CHARACTERISTICS OF RESPIRATORY MECHANICS IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE

M. Roca¹, F. Mitu¹, O. Mitu², Iulia-Cristina Roca²*, Maria-Magdalena Leon¹, T. Mihăescu²
University of Medicine and Pharmacy "Grigore T. Popa" – Iasi
Faculty of Medicine
1. Department of Medical Specialties (I)
2. Department of Medical Specialties (II)
*Corresponding author. E-mail: iuliaroca@yahoo.com

CHARACTERISTICS OF RESPIRATORY MECHANICS IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE (Abstract): In chronic obstructive pulmonary disease (COPD) the changes in respiratory thoracoabdominal mechanics result from both hyperinflation and functional and structural skeletal muscle alterations. **Aim:** Evaluation of the particularities of respiratory movement in COPD and identification of inter-relations between respiratory thoracoabdominal mechanics and clinical and functional respiratory status. **Materials and Methods:** This study comparatively analyzed the respiratory thoracoabdominal mechanics recorded by polygraphy, using piezoelectric film belts, in 34 COPD patients and 30 healthy subjects, during rest, and during 6-minute walk test. **Results:** In COPD patients, phase angle between direction of thoracic and abdominal respiratory movements presented significantly higher values compared to the control group, for supine (p=0.023) and sitting position (p=0.001), revealing the presence of paradoxical respiratory movements. Furthermore, phase angle dynamics increased significantly during walking test compared to sitting position (p=0.001). Quantitative difference of end-expiratory pulmonary volume (qDEEL) correlated with pack-years (r=0.372, p=0.03) in supine position, and with body mass (r=0.338, p=0.05) and St. George activity score (r=0.353, p=0.041) during walking test. Rib cage inspiratory contribution to tidal volume ratio (%RCi) inversely correlated with pack-years (r=-0.417, p=0.014) and body mass index (r=-0.344, p=0.047) in supine position, and with St. George activity score (r=-0.345, p=0.046) in sitting position. **Conclusions:** In COPD patient thoracoabdominal mechanics is characterized by paradoxical respiratory movements, more prominent during exercise. The alteration of thoracoabdominal mechanics correlated with St. George activity score, pack-years and body mass. **Keywords:** COPD, RESPIRATORY MECHANICS, PLETHYSMOGRAPHY.

Muscle dysfunction is an important comorbidity in chronic obstructive pulmonary disease (COPD), found in interrelation with bronchial obstruction and lung emphysema, together with these causing alterations in exercise capacity through complex mechanisms, including change in thoracoabdominal respiratory mechanics (1). Hyperinflation caused by emphysema results in lung ventilation inefficiency, use of accessory respiratory muscles, muscle fatigue and altered respiratory mechanics. On an alternative pathogenic pathway, systemic inflammation from COPD causes structural and functional muscle alterations, skeletal muscle dysfunction, involving intercostals
M. Roca et al.

muscles and diaphragm. These are reflected in clinical, respiratory functional and respiratory mechanical effects (2).

The aim of this study was to analyze the pattern of respiratory movements in COPD and to identify interrelations between respiratory thoracoabdominal mechanics, and clinical and functional respiratory status.

MATERIAL AND METHODS

This prospective, case-control study consisted in a comparative assessment of the respiratory movement patterns in two groups: a group including patients with COPD admitted to the Clinic of Pulmonary Diseases Iasi, and a control group including healthy volunteers.

The subjects in the two groups were thus selected as to match for age, gender and body mass index. Considering the small number of female patients with COPD admitted to the clinic, we limited our research to males.

COPD was diagnosed according to GOLD guidelines (3). Ventilatory function was measured by spirometry, including bronchodilator response assessment. The clinical evaluation included dyspnea assessment using Modified Medical Research Council Dyspnea Scale, mMRC (4), body mass index (BMI) calculation, assessment of quality of life in COPD by St George’s Respiratory Questionnaire (SGRQ) (5), exercise capacity assessment by 6 minute walking test (6MWT) (6). Smoking status was assessed by calculating pack-years index.

Thoracoabdominal respiratory movements were recorded by polygraphy, with the polygraph SOMNO-check effort Weinmann (SOMNOcheck® Effort, Weinmann®, Germany), and two piezoelectric film belts, a thoracic belt and an abdominal belt, as follows: 6 minute recording in supine position; 6 minute recording in sitting position; 6 minute recording during 6 minute walking test.

