Conclusion two is partly due to the fact that measurement errors tend to be larger in the 0.5 radius region because of the relative thickness of the line, which makes it hard for the investigator to measure the angle accurately. The authors, therefore, doubt whether it is beneficial to use 6 observations ($v_{0.5}$, $v_{1.0}$, $v_{1.5}$, $v_2$, $v_{2.5}$, and $v_3$) instead of 3, especially if $v_{0.5}$ were included.

## DISCUSSION

Of the patients with complaints of nasal obstruction, three reported unilaterally decreased nasal passage after surgery. This was confirmed by postoperative rhinomanometry.

In those who were highly satisfied after surgery, the rhinomanometric examination showed a clear improvement in 70% and a moderate improvement in the remaining 30%.

From the results in Table 1, it is clear that there exists a significant difference between the mean values of the different variables in the healthy and pathological populations. Moreover, expiratory values are lower than the inspiratory ones in the pathological group before surgery and, to a less extent, in both the normal and pathological population after surgery.

These findings agree with the larger resistance found by Fischer (1970) during inspiration with an arteficial nose model.
This difference between in- and expiration appeared not to be significant according to Table 3, which seems to contradict the previously obtained results. However, this is not entirely true as the extent of significant differences, which is pronounced in some individual cases (Figure 3), is counterbalanced by the cases where this is not so. Yet a difference between $v_{0i}$ and $v_{0e}$ in the same person and for the same nostril is always pathological since normal subjects never show a kink in their recordings.
The main thing, of course, is that rhinomanometry shows a significant increase before, and after surgery (Table 4). This alone already justifies the use of the rhinomanometer as a routine examination for nose complaints.
It further appears that an increase in measuring points, even in the clearly pathological model, does not result in an improved fit of the curve. This has already been reported by Broms et al. (1980). One should, however, take into account that both the distribution of our normal curves and the evaluation of the pathological curves point to a marked difference between our criteria for selection and those of Broms et al. (1980). The distribution of the normal control group (Table 1a) is clearly smaller than that of Broms et al., despite there having been no decongestants used in the Clement group. The explanation may be that the authors used stricter selection criteria in the choice of their normal subjects (Clement et al., 1980). Moreover, the selection within the group appeared to be different. The same authors included all pathological cases scheduled for surgery in this group, i.e. also patients with complete unilateral or bilateral nasal obstruction, showing a straight line in the recording.
This explains the wide distribution of all variables in the pathological group (Table 1a).
The authors of this report repeatedly noticed a kink at the site of origin of the recording, which was not reported by Broms.
In a few individual cases, a clear-cut difference was observed between the measured and calculated value (case 2, Table 7).

Table 7. Difference between measured and computed values in case 2.

| | | inspiration | | | expiration | | |
|---|---|---|---|---|---|---|---|
| | | 0.5 | 1.5 | 2.5 | 0.5 | 1.5 | 2.5 |
| right | measured | 21 | 28 | 34 | **14** | 33 | 43 |
| | computed | 21.44 | 27.61 | 33.90 | **25.04** | 33.60 | 42.0 |
| left | measured | **18** | 40 | 59 | **14** | 33 | 43 |
| | computed | **25.76** | 41.43 | 56.90 | **25.33** | 33.58 | 42.0 |

The bold values show a clear-cut difference between the measured and computed values.

Together with the conclusion of Table 6 on the average absolute deviation, this leads to the question whether one actually does have the best way to calculate the coefficient of formula (1). Indeed, because of the factor $r^2$ in (2), it is clear that the observation for small radii are "down weighted": a certain deviation of $v_1$ is counted 9 ($= 3^2$) times less than the same deviation in $v_3$; so one would not be surprised if the resulting model does not fit so well at this end. Therefore, the authors suggest a modification of (2) where the factors $r^2$ are deleted, yielding a simpler and more standard formulation.

In connection with the correction constant $e$ in formula (1), one notes that it was never significantly different from zero for the apparatus of this investigation (Table 8). Also it was not possible to find a significant result (comparison in correlation) in connection with this quantity.

Table 8.

| | mean value of $e$ | standard deviation of |
|---|---|---|
| before treatment | −.0099 | .119 |
| after treatment | .0055 | .102 |

In conclusion one can state that rhinomanometry, especially the Broms' model shows:

1. a clear-cut difference between normal values and pathological pre- and post-operative values;
2. a significant improvement of the parameters before and after surgery.

Furthermore the criteria for pathogenicity must not only be limited to the study of the nasal resistance (Figures 1, 2 and 3) but must also include the existance of a kink in the recording at the level of the origin (Figures 1 and 3), a pathological bending of the recording (Figures 1 and 3), which is reflected by the elevated

Active anterior rhinomanometry expiration $\mathring{V}$ inspiration

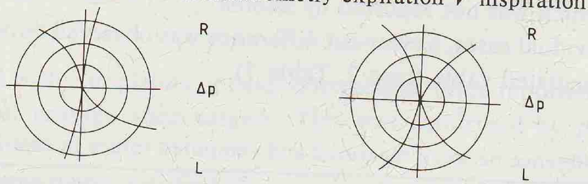


Figure 1. Patient 3.

