Influence of Face Mask on Breathing During Hyperventilation Test

Tudor BESLEAGA[1], Pascale CALABRESE[2], Victor VOVC[1], Pierre BACONNIER[2], Ion MOLDOVANU[1], Andre EBERHARD[2]

[1]*State University of Medicine and Pharmacy "N. Testemitanu", Chisinau, R. Moldova*

[2]*Lab. PRETA-TIMC, University Joseph Fourier, Grenoble, France*

***Abstract*- The aim of present study was to evaluate the changes of breathing pattern related to the influence of the face mask during voluntary hyperventilation. We compared respiratory variables in recordings with and without mask in different periods of hyperventilation test. Our finding – the mask increases some variables at rest (inspiratory time) and during recovery period after voluntary hyperventilation: (inspiratory time, tidal volume and pulmonary ventilation). The mask decreases respiratory variability at rest and during recovery periods. These effects can be provided by behavioural influence and the additional dead space of apparatus.**

I. INTRODUCTION

Respiratory inductance plethysmography (RIP) is a non-invasive method for measurements of rib cage and abdomen respiratory movements. These rib cage and abdominal cross sectional area changes allow calculating respiratory volumes. Respiratory airflow is recorded by pneumotachograph, but the using of mouthpiece or a facial musk can change breathing pattern by behavioural influences and by additional apparatus dead space.

Calabrese et al. [1] compared pneumotachographic airflow (PNT) and RIP derivative signal of quiet respiration, during voluntary hyperventilation and recovery periods, RIP derivative signals were filtered by an adjusted filter based on each subject pneumotachographic airflow signal (PNT). Authors concluded that the adjusted filter calculated from quiet respiration can be used in different conditions: quiet respiration, hyperventilation and recovery after hyperventilation to obtain adequate derivative RIP signal.

Change of interactions between automatic and behavioural regulatory mechanisms of respiration occurs during voluntary hyperventilation. The aim of our research was to determine the influence of the mask on breathing pattern in healthy subjects in different periods of hyperventilation test.

II. MATERIALS AND METHODS

We studied six healthy volunteers between 25 and 39 years of age, five of whom were men. All subjects provided informed consent and the study was approved by the relevant ethics committee (CHU Grenoble). Breathing was recorded with a flowmetter Fleish head n°1 and differential transducer (163PC01D36, Micro Switch) mounted on the face mask (dead space of apparatus was 60 ml) and with RIP (Visuresp, RBI). End tidal CO_2 fraction ($F_{ET}CO_2$) was measured using infrared CO_2 analyser (Engstrom Elisa/Elisa MC). Subjects were recorded in semi-supine position at rest – 3 min (REST), during voluntary hyperventilation at each subject spontaneous respiratory frequency and recovery – 9 minutes (protocol THVm); and successively at rest – 3 minutes (REST20), during voluntary hyperventilation at 20 breaths/min - 3 minutes and recovery period (REC20) - 9 minutes (protocol THV20m). Subjects were encouraged to increase tidal volume in order to decrease $F_{ET}CO_2$ by 1% below the rest levels. These two protocols were repeated without facial mask, the $F_{ET}CO_2$ was collected by nose clip (protocols THV and THV20). Before the recording without mask we recorded the 2 minutes period of quiet respiration simultaneously with flowmeter and RIP to calculate individual adjusted filter. **Analysis:** All signals were digitized at a rate of 100 Hz. The 15 most regular consecutive breaths of the airflow signal formed the reference part [1]. A least squares method was used over this part of signal to obtain a RIP volume signal (VRIP) by combination of rib cage (RCRIP) and abdominal (ABDRIP) signals compared to the integrated flow signal (VPNT):

$$VRIP_k = \tau\ RCRIP_k + \alpha\ ABDRIP_k \quad (1)$$

Where $\tau = 2$ was imposed [3]. The derivative of VRIP (FRIP) was then calculated by using centred divided differences:

$$FRIP_k = (VRIP_{k+1} - VRIP_{k-1}) / 2\Delta t \quad (2)$$

A transfer function was calculated over the reference part between RIP derivative and airflow signal to take out an adjusted filter. Then the adjusted filter calculated on the reference part of signals was applied on the entire recording. We calculated adjusted filter from rest period in recordings with mask (THVm and THV20m) and from two minutes recording period with PNT and PIR preceding recordings without mask (THV and THV20). The derivative signals PIR were used to calculate respiratory variables for all periods of test.

