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Evaluation of upper airway obstruction after partial laryngectomies by radiological method and flow–volume loop analysis

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Abstract

Anatomical and functional estimations of the upper airways in patients after partial laryngectomies (cordectomy, hemilaryngectomy, enlarged hemilaryngectomy) carried out due to cancer are discussed in this paper. The post-operative lumen of the larynx and the trachea were estimated by radiological examination. The coefficient larynx/trachea (L/T) was proposed to describe fixed obstruction.

At the same time, all patients underwent spirometric examinations. Inspiratory and expiratory parameters of the flow–volume loop were evaluated. In 39 patients the L/T coefficient was lower than in a group of patients with chronic bronchitis ($p<0.05$). Also inspiratory and some expiratory parameters of the flow–volume loop decreased in contrast to the group with chronic bronchitis. All results showed the usefulness of radiological and spirometric methods in detecting upper airway obstructions and confirmed their fixed character. The influence of the area of operation on the degree of upper airway obstruction was emphasized.

Key words: Laryngeal neoplasms, surgery; Respiratory function tests

Introduction

Partial laryngectomies due to cancer have been introduced gradually since the end of the C19th (Bailey and Biller, 1985). These operations help to preserve the natural protective, respiratory and phonatory function of the larynx in comparison to total laryngectomies, where all these functions are lost.

There are many different kinds of partial laryngectomies depending on the spread and location of the cancer. Partial laryngectomies include cordectomy, hemilaryngectomy and also enlarged hemilaryngectomy. They are performed in one half of the larynx only, not exceeding the median line, by a common method of surgery. In this paper we have evaluated the anatomical and functional disturbances of the upper airway after partial laryngectomy. To evaluate functional disturbances in air flow we applied flow–volume loop analysis.

Conventional spirometry records the forced respiratory manoeuvres as the expired or inspired volume *versus* time. Since the instantaneous change in volume *versus* time is gas flow, it is possible to compute and plot the spirogram as flow *versus* time or flow *versus* volume. The more common and widely used approach is the flow–volume curve presentation. The advantage of the flow–volume curve is that instantaneous flow can be determined at any point in the vital capacity. The classification of the flow–volume loop changes in upper airways obstruction was proposed by Miller and Hyatt (1973) and Miller (1985). They suggested three main types of flow–volume loop disturbances: (1) fixed upper airway obstruction where both inspiratory and expiratory flow–volume loop parameters were diminished; (2) variable extrathoracic, where only the inspiratory part of the flow–volume loop was affected; and (3) intrathoracic where only the expiratory part of the flow–volume loop parameter was diminished.

The aim of this study was to classify spirometric and flow–volume loop changes into one of the proposed types and distinguish the eventual influence of coexisting chronic bronchitis on the flow–volume loop in patients after operations.

Materials and methods

Thirty-nine male patients from the II Clinic of Laryngology, Silesian Medical Academy, Zabrze were studied. They were operated on for cancer between the years 1978 and 1988. In all of them laryngeal carcinoma was histologically confirmed. They were aged 32 to 70 years (mean 55 years) and divided into three groups depending on the type of operation.

Radiological and flow–volume loop examinations were also performed in 20 patients with chronic bronchitis. They were carefully selected for sex, age, growth, body weight and the two spirometric parameters forced vital capacity (FVC) and forced expiratory volume at the first second (FEV_1) were taken into account. FVC and FEV_1 changed as the last spirometric parameters in upper air-

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TABLE I
VALUES OF L/T COEFFICIENT AND SPIROMETRIC PARAMETERS (MEAN $\bar{x}$; standard deviation ± SD)

