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Gas exchange abnormalities and medical history features relationship in chronic obstructive pulmonary disease patients

Key words: *chronic obstructive pulmonary disease, smoking status, capnometry.*

Experts GOLD (Global Initiative for Chronic Obstructive Lung Disease) in 2011 identified: chronic obstructive pulmonary disease (COPD), a common preventable and treatable disease, is characterized by persistent airway limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients [8]. Pathological changes in COPD occur in the four structures of lungs: the central airways, peripheral airways, lung parenchyma, blood vessels of the lungs, which in various forms present in each patient. These different pathogenesis mechanisms leading to pathophysiological disorders – hypersecretion of mucus, mucociliary dysfunction, airway obstruction, lung hyperinflation, gas exchange abnormalities, pulmonary hypertension and systemic effects [10].

Breathing provides gas exchange of oxygen (O_2) and carbon dioxide (CO_2) between the environment and the body, depending on its metabolic demand and includes several stages. The first stages, or external respiration – the exchange of O_2 and CO_2 between the environment and the pulmonary capillary blood, includes two components: pulmonary ventilation – gas exchange between the environment and the alveolar air of the lungs and gas exchange between alveolar air and pulmonary capillary blood. The second stage of breathing – is blood transport of O_2 and CO_2, the third – the exchange of O_2 and CO_2 between blood and body cells and the fourth – tissue respiration. In the process of pulmonary ventilation resumed gas composition of the alveolar air. Alveolar ventilation directly affects the content of O_2 and CO_2 in the alveolar air and thus determines the nature of gas exchange between blood and alveolar air [3].

One of the factors for the maintenance of normal arterial blood gas concentration is the optimal ratio of alveolar ventilation (Va) and blood perfusion (Q). The optimum level of Va/Q should be 0,86. Reduced levels of this ratio lead to arterial hypoxemia and hypercapnia, increased means useless ventilation. Among the causes of arterial hypoxemia imbalance Va/Q is 95 %, and alveolar hypoventilation – 5 % of cases. Both pathogenic processes occur in COPD [9].

We study the possibility of non-invasive determination of gas exchange in patients with COPD with the use capnometry. Capnometry – a measurement and digital display of concentration or partial pressure of carbon dioxide (CO_2) in the air that the patient inhales or exhales during the respiratory cycle [7]. For pulmonary practice in general, and in the management of patients with COPD in particular, the possibility capnometry not understood. In the available literature there is no definitive data on the use capnometry in COPD and the matching results of capnometry to the anamnesis features.

This study was performed with the aim to improve the gas exchange abnormalities diagnosis in patients with COPD by applying techniques capnometry. For this purpose the following tasks were decided:

- provide the analysis of comorbidities in COPD patients;
- to examine the smoking status of patients in the study groups;
- to find the relationship between smoking status and capnometry results in COPD patients;
- to examine the impact of exposure to hazardous industrial and domestic factors on the gas exchange in COPD patients.

Materials and methods

This work was financed from the state budget of Ukraine.

The study was coordinated with the local Medical Ethics Committee of the NIPhP NAMS, participants were familiarized with the study protocol and signed an informed consent form to participate in the study.

Table 1

Gender and age distribution of patients

Indicators	Stage II COPD patients (n = 30)	Stage III COPD patients (n = 45)	Stage IV COPD patients (n = 25)
Mean age (years), (M ± m)	57,5 ± 2,1	59,0 ± 1,8	65,6 ± 1,8*
Male (number)	23	30	21
Male (%), (M ± m)	76,7 ± 7,7	66,7 ± 7,0	84,0 ± 7,3
Female (number)	7	15	4
Female (%), (M ± m)	23,3 ± 7,7	33,3 ± 7,0	16,0 ± 7,3

Note: * – statistically significant difference between patients with stage IV COPD and patients with COPD stages II and III, $p < 0,05$.

The diagnosis of COPD and the selection of patients regarding the stages of COPD was performed on the base of Order of Ministry of Health of Ukraine № 128 from 19.03.2007 «On approval of clinical protocols of medical care in Pulmonology» [2]. Patients with COPD were divided into three groups depending on the stage of the disease, which have the following names in further text:

- stage II COPD patients;
- stage III COPD patients;
- stage IV COPD patients.

All participants held a general physical examination, including anamnesis, focusing on the features of comorbidity, smoking status, presence of contact with industrial and household hazards, and also capnometry was performed.