The signals, represented by filtered and scaled respiratory abdominal (AB) and thoracic (RC) wave forms, were processed and analyzed using the software VivoSense Complex Respiratory Analysis Version 2.0, from Vivonoetics (Vivonoetics, San Diego, California) (7). This allowed the analysis of the following parameters of the respiratory mechanics:

- Inspiratory tidal volume (Insp Vol) and expiratory tidal volume (Exp Vol);
- $T_{pef}/T_e$: Time to reach peak expiratory tidal flow over expiration time;
- $\%RC_i, \%RC_e$: Percent Rib Cage Inspiratory/Expiratory Contribution to Tidal Volume Ratio,
- $Ph\ Angle$: percentage agreement between direction of RC and AB movements during breath;
- $|Ph\ Angle|$: Absolute value of AB-RC Phase Angle;
- $Ph\ Angle\ (Area)$: AB-RC Phase Angle - was computed from Lissajous loops between RC and AB excursions. The sign of the phase angle indicates whether AB is ahead of RC ($Ph\ Angle>0$) or behind ($Ph\ Angle<0$) (7);
- $qDEEL$: quantitative difference of end-expiratory pulmonary volume;
- Work of breathing.

Statistical data analysis was done using Statistical Package for the Social Sciences (SPSS 16.0) and MedCalc 12.1. Statistical significance threshold was set at $p=0.05$.

RESULTS

Our study included a group of 34 patients with COPD (mean age $65.4 \pm 8.6$) admitted to the Clinic of Pulmonary Dis-
Characteristics of respiratory mechanics in chronic obstructive pulmonary disease

- Assessment of estimated respiratory tidal volumes: expiratory volume ($\text{Exp Vol}$), inspiratory volume ($\text{Insp Vol}$)

In supine position, respiratory volumes were significantly lower in the COPD group than in the control group, both for expiratory volumes (357.1±142.6 ml in COPD group and 506.2±269 ml in control group, $p=0.004$) and inspiratory volumes (357.1±143.1 ml in COPD group and 505.7±268.6 ml in controls, $p=0.004$), respectively.

Respiratory volumes inversely correlated with body mass index in COPD group ($r=-0.436$, $p=0.01$). Respiratory volumes dynamics in COPD patients showed a significant increase at transition from supine to sitting position ($p=0.027$), followed by a significant decrease during walking test ($p<0.001$).

- Assessment of the absolute value of $\text{AB-RC Phase Angle}$ |$\text{Ph Angle}$|

In supine position, the percentage value of $\text{AB-RC Phase Angle}$ presented significantly higher values in COPD group than in the control group (58.7±43.7 in COPD group and 36.9±32.1 in the control group, $p=0.023$), revealing the presence of paradoxical respiratory movement in COPD patients. The same was found for the sitting position (44.3±33.4 in COPD group, and 24.1±17.4 in control group, $p=0.001$).

The phase angle difference between COPD and control group became insignificant during walking test (78.5±38.2 in COPD group, and 60.4±29.9 in the control group, $p=0.071$).

Phase angle dynamics presented a mild decrease, below statistical significance ($p=0.278$) at the transition from supine to sitting position, followed by a significant increase, compared to sitting position, during walking test (from 44.3±33.4 to 78.5±38.2, $p=0.001$) (fig. 1).

- $\text{AB-RC Phase Angle assessment: Ph Angle (Area) and |Ph Angle (Area)|}$

The parameter |$\text{Ph Angle (Area)}$| showed significantly higher percentage values in COPD group than in the control group, in supine position (59.3±45.6 in
COPD group and 36.5±32.3 in the control group, p=0.03) and in sitting position (43.5±33.5 in COPD group and 23.5±18 in the control group, p=0.001). During walking test, COPD subjects presented significantly higher values of Ph Angle (Area) compared with the controls (19.4±54.2 in COPD group and -5.3±30.4 in the control group, p=0.026). These results revealed the presence of paradoxical respiratory movements in COPD patients.

|Ph Angle (Area)| dynamics in COPD patients presented a mild decrease, statistically insignificant (p=0.244) at the transition from supine to sitting position, followed by a significant increase during walking test, compared with sitting position (from 43.5±33.5 to 77.5±42.3, p=0.001).

- **Quantitative difference of end-expiratory pulmonary volume qDEEL**

  The dynamics of qDEEL (expressed in milliliters) in COPD patients showed a mild increase, below statistical significance (p=0.308) during transition from supine to sitting position, followed by a significant increase during walking test, compared to both supine (73.1±34 compared to 32.7±27.8, p<0.001) and sitting position (73.1±34 compared to 43.3±27.2, p<0.001). However, an increase in qDEEL during walking test was also found in the control group, the difference between COPD and control group being insignificant (p=0.59).

