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S. G. Opimakh
State Organization «National Institute of Phthisiology and Pulmonology named after F. G. Yanovsky NAMS of Ukraine»

Possibilities of capnometry in alveolar ventilation assessment in chronic obstructive pulmonary disease patients

Key words: *chronic obstructive pulmonary disease, alveolar ventilation, capnometry.*

Chronic obstructive pulmonary disease (COPD) is one of the most important medical and social problems both in Ukraine and in the world. Its relevance is due to high rates of prevalence, morbidity, mortality and growing economic losses. The problems of COPD is insufficient emphasis on prevention, late diagnosis and lack of adequate treatment [3].

Gas exchange abnormalities are the part of the pathophysiology of COPD. In the Global Initiative for Chronic Obstructive Lung Disease (GOLD) summarized that gas exchange disorders – a reduction of ventilation and ventilation drive, worsening respiratory muscle function due to high work of breathing in severe obstruction and hyperinflation, ventilation-perfusion disorders are result in the hypoxemia and hypercapnia [6]. For COPD significant pulmonary ventilation (during which the gas composition of the alveolar air is renewed) violations are inherent. Alveolar ventilation directly affects the content of oxygen and carbon dioxide (CO_2) in the alveolar air and thus determines the nature of gas exchange between blood and air fills the alveoli. The value of the «dead» space affects on the composition of the alveolar air. Anatomical «dead» space – is the upper airways, trachea, bronchi and terminal bronchioles that does not participate in gas exchange. Its volume is about 2 ml/kg body weight. Alveolar «dead» space – is the alveoli that are ventilated but partially or completely have not blood perfusion. The amount of anatomical and alveolar «dead» spaces – a physiological or functional «dead» space. VD / VT ratio (dead volume / tidal volume) – physiological «dead» space as the proportion of tidal volume reflects a balance of ventilation and perfusion and in normal rest is approximately 30 % [4].

Direct estimation of alveolar ventilation is almost inaccessible in the clinic. However, it is possible to alveolar ventilation diagnosis by applying capnometry techniques. Capnometry – is measurement and digital display of concentration or partial pressure of carbon dioxide in the air that inhales or exhales patient during the respiratory cycle [7]. By integrating capnometer and pneumotachometers in one device and the unique opportunity of capnometry to calculate CO2-free air portions during exhalation as the volume of the «dead» space and its part in the tidal volume makes it possible to evaluate the efficiency of alveolar ventilation.

This study was performed with **the aim** to investigate the possibilities of capnometry in alveolar ventilation assessment 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 National Institute of Phthisiology and Pulmonology, participants were familiarized with the study protocol and signed an informed consent form to participate in the study.

The study involved 135 participants including 100 COPD patients and 35 healthy subjects.

The diagnosis of COPD and the distribution of patients according to the severity of the disease ware 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» [1]. Healthy individuals in this study were considered participants with normal respiratory function, in whom there was no bronchoobstructive diseases at the time of the survey.

Study groups:

- stage II COPD patients, n = 30 (23 men and 7 women) with a mean age (57,5 ± 2,1) years and the average forced expiratory volume at timed interval of 1,0 second (FEV_1) (64,3 ± 1,5) %.
- stage III COPD patients, n = 45 (30 men and 15 women) with a mean age (59,0 ±1,8) years and the average FEV_1 (41,0 ± 0,8) %.
- stage IV COPD patients, n = 25 (21 men and 4 women) with a mean age (65,6 ± 1,8) years and the average FEV_1 (26,4 ± 0,6) %.
- healthy individuals, n = 35 (19 men and 16 women) with a mean age (48,0 ± 2,4) years and the average FEV_1 (99,1 ± 1,5) %.

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

- the volume of «dead» space, ml (VD, ml);
- part of the «dead» space of the tidal volume (VD / VT), %;
- volume ventilation, liters per minute (V′E, l/min);
- alveolar ventilation volume, liters per minute (V_a, l/min).

Prior to the test the essence of the procedure explained to the patient. A survey conducted in the sitting position, the patient is breathing ambient air for 5 minutes through a mouthpiece with a nose clip to the entire flow of air inhaled or exhaled, passed through the analyzer. Then within 3 minutes data of the capnometry recorded.

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 [2]. The parameters studied in this work were evaluated by determining the mean (M), the mean error (m), reliability (t), the level of significance (p).

Results and discussion

For all 135 study participants capnometry was analyzed. Minute ventilation in rest was the highest in COPD stage IV patients – (12,6 ± 0,6) l/min (Table), statistically significantly higher relative to COPD stage II patients – (11,1 ± 0,4) l/min. and healthy subjects – (10,5 ± 0,3) l/min. Minute ventilation in COPD stage III patients – (12,2 ± 0,5) l/min. was significantly higher than in healthy individuals.