Smoking history was calculated in terms of «pack-year». One pack-year smoking – is the average number of cigarettes that burned per day multiplied by the number of years of smoking divided by 20 (due to the fact that 1 pack contains 20 cigarettes). It is believed that the man had never smoked, if smoking index is less than 0,20 for a lifetime [6]. The total number of pack-year = number of cigarettes per day x number of years tobacco smoking / 20.

Capnometry was conducted on a set for the study of the cardiorespiratory system «Oxycon Pro», «Cardinal Health» (Germany), the following parameters were evaluated:

- end-tidal fractional concentration of carbon dioxide in exhaled air, % ($FETCO_2$, %);
- the volume of «dead» space (part of the air that does not participate in gas exchange), ml (Vde, ml);
- part of the «dead» space of the tidal volume, % (Vde%VT).

Anatomical «dead» space – is the upper airways, trachea, bronchi and terminal bronchioles, that do not participate in gas exchange. Alveolar «dead» space – is the alveoli that are ventilated but have not blood perfusion partially or completely. The amount of anatomical and alveolar «dead» spaces – is physiological or functional «dead» space. Value Vde/VT (dead volume / tidal volume) – physiological «dead» space as a proportion of tidal volume reflects Va/Q imbalance and normally at rest is about 0,3. Increasing this parameter indicates the imbalance of ventilation and perfusion [5].

Data collection and mathematical processing carried out by licensing software products included in the package Microsoft Office Professional 2007 license Russian Academic OPEN No Level № 43437596. Statistical analysis was performed using mathematical and statistical features MS Excel, as well as additional statistical functions developed by S. N. Lapach, A. V. Tschubenko, P. N. Babich [1]. The parameters studied in this work were evaluated by determining the mean (M), the mean error (m), reliability (t), the level of significance (p), parts (percentages) and their error followed by comparison using t Student-test. Correlation analysis was carried out using the parametric Pearson correlation with subsequent authenticated results using Student's criterion.

Regression analysis was performed using the statistical features MS Excel, a pair of linear regression equation was as follows:

$Y = kX + b,$

where Y – the resulting feature, X – factor variable, k and b – numerical parameters of the equation.

Results and discussion

The study involved 100 participants (74 men and 26 women) aged 38 to 84 years, mean age (61,0 ± 1,0) years. Distribution of patients in groups by sex and age are presented in table 1.

Data table 1 shows that the groups were not equally distributed by age, with increasing severity of disease as patient's age increases. In all investigated groups the proportion of men is higher than women. Identified age and gender differences generally correspond context that COPD is more common among males and persons older than 40 years [8].

The damage of the cardiovascular system: coronary heart disease, essential hypertension, atrial fibrillation dominated among comorbidity in COPD patients regarding anamnesis vitae. These conditions occurred in 18 (60,0 ± 8,9) % of patients with COPD stage II, 20 (44,4 ± 7,4) % of COPD patients stage III and 17 (68,0 ± 9,3) % of patients with stage IV COPD without statistically significant differences of the data between groups. Also there have been reported diabetes, OSAHS, chronic pancreatitis, chronic gastritis, chronic cholecystitis, osteochondrosis. Among the rare cases of comorbidity in patients with COPD were vibration disease, glaucoma, cataracts, anemia, varicose disease of the lower extremity veins, bronchiectasis, cochlear neuritis, cholelithiasis, obesity, lichen planus, chronic sinusitis.

Table 2

Smoking status of examined patients, n, % (M ± m)

Patient's groupe	n, %	No smokers	Past smokers	Current smokers	Smoking history, 10 pack years
Stage II COPD patients (n = 30)	n	11	11	8	33,4 ± 5,5
	%	36,7 ± 8,8	36,7 ± 8,8	26,7 ± 8,1	
Stage III COPD patients (n = 45)	n	16	18	11	40,7 ± 5,0
	%	35,6 ± 7,1	40,0 ± 7,3	24,4 ± 6,4	
Stage IV COPD patients (n = 25)	n	3	15	7	56,1 ± 6,3*
	%	12,0 ± 6,5	60,0 ± 9,8	28,0 ± 9,0	

Note: * – statistically significant difference between patients with stage II and IV COPD, $p < 0,01$.

