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The impact of subtotal strumectomy on respiratory function in patients with thyroid-induced tracheostenosis

Stenosis of the upper respiratory tract is a relatively rare cause of respiratory complications though clinically significant due to a potential life-threatening acute respiratory failure. Larynx is the most common stenosis localization (1, 3, 5, 11), followed by trachea. Stenoses can be primary or secondary. Secondary stenoses are caused by external compression, among which thyroid pathology is the most common cause (14). Thyroid pathology, which is mostly goiter, can narrow the trachea by direct compression or translocation. Retrosternal localisation especially facilitates trachea's deformation due to rigid bone structures of upper thorax aperture. A slight volume increase of one organ in this narrow space can lead to translocation and deformation of other structures. Even trachea, although furnished with stiff cartilages, cannot withstand the constant pressure for a longer time. This leads not only to reversible stenosis but can also result in an organic malformation of trachea wall.

Adequate respiratory efficiency, measured by spirographic and arterial blood gas analysis, depends mostly on undisturbed air flow and lung condition. The influence of a single factor on overall respiratory efficiency is difficult to evaluate because of complexity of the airflow in different parts of airways.

The aim of this study was to evaluate the respiratory function and efficiency in patients with tracheostenosis due to goiter and the impact of subtotal strumectomy on this efficiency.

MATERIAL AND METHODS

Fifty nine patients with goiter of different etiology were included in the study. All the patients were diagnosed and pre-evaluated in the Internal Medicine Department of Voivodship Specialistic Hospital in Radom between June 1996 and March 1999 and subsequently operated on in the Thoracic Surgery Department of Medical University in Lublin. The evaluated population consisted of 53 women aged 15 to 65 (average 43.3) and 6 men aged 21 to 68 (avg 45.7) years. In 43 cases the goiter was localized on neck, in 16 (27%) cases retrosternally. According to WHO criteria 20 patients had II grade goiter, 39 – III grade. Thirty eight patients (64.3%) required thyreostatic treatment before operation, the remaining 21 had normal thyroid function. Thirteen patients had Graves-Basedow goiters, 25 hyperthyroid nodular goiters and 21 simple nodular goiters.

The grade of stenosis was measured as a relative loss of cross-section related to the widest section of the trachea. The evaluation was performed with the use of neck x-ray in two projections: lateral and anteroposterior. Measured diameters (lateral and frontal) were used to calculate the cross-section field (assumed as a field of ellipse) with the use of formula $X=\pi*a/2*b/2$, where: a – anteroposterior diameter of trachea lumen, b – lateral diameter of trachea lumen.

According to percentage loss the patients were subdivided into four groups as in Table 1.

Table 1. Groups according to the grade of stenosis

Group	Relative loss of cross-section trachea field	Number of patients
I	up to 25%	11
II	25–50%	22
III	50–75%	16
IV	above 75%	10

We analyzed: 1) grade of stenosis, according to measured trachea's dimensions, 2) respiratory function, evaluated by spirography (TV, VC, IC, FEV_1, $FEV_1\%VC$, PEF, PIF, $MEF_{50\%}$, $MIF_{50\%}$, FEV/PEF, $MEF_{50\%}/MIF_{50\%}$) and arterial blood gas analysis (PaO_2, $SatO_2$, $PaCO_2$, pH), 3) clinical evaluation of symptoms and patients' complaints. All the parameters were measured twice: directly before the surgery and three months after it. The relative stenosis (ΔX) was calculated with the following formula: $\Delta X=(D2-D1)/D2*100\%$, where: D1 – field of cross-section in the narrowest part of trachea calculated as above, D2 – field of cross-section in the widest part of trachea.

Respiratory functions were evaluated with the use of ABC Pneumo 2000 spirometer, and CIBA Corning 248 blood gas analyzer.

The average values, standard deviations and net differences before and after surgery were statistically analyzed with Systat 7.0. Student's T-test was used to check statistical significance of observed differences between evaluated parameters.

RESULTS

The average diameters of trachea's lumen and average cross-section field deficiencies are shown in Table 2.

Table 2. Trachea's measurements before and after surgery

Group	Before surgery					After surgery				
	widest part		stenosis		avg. cross-section field loss	widest part		stenosis		avg. cross-section field loss
	a (mm)	b (mm)	a (mm)	b (mm)		a (mm)	b (mm)	a (mm)	b (mm)	
I	16.1	16.1	14.9	15.1	13.0%	16.6	17.4	16.3	17.0	3.5% $p<0.05$
II	16.3	16.5	12.4	12.8	41.8%	16.7	17.4	15.9	15.8	12.9% $p<0.05$
III	15.7	16.0	9.7	10.3	60.6%	16.1	16.7	14.6	15.3	16.1% $p<0.05$
IV	15.6	16.3	5.6	8.5	81.4%	17.0	16.9	15.8	15.3	8.4% $p<0.05$
Total	16.0	16.3	11.1	11.9	48.2%	16.6	17.1	15.6	16.0	11.3% $p<0.05$

Subtotal strumectomy resulted in a significant widening of the stenosis in all groups. The improvement was the highest in group IV.

