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The indirect measurement of laryngeal and tracheal resistance

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SUMMARY

We used a body-plethysmograph to determine air-way resistances in 485 cases of laryngeal and tracheal stenoses. We decided in 143 cases to intervene after observing resistance exceeding 60 mm H_2O/l and sec.

A vocal chord was lateral fixated in 49 patients suffering bilateral recurrent paralysis. Optimal results were obtained at a postoperative resistance level of 30 mm H_2O/l and sec (standard value: 14.77 ± 6.53—$n = 387$). The patients could carry out work of medium intensity and had a steady voice.

We performed tracheal interventions in 94 cases of tracheal stenoses. A mean, post-operative resistance of 29.9 mm H_2O/l and sec, with a tracheal diameter of 7–8 mm was attained. In practice, only a few patients found the remaining obstruction a hindrance during work of maximal intensity. No recurrences were observed after treatment. Airway resistances exceeding 150 mm H_2O/l and sec were found in 13 new admissions and 73 times in those undergoing therapy. In these cases asphyxiation threatens. These patients have to be tracheotomized or intubated immediately.

In order to arrive at a full picture of the functional efficiency of the glottis and trachea, there remains only to incorporate the peripheral respiratory system. In this area, body plethysmographs have proven to be outstanding.

With patients in the body plethysmograph, breathing excursions of the thorax result in a fluctuation of the cabin pressure. First, the pressure changes in the cabin are registered during a respiratory airflow of 1 l/sec. Subsequently, the corresponding alveolar pressure is recorded interrupting the airflow mechanically. In addition, this gives us the intrathoracic gas volume of patients knowing their weight (intrathoracic gas volume = functional residual capacity) (DuBois 1956).

Laryngeal and tracheal stenoses can be distinguished from obstructions in

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deeper areas of the respiratory system by the resulting curves on the graphs. The resistance which we measured allowed us to draw conclusions concerning the inside diameter of the glottis and trachea (Table 1).

Table 1. Measurements of resistance in the air-way correlated with the width of the posterior commissure and the trachea, and resulting evaluation after Hertz (1968). Note that minor stenoses show up as only small increases in the air-way resistance. Asphyxiation may result from obstructions which exceed 150 mm H_2O/l and sec.

airway resistance mm H_2O/l and sec	evaluation	posterior commissure mm	tracheal lumen Ø mm
4 - 24	normal	> 4	> 9 (♂ 15-22) (♀ 13-19)
25 - 44	slightly impaired	3 - 4	7 - 8
45 - 49	impaired	2 - 3	6
60 - 149	marked impairment	1 - 2	5
> 150	severe impairment-pending asphyxiation	< 1	< 4

RESULTS

The following table lists the most important obstructive lesions of the larynx and the trachea. (Table 2).

Table 2. Measurements of most important obstructive lesions of the larynx and the trachea.

airway resistance mm H O/l a. sec	I normal wide glottis a. trachea, n = 387	II edema of the glottis, n = 25	III larynxtumor, n = 28	IV unilateral recurrent nerve paralysis, n = 63	V bilateral incomplete recurrent nerve paralysis, n = 14	VI bilateral complete recurrent nerve paralysis, n = 95	VII post op. unilateral lateralfixation, n = 49	VIII post op. vocal cord resection, n = 8	IX tracheal stenosis, n = 250	X post op. tracheoplasty, n = 94
4 - 24	375	2	5	44	2	4	9	1	49	32
25 - 44	10	8	7	18	5	31	19	1	71	37
45 - 59	2	5	3	1	5	13	13	5	46	17
60 - 149	-	10	8	-	2	39	5	1	81	8
> 150	-	-	5	-	-	8	3	-	13	-

A. LARYNX STENOSES

As indicated in Table 2, one finds varying levels of resistance in cases of glottic

edema and tumors of the larynx. We had to tracheotomize two cases of laryngeal tumors because of the danger of asphyxiation. In one case we observed a resistance of 107.4, while the other registered 132.9 mm H_2O/l and sec (section II and III of Table 2).

Unilateral recurrent nerve paralysis was indicated by only meagre increases in air-way resistance (section IV of Table 2).