Preoperative recording:
note the kink in the left nasal recording at the level of the origin (the value of $v_{0l}$ is higher than the value of $v_{02}$).
The patency of the left nasal cavity, especially during inspiration, is pathologically reduced. The bending of the left inspiratory limb is pathological.

Postoperative recording:
there exists a definite decrease in the kink of the left nasal recording.

Active anterior rhinomanometry expiration $\mathring{V}$ inspiration

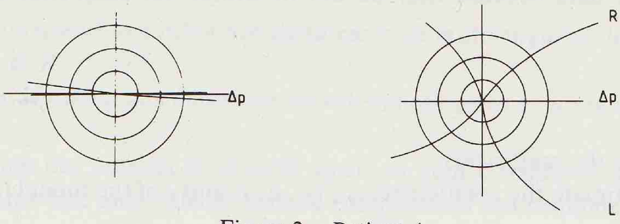


Figure 2. Patient 4.

Preoperative recording:
total blockage of both nostrils.

Postoperative recording:
satisfactory restoration of nasal patency as well for the right as for the left side.

Active anterior rhinomanometry expiration $\mathring{V}$ inspiration

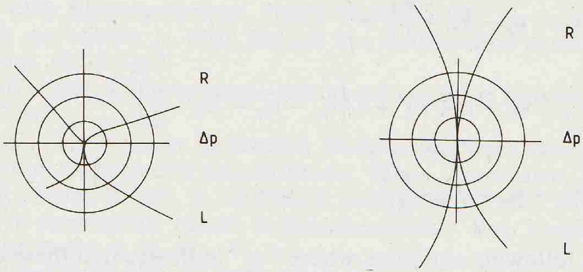


Figure 3. Patient 5.

Preoperative recording:
elevated resistance of the nasal cavity (right side more affected than left side) especially during inspiration, resulting in:

- a kink at the level of the origin, as well for the right as for the left recording (for right side $v_{0i} > v_{0e}$ and for the left side $v_{0i} < v_{oe}$)
- a pathological bending of the recording for the left side during inspiration and for the right side during inspiration and expiration
- the expiratory limb of the right nasal cavity does not reach the circle with radius 3.

Postoperative recording:
complete normalisation of the recording of both nasal cavity.

value of *c*, and the fact that the recording does not reach the circle with radius 3 (Figure 3).

As a final conclusion, the authors would like to point out that the nasal passage evaluation during anterior rhinoscopy should be performed with the aid of the rhinomanometric data.

Usually, however, the reverse takes place and one rejects the objective rhinomanometrical data because they do not fit within our subjective rhinoscopy findings.

## APPENDIX

*Calculation of the coefficients*

In order to estimate the coefficients $v_{0i}$, $v_{0e}$, $c_i$, $c_e$ and $e$ of the model (1) we minimize:

$$Q(v_{0i}, v_{0e}, c_i, c_e, e)$$
$$= 1(v_{1i} - v_{0i} - c_i - e)^2 + 4\left(v_{2i} - v_{0i} - 2c_i - \frac{e}{2}\right)^2$$
$$+ 9\left(v_{3i} - v_{0i} - 3c_i - \frac{e}{3}\right)^2 +$$
$$1(v_{1e} - v_{0e} - c_e + e)^2 + 4\left(v_{2e} - v_{0e} - 2c_e - \frac{e}{2}\right)^2$$
$$+ 9\left(v_{3e} - v_{0e} - 3c_e + \frac{e}{3}\right)^2.$$

This yields the following equation, where " $\wedge$ " indicates that these quantities are estimated:

$$\hat{e} = \frac{3v_{1i} - 6v_{2i} + 3v_{3i}}{116} - \frac{3v_{1e} - 6v_{2e} + 3v_{3e}}{116}$$

$$\hat{c}_i = \frac{-623v_{1i} - 958v_{2i} + 1581v_{3i} - 15v_{1e} + 30v_{2e} - 15v_{3e}}{2204}$$

$$\hat{v}_0 = \frac{1735v_{1i} + 3142v_{2i} - 2673v_{3i} + 63v_{1e} - 126v_{2e} + 63v_{3e}}{2204}$$

The expression of $\hat{c}_e$ and $\hat{v}_e$ are obtained by replacing every $i$ by $e$, and every $e$ by $i$ in the equations of $\hat{c}_i$ and $\hat{v}_{0i}$.


## RÉSUMÉ

Les auteurs ont étudié le mérite du modèle mathématique de Broms' pour une population pathologique.

On a comparé les différents paramètres d'un groupe pathologique à ceux d'une groupe normal, concluant à des différences significantes de $v_0$, $v_2$ et $R$.

Par contre, les moyennes de $v_0$ avant et après l'opération restent invariés.

Cependant, il y a une corrélation positive très élevé entre les valeurs inspiratoires et expiratoires.

On a toujours trouvé une influence significante de la chirurgie sur les paramètres $v_1$, $v_2$, $v_3$, $v_0$ et *R*.

En outre, la déviation absolue entre les valeurs calculées et enregistrées est très minime.

La conclusion des auteurs se résume ainsi: on peut considérer la rhinomanométrie comme une aide valable dans la comparaison des résultats pré- et postopératoires.

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