Table 3 summarizes average values of spirometric parameters before and after surgery.

Table 3. Comparison of spirometric parameters

Group	Time point	TV (l)	VC (l)	IC (l)	FEV_1 (l)	FEV_1% VC (%)	PEF (l/s)	PIF (l/s)	$MEF_{50\%}$ (l/s)	$MIF_{50\%}$ (l/s)
I	before	0.606	4.020	2.775	3.341	83.073	7.952	4.161	5.194	4.120
	after	0.508	3.792	2.327	3.254	86.251	7.074	5.400	4.745	5.205
II	before	0.582	3.308	2.175	2.658	79.669	6.105	3.970	3.718	3.748
	after	0.462	3.289	2.192	2.715	82.979	6.195	3.633	3.908	3.486
III	before	0.496	3.158	2.143	2.662	84.825	5.564	3.681	3.934	3.474
	after	0.361	3.108	2.001	2.598	85.813	5.771	3.809	3.717	3.475
IV	before	0.573	3.419	2.184	2.536	71.780	4.692	3.803	3.369	2.966
	after	0.628	3.257	2.224	2.804	84.651	6.866	4.501	4.022	3.512
Total	before	0.562	3.419	2.280	2.766	80.365	6.063	3.899	3.992	3.611
	after	0.472	3.328	2.171	2.799	84.641	6.358	4.157	4.032	3.808

TV – tidal volume, VC – vital capacity, IC – inspiratory capacity, FEV_1 – forced expiratory volume 1 second, FEV_1%VC – FEV_1 as % of VC, PEF – peak expiratory flow, PIF – peak inspiratory flow, $MEF_{50\%}$ – maximum expiratory flow at 50% expiration volume, $MIF_{50\%}$ – maximum inspiratory flow at 50% inspiration volume

The average tidal volume (TV) increased after surgery only in group IV. In the other groups TV decreased, but it achieved statistical significance only in group II. In all the groups vital capacity (VC) was lower after surgery, this decrease being statistically significant in group I ($p<0.05$). Inspiratory capacity (IC) decrease was also statistically significant in group I ($p<0.05$). The increase of FEV_1 was not statistically significant, but the analysis of FEV_1%VC revealed a statistically significant increase after surgery in group IV. Analysis of flow measurements revealed a slight but statistically significant increase of PEF and MIF_{50}% only in group IV. The changes of PIF and MEF_{50}% were not significant in all the groups. Values of FEV_1/PEF remained mostly unchanged in groups I–III, but in group IV (where average value was above 8.0 before surgery) it decreased after strumectomy and the difference was statistically significant. Analysis of parameters in all the groups revealed that statistically significant were changes of TV and FEV_1%VC.

The average values for blood gas analysis before and after surgery are summarized in Table 4.

Table 4. Average values of blood gas analysis before and after surgery

Group	Time point	PaO_2 (mmHg)	$SatO_2$ (%)	$PaCO_2$ (mmHg)	pH
I	before	83.64	95.90	40.75	7.43
	after	88.23	96.88	38.85	7.45
II	before	82.23	94.62	39.20	7.43
	after	87.75	96.76	38.07	7.45
III	before	88.34	96.53	38.49	7.42
	after	81.98	95.60	39.09	7.40
IV	before	78.76	93.63	38.22	7.44
	after	87.00	97.03	36.33	7.45
Total	before	83.56	95.21	39.13	7.43
	after	86.15	96.51	38.20	7.44

PaO_2 – partial pressure of oxygen, $PaCO_2$ – partial pressure of carbon dioxide, $SatO_2$ – blood oxygenation

Changes of PaO_2 were not significant. The biggest increase was observed in group IV. There were statistically significant differences of $SatO_2$ and $PaCO_2$ in group I. All other changes were not significant. The average changes of blood gas parameters were not significant when analyzed in total for all the groups. Gender had nearly no influence on the analyzed parameters, apart from changes of FEV_1%VC, which were significantly higher in men. Age was also not correlated with changes of the analyzed parameters. Retrosternal goiter influenced a decrease of IC. Change of PIF was significantly higher in patients with III[rd] grade goiter in comparison to II[nd] grade goiter. Blood gas parameters' changes were not correlated with age, gender or goiter grade and localization.