Recovery periods are divides in three intervals: first three minutes- REC3m and REC20_3m, 4^{th} -6^{th} minutes- REC6m and REC20_6m, last three minutes- REC9m and REC20_9m. Respiratory variables: mean duration of respiratory cycle (Tt), inspiratory and expiratory times (Ti and Te), tidal volume (Vt), mean inspiratory flow (Vt/Ti), Ti/Tt ratio, minute pulmonary ventilation (Ve), tidal CO_2 fraction ($F_{ET}CO_2$) and their variation coefficients were calculated.

III. RESULTS

The values of respiratory variables (medians, quartiles, superior and inferior values) calculated for periods of performed tests (THV, THVm and THV20, THV20m), also the significant differences determined with test Wilcoxon are represented on the figure n°1.

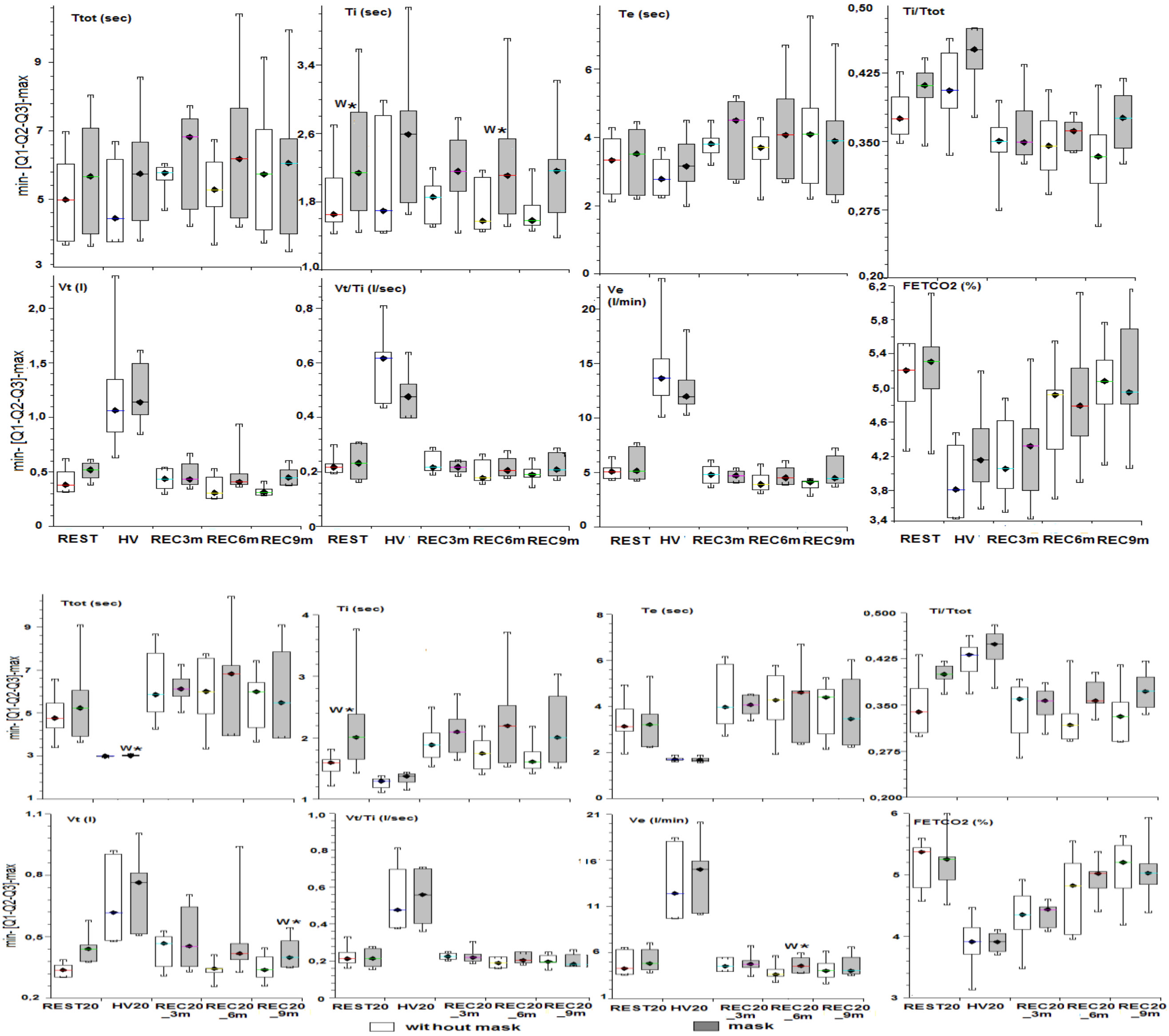

Fig. 1. Respiratory variables of hyperventilation tests recorded with and without mask (THV, THVm and THV20,THV20m)