We separately analyzed the comorbidities of the 15 patients, which have the case of hypercapnia according capnometry with $FETCO_2 > 5,5$ %. In these patients the incidence of coronary heart disease and essential hypertension is (86,7 ± 8,8) % (13 of 15 patients) and in patients without hypercapnia – in (49,4 ± 5,4) % (42 of 85 patients), statistically significant difference, $p < 0,01$. Thus, during hypercapnia the frequency of concomitant cardiovascular disease increases by almost twice.

Examined smoking status of patients reflects the current overall negative trend of tobacco smoking. Thus, in our country, 58 % of men and 14 % of women consider themselves smokers. Among adolescents 13 – 16 years the prevalence of smoking is 50 %. Ukraine takes the second place in the world in number of cigarettes burned per person per year [4]. Among the examined patients 70,0 % of individuals are current smokers or past smokers. Maximum individual length of smoking among patients examined reached in 61 (from youth to old age), the maximum index of smoking – 112 pack-years, and the number of cigarettes burned in a single day – 50 pieces (2,5 packs).

The characteristics of smoking status between groups of examined patients is shown in table 2.

The most quantity of current and past smokers are in stage IV COPD patients (28,0 ± 9,0) and (60,0 ± 9,8) % respectively. Index of smoking is highest in patients with stage IV – average (56,1 ± 6,3) pack-years, statistically significant relative to patients with COPD stage II – (33,4 ± 5,5) pack-years, $p < 0, 01$.

Inherent harmful impact of smoking on lung function is confirmed by the results of capnometry. Thus, the Pearson correlation coefficient r for smoking status and the part of the «dead» space of the respiratory volume (Vde/VT) is 0,65, $p < 0,05$ (fig. 1). According to the resume of the correlation analysis of the results of capnometry and smoking history can conclude that smoking contributes to a violation of ventilation and deepening of ventilation-perfusion imbalance.

Conducted regression analysis that describes the function of the dependent variables as ($Y = 0,1855 X + 25,305$), can provide the link between smoking history and part of the «dead» space in tidal volume ($Vde\%VT = 0,1855 \times$ smoking history + 25,305). That, each pack-year smoking increases the part of the «dead» space in tidal volume by about 0,2 % and thus contributes to deepen the imbalance of ventilation and perfusion (based on analysis of data from 100 patients examined by us with COPD, 70 of whom smoke or smoked in the past).

With certain industrial and household hazardous factors encountered 51 patients. Patients noted the following factors associated with certain professions: abrasive stone (caster), metal shavings (turner), chemicals, dust (tractor), tar, bitumen (roofer), dust, lime, cement (builder), plaster, fiberglass (sculptor), chlorine (employee treatment plant street). Average length of exposure to harmful factors was 21,6 years. The contact with harmful factors affects the course of COPD, because we examined patients revealed the relationship between duration of exposure to hazards and volume ventilation «dead» space that is defined by results of capnometry. The results show that between these parameters there is a strong direct correlation with statistical significance of $p < 0,05$. Thus, the Pearson correlation coefficient r for the duration of exposure to hazards and volume ventilation «dead» space (Vde) is 0,686 (fig. 2).

Conducted regression analysis that describes the function of the dependent variables as ($Y = 3,943 X + 171,15$), allows us to represent relationship between the duration of exposure to hazards and volume of «dead» space, defined by capnometry as ($Vde = 3,943 \times$ experience + 171,15). So every year contact with harmful environmental factors increases the amount of ventilation «dead» space of 4 ml (based on analysis of data from 100 surveyed our COPD patients, 51 of whom had contact with harmful factors).

Conclusions

1. Cardiovascular system diseases are dominated among comorbidity in COPD patients regarding anamnesis vitae, and in patients with hypercapnia the incidence of cardiovascular diseases is almost twice as high as in other patients from (49,4 ± 5,4) % to (86,7 ± 8,8) % , $p < 0,01$.

2. Smoking history is the highest in the fourth group – (56,1 ± 6,3) pack-years, statistically significant relative to patients with stage II COPD patients – (33,4 ± 5,5) pack-years, $p < 0,01$.