All the patients achieved clinical improvement after surgery. Usual pre-treatment symptoms or complaints like dyspnoe, stridor, *vena cava superior* syndrome or poor exercise tolerance were resolved or noticeably decreased. All the patients were satisfied with surgery results, though two of them reported persistent subjective discomfort in the neck which diminished after surgery but not disappeared completely.

DISCUSSION

The severity of respiratory failure still remains a complex result of stenosis and underlying pulmonary pathology (11, 14). Most authors agree that even heavy stenosis does not have to result in a respiratory failure as the compensation capabilities of respiratory system are extremely high. According to Perelman (11), the decompensation symptoms start to be recognizable when more than 50% of previous trachea's lumen is missing. Nevertheless, symptoms of respiratory distress could be expected even if only 1/3 of previous lumen is missing when inflammation process coexists (9, 10). Because the airflow in strictured trachea is turbulent, the airway resistance is inversely proportional to the trachea's lumen radius to fifth power. That is why the respiratory insufficiency arises so quickly with any further narrowing. In patients with stenosis greater than 50–70% of initial lumen respiratory distress can be life-threatening (11). Despite this, acute respiratory failure due to thyroid pathology remains relatively rare. Overall quota of such cases among all thyroid-related stenoses remains consistently low at 2–3% abroad (7, 15) and even in Poland at 0.5% (6). In rare cases of acute tracheostenosis, for instance due to haematoma or direct trauma, the severity of symptoms does not correlate directly with the grade of the stenosis (6, 11).

The basic diagnostic method of tracheostenosis evaluation is a plain radiogram in two projections: antero-postrior and lateral. This simple procedure is not accurate enough in cases of tracheomalation when the tracheal walls dynamically collapse during breathing. Computer tomography seems to be a more precise method for diagnosing potential causes and severity of tracheal pathology. A plain radiogram seems to be relatively accurate in cases of simple stenosis due to non-malignant goiters and was used in many studies for initial evaluation of stenosis.

Demedts et al. tried to establish the correlation between tracheostenosis and spirometric findings. They compared a group of patients with thyroid-related stenosis (proved with X-ray and CT) with a group of free volunteers simulating the stenosis by breathing through a stiff tube (2). They were not able to find a good correlation between spirometry and radiological findings. The changes in spirometric evaluation were statistically insignificant. Only PEF reduction was consistently diminished, but definite changes in spirometry were observed when the airway diameter was 6mm or smaller. They also observed that only about 60% of stenoses diagnosed by CT were visible on plain X-ray. This could be a result of different position of the patient during both diagnostic procedures (horizontal at CT and vertical at X-ray).

Blood gas analysis is an ultimate test of respiratory function. Any significant airflow disturbance should lead to its changes. Thus, huge compensative capabilities of respiratory system limit the usefulness of this evaluation method to the most severe cases of stenosis. Levels of blood gases correspond better with the condition of lungs than with airflow disturbances.

The influence of thyroid-related tracheostenosis on respiratory function is not only correlated with goiter size but also its localization. Retrosternal goiter is more likely to cause tracheostenosis. The study of Miller and Pincock reports 50% incidence of retrosternal goiter in the group of patients with stenosis and only 33% in patients without stenosis (8). In other studies trachostenosis was observed in 72.9% and 80% of retrosternal goiters (12). These cases were also reported to have poorer clinical and functional outcome, with the increased incidence of complications, need of intubation after surgery and not satisfactory surgery results. Relatively low incidence of retrosternal goiters in our material (27%) can be responsible for better results in our study. We observed only one case of tracheal walls collapse after surgery, requiring 24-hours intubation. All other patients did not require such procedures, contrary to some literature suggestions.

It remains not sufficiently proven which of the functional tests correspond best with the grade of tracheostenosis and what kind of changes are to be expected due to it. Our study reveals a consistent, although slight, decrease of flow parameters and increase of tidal volume, due to stenosis. These changes reformed consistently after trachea-widening surgery. Increase of $FEV_1\%/VC$ seems to correspond best with clinical improvement after strumectomy.

The flow/time loop analysis was introduced to pulmonary evaluation for more precise diagnosis and description of airflow changes in bronchial asthma and COPD. In some trials this method was also used to evaluate tracheal airflow. Jaurequi et al. revealed that 60% of patients with goiters had changes in flow/time loop and that these changes disappeared after strumectomy. Other authors suggested that FEV_1/PEF ratio, higher than 10, may be useful in differentiation of upper and lower respiratory tract obstruction. Miller and Pincock still suggest that FEV_1/PEF higher than 8.0 has 64% sensitivity and 90% specificity in diagnosing of upper respiratory tract obstruction. Our observations revealed FEV_1/PEF over 8.0 only in patients with most exacerbated stenoses (over 75% of lumen loss).