Bilateral recurrent nerve paralysis showed a varying increase in air-way resistance, according to the vocal chord position (section IV and VI in Table 2).

Unilateral lateral-fixation of a vocal chord should be done with values greather than 60 mm H_2O/l and sec. One thing these series of measurements (Stange, 1974) has clearly shown is that a postoperative resistance around 30 mm H_2O/l and sec presents the most advantageous compromise: the patient has an adequate voice and receives enough air even for medium exercise. As can be seen in Table 2, this favourable level was achieved (section VII of Table 2) by the majority of our patients (41 out of 49).

Eight lateral fixations were unsuccessful. Air-way resistance remained above 60 mm H_2O/l and sec. Without exception, the trouble lay in narrow larynxes with a sharp-angled thyroid cartilage. Except for one case, these patients were helped by vocal chord resections after laryngo-fissure (section VIII of Table 2).

B. TRACHEAL STENOSES

Tracheal stenoses occur mainly as stenoses of the upper part. During the last six years, we have measured a total of 260 tracheal stenoses with body-plethysmography. We found the widest range of resistances, from 7.5 to 566.4 mm H_2O/l and sec (section IX in Table 2). 13 of the patients were in such distress that we had to tracheotomize (9x) or intubate (4x) immediately. Here resistances were measuring from 154.5 mm H_2O/l and sec to 566.4 mm H_2O/l and sec. 150 mm H_2O/l and sec is for us the critical value where we intervene immediately.

Resistances greater than 60 mm H_2O/l and sec were found in 94 patients. This was an indication for tracheoplasty. The following gives the functional results of these operations.

a. Short, soft tracheal stenoses: external stentings (Schobel)

15 short, soft tracheal stenoses were operated with external (Schobel) stentings (Beck 1968). We have found that almost all patients came into the upper-normal range of air-way resistance after intervention (mean value at 30.4 mm H_2O/l and sec). Where Schobel stentings failed to achieve the effect desired, we continued through installation of a groove.

b. Long, soft tracheal stenoses: formation of grooves

We had to install a tracheal groove (Lange, 1975) in 23 patients suffering from long, soft tracheal stenoses and in those cases who could not be fitted with

external Schobel stentings. The mean postoperative air-way resistance registered 34.5 mm H_2O/l and sec corresponding to a tracheal diameter of 7–8 mm. The remaining obstruction presented no obstacle to breathing except during heaviest work. At first some patients complained of congestion, but this disappeared without exception after a few weeks of recovery for the ciliated epithelium.

c. Short, rigid tracheal stenoses: bouginage

14 short, rigid tracheal stenoses, which crop up in numbers after a lengthy intubation period, were treated with a bougie (Lange, 1975). It suffices in many instances to use this treatment only once, though repeated interventions are occasionally necessary. An additional application of cortisone has proven valuable. The mean value of our measurements, following bouginage, was 27.1 mm H_2O/l and sec corresponding to a diameter of 8 mm. Though the results of such treatments were not always satisfactory, they should be tried in selected cases such as cicatrical pterygium, because of their simplicity

d. Short, rigid tracheal stenoses: horizontal resection

6 short, rigid tracheal stenoses on which we could not perform a bouginage, were resected. A mean value of 28.2 mm H_2O/l and sec was established postoperatively. This corresponds to an average tracheal diameter of 8 mm.

e. Long, rigid tracheal stenoses: formation of grooves

The installation of a groove, in the case of 45 long, rigid tracheal stenoses, takes months to accomplish. Several operative measures are often needed. We noticed that normal diameters of over 15 mm and the corresponding air-way resistances of 15 mm H_2O/l and sec could only seldom be achieved. Our mean value was 28.5 mm H_2O/l and sec, at a diameter of 8 mm. This average width is fully adequate for work of medium endurance, and none of the patients was in discomfort.