  The value of qDEEL assessed in supine position correlated with pack-years (r=0.372, p=0.03); value of qDEEL assessed in sitting position correlated with body mass in COPD group (r=0.361, p=0.036). The value of qDEEL assessed during walking test correlated with body mass (r=0.338, p=0.05) and St. George activity score (r=0.353, p=0.041).

- **Percent Rib Cage Inspiratory Contribution to Tidal Volume Ratio % RCI**

  Percent rib cage inspiratory contribution to tidal volume ratio (% RCI) assessed in supine position in the COPD group inversely correlated with pack-years (r=-0.417, p=0.014) and body mass index (r=-0.344, p=0.047).

  %RCI ratio assessed in sitting position inversely correlated with St. George activity score in the COPD group (r=-0.345, p=0.046).

- **Respiratory rate**

  Respiratory rate presented significantly higher values in COPD group than in the control group in supine position (23.3±3.8 min⁻¹ compared to 18.9±5.4 min⁻¹, p=0.002), sitting position (24.4±4.9 min⁻¹ compared to 18.9±4 min⁻¹, p<0.001) and during walking test (29±4.5 min⁻¹ compared to 26.7±6.5 min⁻¹, p=0.017). The transition from resting to walking test resulted in a significant increasing of respiratory rate (p<0.001).

  Respiratory rate assessed in sitting position correlated with body mass index (r=0.363, p=0.035). Respiratory rate assessed during walking test correlated with pack-years (r=0.373, p=0.030) in COPD patients.

- **Assessment of inspiratory time: Ti**

  Inspiratory time corresponding to supine position correlated to pack-years in COPD group (r=-0.374, p=0.029). Inspiratory time corresponding to sitting position inversely correlated with body mass index in COPD group (r=-0.342, p=0.048). Mean inspiratory time during 6 minute walking test correlated with pack-years in COPD group (r=0.419, p=0.014).

- **Time to reach peak expiratory tidal flow over expiration time: Tpef/Te**

  The dynamics of Tpef/Te values in COPD subjects proved similar mean values for supine and sitting position (0.46±0.05 and 0.45±0.03, p=0.918), with a significant increase during walking test, compared with both supine (p=0.001) and sitting
position (p<0.001). During walking test the mean value of Tpef/Te was significantly higher in COPD group than in the control group (0.5±0.02 compared to 0.48±0.02, p=0.002). Mean Tpef/Te value in supine position correlated with both body mass (r=0.382, p=0.026) and height (r=0.620, p<0.001), in COPD patients.

- **Assessment of work of breathing**

  Work of breathing presented significantly higher values in COPD group, compared with the control group in supine (p<0.001) and sitting position (p=0.003), the difference becoming insignificant during walking test (p=0.174).

  The dynamics of the work of breathing in COPD subjects showed a mild, insignificant decrease during transition from supine to sitting position (p=0.228), followed by a significant increase during walking test compared with sitting position (p<0.001).

  The work of breathing correlated with body mass in COPD patients: in supine position (r=0.355, p=0.039); in sitting position (r=0.376, p=0.028); during exercise (r=0.401, p=0.019).

**DISCUSSION**

The dynamics of respiratory tidal volume in COPD patients presented a significant increase at the transition from supine to sitting position. This improvement may be explained by a more efficient use of respiratory muscles in sitting position and by a more efficient functioning of the diaphragm.

Exercise represented by 6 minute walking test resulted in a significant decrease of inspiratory/expiratory volumes compared to resting values (p<0.001) in both COPD and control group. Tidal volume corresponding to supine position inversely correlated with body mass in COPD group.

Phase angle between thoracic and abdominal movements presented significantly higher values in COPD than in the control group in both supine and sitting position (p=0.023 and p=0.001, respectively).

Phase angle dynamics in COPD patients showed a mild, insignificant decrease (p=0.278) at the transition from supine to sitting position. This decrease of thoracoabdominal asynchrony could explain the tidal volume improvement.

The mean phase angle value progressively increased during walking test in COPD subjects, insignificantly compared to supine position (p=0.092) and significantly compared to sitting position (p<0.001), but compared to control group the difference became insignificant (p=0.071). This observation could be explained by the phenomenon of paradoxical abdominal motion amplification during exercise in COPD patients.