The correlations of blood gases analysis with tracheostenosis seem to be extremely complex. Due to huge adaptation capacity of respiratory and cardiovascular system the changes in blood gases' levels were observed only in cases of severe stenosis (group IV). In the beginning tracheostenosis seems to affect blood oxygenation and subsequently also the level of $PaCO_2$. Appearance of such changes suggests on-coming decompensation and should be recognized as an acute respiratory failure warning. Surgical treatment should not be delayed in such cases.

Our observations are mostly consistent with literature data: retrosternal goiter is more prone to cause tracheostenosis. High grade stenosis leads to measurable changes in respiratory function tests. That corresponds with a widely accepted opinion that clinical symptoms of stenosis appear when the trachea diameter falls below 6 mm (2). Usefulness of FEV_1/PEF ratio higher than 8.0 as a sign of tracheostenosis seems to be proven, but MEF_{50}%/MIF_{50}% of more than 1.0 seems not to be correlated with stenosis. We conclude that tracheostenosis due to goiter remains without significant influence on respiratory function test unless less than 75% of previous lumen is missing. Strumectomy allows achieving satisfactory clinical results though they are generally immeasurable with respiratory function tests unless the stenosis is severe.

Patients with severe stenosis should be considered as having high-risk of developing a life-threatening acute respiratory failure and treated surgically without unnecessary delay.

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SUMMARY

The aim of the study was a comparative analysis of strumectomy results in patients with tracheal stenosis due to goiter including chosen parameters of respiratory function. We analyzed 59 patients treated with strumectomy due to goiter. The grade of stenosis was evaluated by conventional x-ray as a deficiency of the field of cross-section at the narrowest tracheal section. Evaluated and compared shortly before and 3 months after surgery were: spirography results (TV, VC, IC, FEV_1, FEV_1%VC, PEF, PIF, $MEF_{50\%}$, $MIF_{50\%}$, FEV/PEF, $MEF_{50\%}/MIF_{50\%}$), blood gas (PaO_2, $PaCO_2$, $SatO_2$, pH) and clinical status with subjective complaints. The lumen of trachea after surgery was significantly wider but it was not mostly related to a significant improvement of respiratory function parameters. Only the patients with more than 75% of lumen deficiency achieved a significant improvement of FEV1%VC. All the patients achieved clinical improvement. Tracheal stenosis due to goiter does not affect measurable respiratory function parameters significantly unless more than about 3/4 of initial trachea's lumen is lost. Strumectomy results in widening of the trachea that does not correspond with measurable parameters of respiratory function in most of the patients except those with more than 75% cross-section trachea's field deficiency.

Wpływ subtotalnej resekcji wola na wydolność oddechową chorych ze zwężeniem tchawicy w przebiegu wola

Celem pracy była ocena wpływu subtotalnej strumektomii na wydolność oddechową u chorych ze zwężeniem tchawicy w przebiegu wola na podstawie analizy wybranych parametrów oceny czynnościowej układu oddechowego. Badaniami objęto 59 chorych z wolem różnego pochodzenia, leczonych operacyjnie subtotalną strumektomią. Stopień zwężenia oceniano przy pomocy radiogramu jako względny ubytek pola przekroju tchawicy w miejscu największego zwężenia. Oceniono bezpośrednio przed zabiegiem i w trzy miesiące po nim i porównano następujące parametry: wyniki badania spirograficznego (TV, VC, IC, FEV_1, FEV_1%VC, PEF, PIF, $MEF_{50\%}$, $MIF_{50\%}$, FEV/PEF, $MEF_{50\%}/MIF_{50\%}$), gazometrycznego (PaO_2, $PaCO_2$, $SatO_2$, pH) oraz stan kliniczny i dolegliwości zgłaszane przez pacjentów. Po zabiegu obserwowano istotne statystycznie powiększenie pola przekroju tchawicy. Nie stwierdzono natomiast, by subtotalna resekcja wpływała istotnie na wartość średnią większości badanych parametrów spirograficznych i gazometrycznych z wyjątkiem pomiarów FEV_1%VC w grupie chorych ze zwężeniem tchawicy powyżej 75%. U wszystkich pacjentów stwierdzono poprawę kliniczną. Zwężenie tchawicy w przebiegu wola nie wpływa istotnie na wyniki badań czynnościowych układu oddechowego, o ile ubytek pola przekroju tchawicy nie przekracza 3/4 pierwotnego. Subtotalna resekcja tarczycy zwężającej światło tchawicy prowadzi do jej poszerzenia, nie wpływa jednak na parametry oceny wydolności oddechowej, z wyjątkiem chorych ze zwężeniem większym niż 75%, u których notuje się istotną poprawę.