The value of «dead» space was also the highest in stage COPD IV patients – (264 ± 14) ml, that was (37,2 ± 1,4) % from the tidal volume. This increase was statistically significant compared with healthy individuals ((173 ± 8) ml – (25,2 ± 0,9) % from the tidal volume), p < 0,01. Also high relative to healthy individuals were «dead» space in COPD stage III patients – (241 ± 9) ml, that was (31,3 ± 1,2) % from the tidal volume. In COPD stages III and IV patients VD / VT ratio is higher than normal for this indicator, which indicates the imbalance of ventilation and perfusion in these patients, which is one of the mechanisms of gas exchange disorders.

Alveolar ventilation in COPD II, III and IV stages patients were – (8,1 ± 0,3), (8,4 ± 0,5) and (7,9 ± 0,5) l/min respectively, in the control group – (7,9 ± 0,5) l/min. Although the value of V_a has no statistically significant differences between groups, we noticed an interesting trend: an increase in minute ventilation is accompanied by improvement of alveolar ventilation and may have adaptive significance in stage III COPD patients. At stage IV COPD the increase V′E is partly occurs due useless «dead» space ventilation with reduced efficiency of alveolar ventilation, which may be a one factor of very severe course of disease in these patients and decompensated pulmonary insufficiency (Figure).

On the other hand we calculated minute «dead» space volume ventilation in the study groups: (3,1 ± 0,2), (3,7 ± 0,1) and (4,7 ± 0,2) l/min in COPD stage II, stage III and stage IV patients respectively and (2,7 ± 0,1) l/min in control group, statistically significant difference between COPD groups, p < 0,05.

We determined the level of ventilation «dead» space in COPD patients at rest and it is high in patients with severe and

Table

Lung ventilation indicators in healthy subjects and in COPD patients (M ± m)

Indicators	Healthy subjects (n = 35)	COPD stage II patients (n = 30)	COPD stage III patients (n = 45)	COPD stage IV patients (n = 25)
V′E, l/min	10,5 ± 0,3	11,1 ± 0,4	12,2 ± 0,5*	12,6 ± 0,6$^{\#§}$
VD, ml	173 ± 8	236 ± 15$^{□}$	241 ± 9*	264 ± 14$^{\#}$
VD/VT	25,2 ± 0,9	27,5 ± 1,1	31,3 ± 1,2$^{*\wedge}$	37,2 ± 1,4$^{\#§°}$
Va, L/min	7,9 ± 0,4	8,1 ± 0,3	8,4 ± 0,5	7,9 ± 0,5

Notes: * – statistically significant difference between healthy subjects and COPD stage III patients (p < 0,01); # – statistically significant difference between healthy subjects and COPD stage IV patients (p < 0,01); § – statistically significant difference between COPD stage II patients and COPD stage IV patients (p < 0,05); □ – statistically significant difference between healthy subjects and COPD stage II patients (p < 0,01); ^ – statistically significant difference between COPD stage II patients and COPD stage III patients (p < 0,05); ° – statistically significant difference between COPD stage III patients and COPD stage IV patients (p < 0,01).

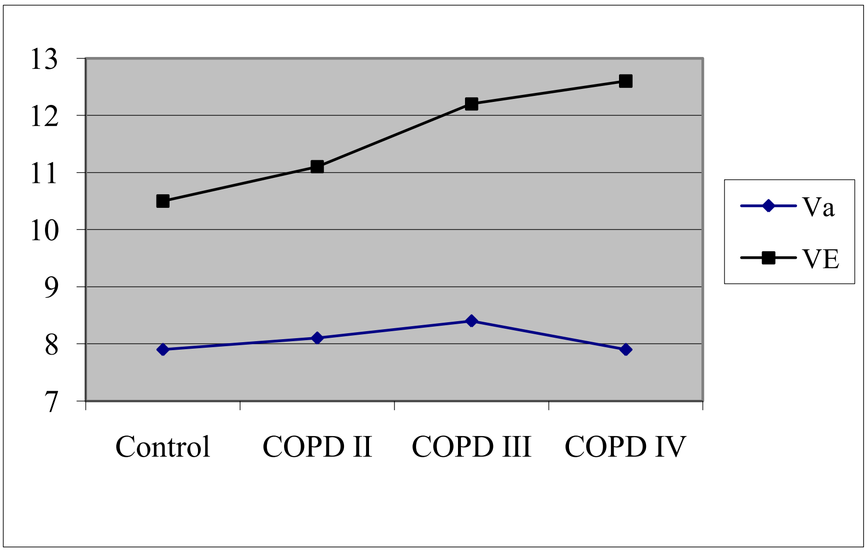

Figure. **The minute and alveolar ventilation in patients studied**

very severe course of the disease. From the literature it is known that during exercise VD / VT ratio increases [5]. Thus, we can assume that during exercise the increase in minute volume of respiration, along with increasing VD / VT may be accompanied by a decrease in effective alveolar ventilation and prevent an increase in physical activity of patients.