Table 3. The development of air-way resistances (mm H_2O/l and sec) following tracheal intervention. The standard deviation of individual values is given in brackets.
As can be seen in Table 3, there is no danger of late stenoses following tracheal intervention. Within the last 6 years, we have not seen any trachea becoming narrow again after the completion of an intervention.

diagnosis	therapy	number of cases	praeoperative values	—1 year postoperative values	—2 years postoperative values	>2 years postoperative values
tracheomalacia	external stenting (Schobel)	12	96,72 (±34,49)	30,42 (±14,84)	31,08 (±5,39)	30,88 (±6,02)
tracheomalacia	open groove	23	116,56 (±55,85)	34,48 (±12,50)	33,08 (±11,11)	33,80 (±5,92)
cicatricial tracheal stenosis	bouginage	13	122,25 (±67,17)	27,94 (±11,43)	27,50 (±7,99)	27,73 (±5,98)
cicatricial tracheal stenosis	open groove	37	111,63 (±64,05)	29,28 (±12,35)	29,11 (±9,20)	29,26 (±9,14)

LONG-TERM RESULTS

Following tracheal intervention, a total of 85 patients were followed-up with air-way resistance measurements over several years duration (Table 3).

RÉSUMÉ

Sur 485 sténoses laryngées et trachéales nous avons effectué la mesure de la résistance des voies aériennes par pléthysmographie (body-plethysmography). La décision d'intervenir chirurgicalement fut prise dans 143 cas où nous avons trouvé des valeurs supérieures à 60 mm H_2O/l et sec. Ces cas se répartissent comme suit:

Dans 49 cas de paralysie du nerf récurrent nous avons effectué une fixation latérale d'une corde vocale. Les meilleurs résultats fonctionnels en période post-opératoire furent obtenus dans les cas où la résistance atteignait des valeurs aux alentours de 30 mm H_2O/l et sec (valeur normale: 14.77 $\pm$ 6,53; n = 387). Les malades avaient alors une bonne tonalité et étaient en même temps capables d'effectuer un travail moyen. Sur 94 maladees atteints de sténoses de la trachér naus avons effectué des plasties trachéales. Dans ce cas la valeur moyenne post-opératoire était de 29.9 mm H_2O/l et sec, ce qui correspond à un diramètre minimal, mais n'etait guère ressenti comme tel que par d'aucuns. Seuls les grands efforts étaient impossibles. Nous n'avons observé aucun cas de récidive après la fin du traitement.

Enfin nous avons constaté des résistances supérieures à 150 mm H_2O/l et sec dans 73 cas en cours de traitement et chez 24 malades à l'admission au service. Dans tous les cas il s'agissait d'insuffisances respiratoires aigues qui nécessitaient l'intervention rapide par trachéotomie ou intubation pour sauver la vie du malade.

ZUSAMMENFASSUNG

An 485 Kehlkopf- und Luftröhrenengen führten wir Atemwegswiderstandsmessungen mit einem Körperplethysmographen durch. In 143 Fällen faßten wir mit Werten größer als 60 mm H_2O/l und sec den Entschluß zur Operation. An 49 Patienten mit doppelseitiger Recurrensparese wurde eine Stimmlippe lateral-fixiers. Es zeigte sich, dass postoperativ bei leicht erhöhten Widerständen um 30 mm H_2O/l und sec (Normalwert: 14.77 $\pm$ 6.53 — n = 387) die günstigsten funktionellen Ergebnisse auftraten: Die Patienten hatten eine feste Stimmgebung und ausreichend Luft auch zu mittelschwerer Arbeit.

An 94 Trachealstenosen führten wir Trachealplastiken durch. Postoperativ resultierten im Mittel ein Widerstand von 29.9 mm H_2O/l und sec entsprechend einer Trachealweite von 7–8 mm. In der Praxis hat es sich gezeigt, dass die Restenge nur von den wenigsten als solche verspürt wurde. Nur maximalen

körperlichen Anstrengungen waren Grenzen gesetzt. Spätrezidive nach abgeschlossener Behandlung wurden in keinem Fall beobachtet.

Bei 24 Neuzugängen und 73 mal im Rahmen der Behandlung sahen wir Atemwegswiderstände größer als 150 mm H_2O/l und sec. Hier drohte Erstickungsgefahr. In allen Fällen mußte umgehend tracheotomiert oder intubiert werden, um das Leben des Patienten nicht unnötig zu gefährden.

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