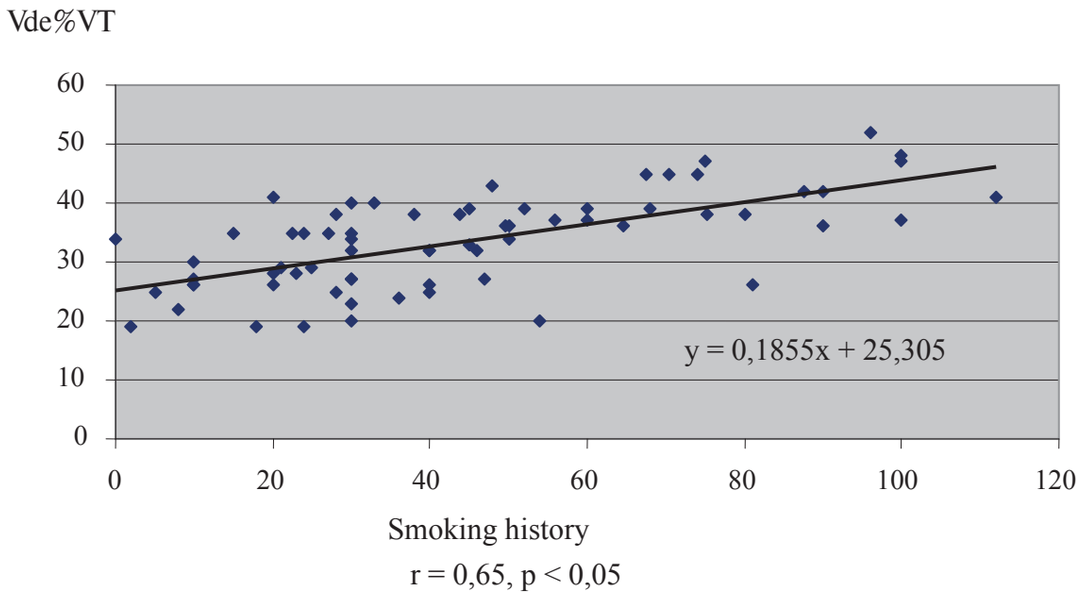

Figure 1. **Correlation between smoking hystory and the part of the «dead» space of the tidal volume and pair linear regression equation.**

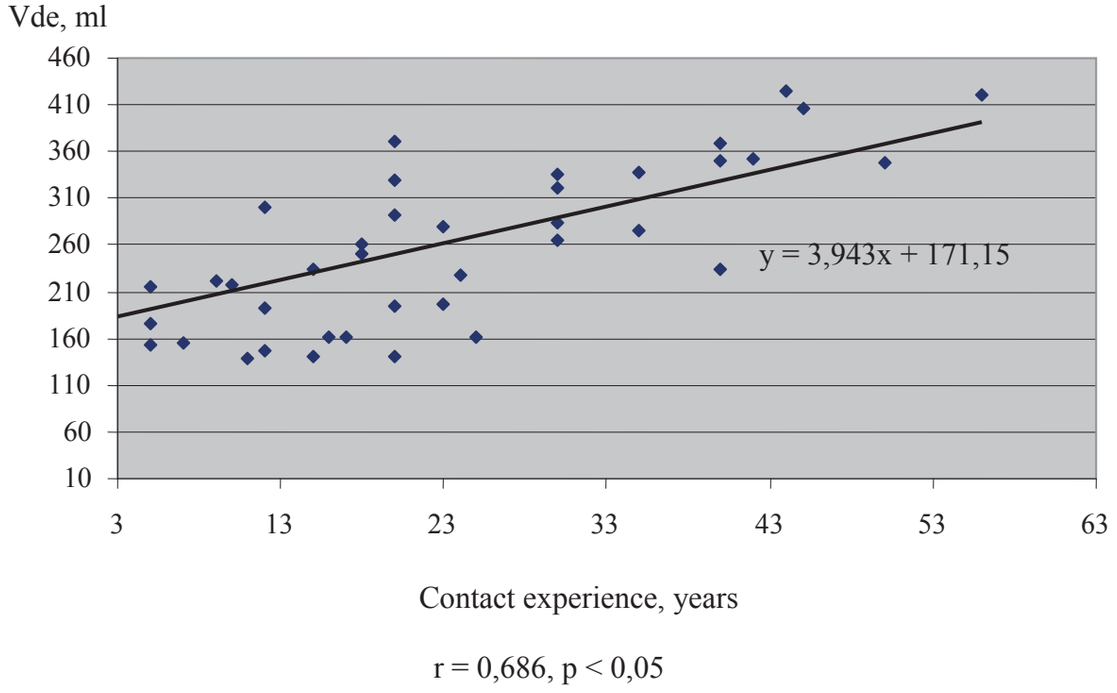

Figure 2. **Correlation between experience exposure to hazards and volume «dead» space and pair linear regression equation.**

3. Each pack-year smoking increases the part of «dead» space in tidal volume by about 0,2 % and thus contributes to deepen the imbalance of ventilation and perfusion (based on analysis of data from 100 COPD patients examined by us, 70 from which current or past smokers).