Brennan et al. demonstrated paradoxical movements of the lower ribcage in COPD patients, explaining these by an increase in intercostals and accessory muscles activity, in addition with a decrease in diaphragm respiratory activity. These mechanisms seem to be favored by hyperinflation in COPD (8).

From this point of view, Vogiatzis et al. have identified two distinct profiles of patients with COPD: one characterized by early hyperinflation during exercise, completely reversible at the end of exercise, and another characterized by late hyperinflation during exercise (9).

Bloch et al. showed that lung volume reduction surgery in COPD patients significantly increases abdominal contribution to tidal volume and decreases the duration of paradoxical abdominal movement during inspiration.

The improvement of thoracoabdominal synchronization and the increase of the abdominal contribution to tidal volume dynamics during the respiratory cycle have the effect of decreasing muscle labor during inspiration by a greater participation of
diaphragm in breathing (10).

Quantitative difference of end-expiratory pulmonary volume (qDEEL) did not show significant differences between COPD and control group in supine and sitting position. During walking test, qDEEL mean value progressively increased in COPD group, being significantly higher than in supine (p<0.001) and sitting (p<0.001) position. However, case-control differences became insignificant (p=0.59).

These results confirmed the data obtained by Aliverti et al. in a study using optoelectronic plethysmography. These proved an immediate increase of the end-expiratory pulmonary volume in COPD subjects associating lower ribcage inspiratory paradox, and a late increase of the end-expiratory pulmonary volume in COPD subjects without paradoxical movements of the lower ribcage. However, during exercise, dyspnea increased similarly in the two categories of COPD patients. In addition, paradoxical movement did not correlate with ventilatory function and exercise capacity; leg effort increased more markedly in the patients without paradoxical movements (11).

CONCLUSIONS
Thoracoabdominal mechanics in COPD is characterized by paradoxical respiratory movements. In our study the trend of phase angle between thoracic and abdominal respiratory movements revealed a significant increase of thoracoabdominal asynchrony during exercise. At rest, the transition from supine to sitting position resulted in a mild improvement of the thoraco-abdominal synchronism. Thoraco-abdominal breathing movements parameters significantly correlate with smoking (pack-years), physical activity score and body mass in COPD patients: quantitative difference of end-expiratory pulmonary volume correlates with pack-years when assessed in supine position, with body mass when assessed in sitting position, and with St. George activity score when assessed during walking; rib cage inspiratory contribution to tidal volume ratio inversely correlates with pack-years and body mass when assessed in supine position and inversely correlates with St. George activity score when assessed in sitting position; mean inspiratory time during walking correlates with pack-years.

Although further research is needed, dual band respiratory plethysmography by polygraphy could be a helpful and accessible method which can bring valuable information defining the clinical phenotypes of COPD patients.

ACKNOWLEDGEMENTS
This paper was published under the frame of European Social Found, Human Resources Development Operational Programme 2007-2013, project no. POSDRU /159/1.5/S/136893

REFERENCES

---

**RELATION OF SERUM HAPTOGLOBIN LEVEL TO ERYTHROPOIETIC ACTIVITY IN BETA THALASSEMIA CHILDREN**

Serum haptoglobin (Hp) is a reliable marker for hemolysis. A team of researchers led by Ragab et al investigated the possible relation between Hp depletion and hemolysis severity, hepatitis C virus (HCV) infection and iron load in β-thalassemia children. The study included 22 β-thalassemia major (TM) and 20 β-thalassemia intermedia (TI) children, as well as age and sex matched healthy controls. Pre-transfusion hemoglobin level, serum ferritin, Hp and transferrin receptor levels (sTfR), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were assessed. Markers of hepatitis C virus (HCV) were determined using PCR. Both patient groups had significantly lower Hp levels compared to the controls, with significant lower levels in TM children. Significant inverse correlations were found between serum Hp and sTfR levels in thalassemia children and among HCV infected patients. The study found that STfR was the only significant independent predictor for serum Hp level. No significant correlation was found between serum Hp and serum transaminases in HCV infected children. The study concluded that serum Hp depletion in thalassemia has a significant relation to the severity of the disease and is correlated with the erythropoietic activity (Ragab SM1, Safan MA2, Badr EA2. Study of serum haptoglobin level and its relation to erythropoietic activity in Beta thalassemia children. *Mediterr J Hematol Infect Dis*. 2015 Feb 15;7(1):e2015019. doi: 10.4084/MJHID.2015.019. eCollection 2015.)

Teodora Vremera