Group	Age (years)	L/T coefficient	Expiratory parameters of flow–volume loop					Inspiratory parameters of flow–volume loop		PIF/PEF ratio	FIF_{50}/FEF_{50} ratio
			FVC	FEV_1	FEF_{50}	FEF_{25}	PEF	PIF	FIF_{50}		
Group 1	$\bar{x}$ 54	$\bar{x}$ 0.21*	80.0	79.2	77.0	97.0*	77.2	3.40	3.12	0.52	1.4
n = 19											
Cordectomy	(41–68)	±SD 0.06	2.0†	2.6†	5.0	5.2	3.2†	1.6	1.3	2.0	8.7
Group 2	$\bar{x}$ 56	$\bar{x}$ 0.16*	73.8	70.5	60.0	68.1	65.7	2.29*	2.00*	0.42*	1.17
n = 12											
Hemilaryngectomy	(38–70)	±SD 0.04	9.7†	2.9†	3.7†	3.8	2.1†	9.1	8.5	9.4	1.0
Group 3	$\bar{x}$ 51	$\bar{x}$ 0.18*	84.8	79.3	64.3	75.0	68.0	2.28*	2.25*	0.45*	0.87*
n = 8											
Enlarged hemilaryngectomy	(32–54)	±SD 0.05	1.5†	1.5†	2.2†	3.1	2.1†	6.8	7.0	1.4	5.5
All patients operated on	$\bar{x}$ 53	$\bar{x}$ 0.19*	79.0	76.6	69.6	83.9*	72.0	2.86*	2.60*	0.50	1.13*
n = 39	(32–70)	±SD 0.06	2.1†	2.5†	4.2†	4.9	2.7†	1.3	1.2	1.7	8.7
Group of patients with chronic bronchitis	$\bar{x}$ 52	$\bar{x}$ 0.48	84.6	75.0	54.4	59.3	74.3	3.87	3.65	0.65	1.71
n = 20	(36–68)	±SD 0.14	1.8†	2.0†	2.6†	2.3	2.5†	1.6	1.4	1.6	7.2

*Statistically significant in comparison to the group with chronic bronchitis.
†Statistically significant in comparison to values of healthy subjects.
FVC, FEV_1, FEF_{50}, FEF_{25}, PEF: (%) of predicted values. PIF, FIF_{50}: (l/s)

way obstruction (Pierzchala, 1982). All patients underwent the same examination. They had a full ENT examination and a general consultation to exclude other diseases which could influence the results.

The post-operative lumen of the larynx and the trachea were estimated by X-ray examination. The larynx and trachea were X-rayed in the frontal (a–p) and saggital (lateral) planes. Then the distance between anterior and posterior commissure of the larynx was measured and marked as 'h'. Also, the diameter of the trachea at the second ring level was measured and marked as '2r'. From the (a–p) plane we measured the width of the post-operative larynx. X-ray examination was carried out during the calm inspiration (positio-respiratoria). We marked this width 'a'. Assuming that the shape of the rima glottis was similar to the triangle, we calculated its area using the formula for the area of a triangle. The cross-sectional area of the trachea was approximated by a circle and calculated according to the formula for its area.

The new coefficient larynx/trachea (L/T) was applied. It is a quotient from the larynx and trachea areas and introduces the lumen of the larynx post-operatively and the whole upper airway. It diminishes the influences of the differences in sex, age, growth and body weight of the patients. The coefficient L/T also takes into consideration possible cicatricial contraction of the trachea after prior tracheotomy.

The flow–volume loop parameters were obtained in each patient according to SEPCR guidelines (Quanjer, 1983) by means of a pneumotacheograph transfer-screen II Jaeger (Würzburg).

The flow–volume loop was composed of the following parameters: FVC i.e. forced vital capacity; FEV_1 i.e. forced expiratory volume at the first second; FEF_{50} i.e. forced expiratory flow at the moment when there is 50 per cent of the vital capacity in the lungs; FEF_{25} i.e. forced expiratory flow at the moment when there is 25 per cent of the vital capacity in the lungs; PEF i.e. peak expiratory flow; PIF, i.e. peak inspiratory flow; FIF_{50} i.e. forced inspiratory flow at the moment when there is 50 per cent of the vital capacity in the lungs.