4. With certain industrial and household hazardous factors encountered 51 patients with COPD from 100, and each year contact with the surrounding hazards increases the volume of «dead» space ventilation in 4 ml (from capnometry data).

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GAS EXCHANGE ABNORMALITIES AND MEDICAL HISTORY FEATURES RELATIONSHIP IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENTS

S. G. Ishchuk

Summary

Background: *In chronic obstructive pulmonary disease (COPD) numerous pathophysiological disorders including disorders of gas exchange take place. We study the possibility of non-invasive determination of gas exchange parameters by capnometry and investigate the compliance between capnometry results and medical history features in COPD patients.*

The purpose of the study: *This study aimed to improve the diagnosis of gas exchange abnormalities in COPD patients with the use of capnometry.*

Results: *A total of 100 COPD patients were enrolled. In patients with hypercapnia the frequency of concomitant cardiovascular diseasei is almost twice higher than in the remaining patients (87 and 49 % respectively). A regression analysis demonstrates relationship between smoking status and «dead» space proportion in the tidal volume as (Vde%VT = 0,1855 × pack-year + 25,305) based on analysis of data obtained from 100 COPD patients, 70 of who are current or past smokers. 51 from 100 COPD patients had contacts with one or other industrial and household hazardous factors. The relation between duration of exposure to harmful factors and the defined by capnometry «dead» space ventilation is (Vde = 3,943 × experience + 171,15).*

Conclusions: *In patients with hypercapnia the incidence of cardiovascular disease is almost twice as high as in other patients. Each pack-year smoking increases the proportion of «dead» space in a tidal volume of about 0.2 %, and thus contributes to the deepening of the imbalance of ventilation and perfusion. Each year contact with harmful environmental factors increases the ventilation «dead» space volume of 4 ml (according capnometry).*

Key words: *chronic obstructive pulmonary disease, smoking status, capnometry.*

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ЗВ'ЯЗОК ПОРУШЕННЯ ГАЗООБМІНУ З ОСОБЛИВОСТЯМИ АНАМНЕЗУ У ХВОРИХ НА ХОЗЛ

С. Г. Іщук

Резюме

Обгрунтування: *При хронічному обструктивному захворюванні легень (ХОЗЛ) відбуваються численні патофізіологічні порушення, в тому числі розлади газообміну. Нами вивчається можливість неінвазивного визначення показників газообміну за допомогою капнометрії і досліджується відповідність результатів капнометрії особливостям анамнезу у хворих на ХОЗЛ.*

Ця робота виконується з метою поліпшити діагностику порушень газообміну у хворих на ХОЗЛ шляхом застосування методики капнометрії.

Результати: *Обстежено 100 хворих на ХОЗЛ. У хворих з гіперкапнією частота супутніх серцево-судинних захворювань майже вдвічі вище, ніж у решти хворих (87 % і 49 % відповідно). Проведено регресійний аналіз, що дає можливість представити зв'язок індексу куріння і частки «мертвого» простору в дихальному обсязі як (Vde%VT = 0,1855 × індекс куріння + 25,305) за результатами аналізу даних, отриманих у 100 обстежених нами хворих на ХОЗЛ, 70 з яких курять або курили в минулому. З тими чи іншими промисловими і побутовими шкідливими чинниками стикався 51 хворий ХОЗЛ з 100 обстежених. Встановлено зв'язок між показниками тривалості контакту з шкідливими факторами і об'ємом вентиляції «мертвого» простору, визначеного за допомогою капнометрії як (Vde = 3,943 × стаж + 171,15).*

Висновки: *У хворих з гіперкапнією частота серцево-судинних захворювань майже вдвічі вище, ніж у решти хворих. Кожен пачка-рік куріння збільшує частку «мертвого» простору в дихальному обсязі приблизно на 0,2 % і тим самим робить внесок у поглиблення дисбалансу вентиляції і перфузії. Щороку контакт зі шкідливими факторами навколишнього середовища збільшує обсяг вентиляції «мертвого» простору на 4 мл (за даними капнометрії).*

Ключові слова: *хронічне обструктивне захворювання легень, статус куріння, капнометрія.*

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