Thus, capnometry allows evaluate the effectiveness of alveolar ventilation in COPD patients.

Conclusions

The increase in minute ventilation in COPD stage III patients is accompanied by improvement of alveolar ventilation, but at stage IV COPD the increase V′E is partly occurs due useless «dead» space ventilation with reduced efficiency of alveolar ventilation.

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ВОЗМОЖНОСТИ КАПНОМЕТРИИ В ОЦЕНКЕ АЛЬВЕОЛЯРНОЙ ВЕНТИЛЯЦИИ У БОЛЬНЫХ ХРОНИЧЕСКИМ ОБСТРУКТИВНЫМ ЗАБОЛЕВАНИЕМ ЛЕГКИХ

С. Г. Опимах

Резюме

Обоснование. *Для хронического обструктивного заболевания легких (ХОЗЛ) характерно значительное нарушение легочной вентиляции, в процессе которой обновляется газовый состав альвеолярного воздуха. Непосредственная оценка альвеолярной вентиляции практически недоступна в клинике. Однако существует возможность диагностики нарушений альвеолярной вентиляции путем применения методики капнометрии. Данная работа выполнялась с целью изучить возможности капнометрии в оценке альвеолярной вентиляции у больных ХОЗЛ.*

Материалы и методы исследования. *В исследовании приняли участие 100 больных ХОЗЛ и 35 здоровых лиц, которым проводили капнометрию.*

Результаты. *Объем минутной вентиляции в покое оказался наивысшим у больных ХОЗЛ IV и III стадий – (12,6 ± 0,6) и (12,2 ± 0,5) л/мин соответственно. Объем «мертвого» пространства также был наивысшим у больных ХОЗЛ IV стадии (264 ± 14) мл, что составляло (37,2 ± 1,4) % от дыхательного объема. Альвеолярная вентиляция у больных ХОЗЛ II, III и IV стадий составляла (8,1 ± 0,3), (8,4 ± 0,5) и (7,9 ± 0,5) л/мин соответственно, а в контрольной группе – (7,9 ± 0,5) л/мин.*

Выводы. *Увеличение объема минутной вентиляции у больных ХОЗЛ III стадии сопровождается улучшением альвеолярной вентиляции, а при IV стадии ХОЗЛ нарастание минутной вентиляции частично происходит за счет «мертвого» пространства со снижением эффективности альвеолярной вентиляции.*

Ключевые слова: *хроническая обструктивная болезнь легких, альвеолярная вентиляция, капнометрия.*

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С. Г. Опимах,
младший научный сотрудник отделения диагностики, терапии и клинической фармакологии заболеваний легких
ГУ «Национальный институт фтизиатрии и пульмонологии им. Ф. Г. Яновского НАМН Украины»
Адрес: ул. Амосова, 10, Киев 03680
тел./факс: +380(44)2756242
email: diagnost@ifp.kiev.uaww

POSSIBILITIES OF CAPNOMETRY IN ALVEOLAR VENTILATION ASSESSMENT IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE PATIENTS

S. G. Opimakh

Abstract

Background: *Chronic obstructive pulmonary disease (COPD) is characterized by significant impairment of pulmonary ventilation, during which the gas composition of the alveolar air is updated. Direct estimation of alveolar ventilation is almost inaccessible in the clinic. However, it is possible to alveolar ventilation diagnosis by applying capnometry techniques.*

The purpose of the study: *This study aimed to investigate the possibilities of capnometry in alveolar ventilation assessment in COPD patients.*

Results: *Minute ventilation in rest was the highest in patients with COPD stage IV – (12,6 ± 0,6) l/min. and stage III – (12,2 ± 0,5) l/min. The amount of «dead» space was also the highest in patients with stage IV COPD – (264 ± 14) ml, that was (37,2 ± 1,4) % from the tidal volume. Alveolar ventilation in patients with COPD II, III and IV stages was (8,1 ± 0,3), (8,4 ± 0,5) and (7,9 ± 0,5) l/min. respectively, in the control group – (7,9 ± 0,5) l/min.*

Conclusions: *The increase in minute ventilation in COPD stage III patients is accompanied by improvement of alveolar ventilation, but at stage IV COPD the increase V'E is partly occurs due useless «dead» space ventilation with reduced efficiency of alveolar ventilation.*

Key words: *chronic obstructive pulmonary disease, alveolar ventilation, capnometry.*

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S. G. Opimakh
Junior research associate,
Department of diagnostic, therapy
and clinical pharmacology of lung diseases
SO «National institute of phthisiology and pulmonology
named after F.G. Yanovsky National Academy
of medical sciences of Ukraine»
Address: 10, Amosova str., Kyiv, 03680, Ukraine
tel./fax: +380(44)2756242
email: diagnost@ifp.kiev.ua