The results of the expiratory part of the flow–volume loop were expressed in percentage of predicted values according to SEPCR (Quanjer, 1983; Miller and Pincock, 1988). To characterize the shape of the loop we introduced two further coefficients: PIF/PEF and FIF_{50}/FEF_{50}. They allowed a comparison of the inspiratory and expiratory part of the flow–volume loop (Jordanglou and Pride, 1968; Shim *et al.*, 1972). The inspiratory parameters because of a lack of predicted values were expressed in l/s.

For a comparison of the results between groups 1, 2 and 3 the Kruskal–Wallis test was used. For a comparison of the results of the whole group of patients ($n = 39$) with the group with chronic bronchitis Student's t-test was used.

All expiratory flow–volume parameters obtained were expressed as standardized residuals according to Miller and Pincock (1988):

$$SR = \frac{x - x_n}{RSD}$$

where: SR = standardized residuals; x = recorded value; x_n = predicted value; RSD = residual standard deviation from the regression equation used for the prediction.

According to SEPCR (Quanjer, 1983) and Miller and Pincock (1988) recommendations in the healthy population the expressed parameters are within the normal range if their values expressed as standardized residuals (0 ± 1.96). Therefore the results obtained in patients who had been operated upon and one group of patients with chronic bronchitis expressed as standardized residuals were compared with reference to healthy subjects using Student's t-test (Sawicki, 1981).

Results

Mean value of the L/T coefficient in the group of patients with chronic bronchitis was statistically significantly higher than in the examined group of patients taken together and separately. There were no statistically significant differences in the L/T ratio between particular groups of patients, although in groups 2 and 3 the differences were lower than in group 1.

Mean values of the FVC, FEV_1, FEF_{50} and PEF in all examined patients were significantly lower in comparison to the healthy population. The expiratory parameters did not differ significantly within the examined groups of patients.

In patients with chronic bronchitis all expiratory parameters including FEF_{25} were significantly reduced in comparison to the healthy population ($p<0.05$). All patients after their operations showed significantly higher values of FEF_{25} than patients with chronic bronchitis.

In all patients and in groups 2 and 3 separately the inspiratory parameters (PIF, FIF_{50}) were significantly lower than in patients with chronic bronchitis. In group 1 this parameter did not differ significantly from parameters for patients with chronic bronchitis. The coefficients PIF/PEF and FIF_{50}/FEF_{50} were the lowest in group 3 and were significantly lower than in patients with chronic bronchitis.

We found a significant correlation in the whole group of examined patients after surgical procedure between L/T and PIF ($r = 0.34$; $p<0.03$), PEF ($r = 0.55$; $p<0.01$), FEF_{50} ($r = 0.72$; $p<0.001$), FEF_{25} ($r = 0.66$; $p<0.001$), FIF_{50} ($r = 0.31$; $p<0.05$).

In contrast there was no correlation between the L/T ratio and examined parameters of the flow–volume loop observed in the group of patients with chronic bronchitis.

Discussion

The results obtained indicate that all surgical procedures on the larynx cause anatomical and functional impairment. There were radiological signs of stenosis of the upper airway, expressed by a reduced L/T ratio. Also, both expiratory and inspiratory parts of the flow–volume loop were affected. More decreased parameters of the flow–volume loop were observed in patients after more extensive surgical procedure.

The correlations between the L/T ratio and some the flow–volume loop parameters can indicate that the L/T ratio diminished in patients after the surgical procedure influenced directly the flow–volume loop parameters.

The shape of the flow–volume loop characterized by values of the expiratory and inspiratory parameters suggest a fixed obstruction of the upper airway (Miller and Hyatt, 1973). This fixed type of upper airway is well known in patients with laryngeal tumours, vocal fold paralysis, stenosis of the trachea (Shim *et al.*, 1972; Pierzchala, 1982). In available laryngological and pulmonological literature the problem concerning the influence of laryngeal operations on air flow has not been studied yet, so we cannot compare our results with other authors' results.

Our results also suggest that patients with chronic bronchitis can be distinguished from post-operative laryngeal patients on the basis of inspiratory parameters which are unaffected in chronic bronchitis. The end-expiratory parameters (FEF_{25}) are more diminished in patients with chronic bronchitis than in patients after surgical procedures.

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