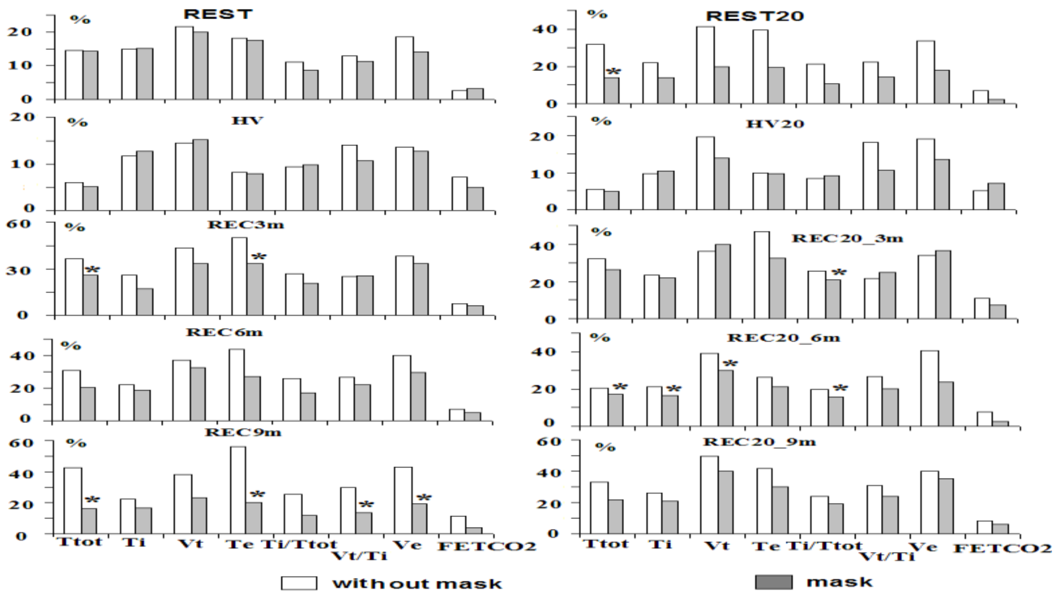

Fig. 2. Variation coefficients of respiratory variables determined in periods of tests recorded with and without mask (THV, THVm and THV20, THV20m)

The mask increases inspiratory times at rest (REST) and during second interval (REC6m) of test THV. During test THV20 the mask increases Ti at rest (REST20), tidal volume Vt during the last 3min (REC20_9m) and minute ventilation Ve during REC20_6m interval of recovery period.

The variation coefficients (medians) of respiratory variables of tests (THV, THVm and THV20, THV20m), and significant differences determined by Wilcoxon test are represented on the figure n°2. The mask decreases variation coefficients of Tt and Te during REC3m interval and Tt, Te, Vt/Ti and Ve during last 3min of recovery period (REC9m) of THV. The mask decreases variation coefficients Tt of the second rest period (REST20) Ti/Tt during first three minutes of recovery (REC20_3m) and Tt, Ti, Vt and Ti/Tt during interval REC20_6m

IV. DISCUSSIONS

Precedent studies describe influence of the face mask on the respiratory variables [4], [5]: increase of the tidal volumes and ventilation, decrease of the respiratory rate. We found more differences between breathing with and without mask during recovery periods after voluntary hyperventilation tests. The changes between automat-metabolic and behavioural regulatory mechanism make these period more sensitive to behavioural influences produced by the facial mask. The decrease of respiratory variability in the records with mask can be also explained by these behavioural influences. The absence of differences during voluntary hyperventilation periods can be explained by domination of voluntary control of breathing.

The small dead space of the face mask and pneumotachograph had minimal effect on the breathing pattern, but it cannot be completely excluded.

V. CONCLUSIONS

The application of the respiratory inductance plethysmography provides more native breathing pattern by excluding influences of the facial mask. It can be useful in the study of breathing pattern in voluntary hyperventilation, and its application is suitable in the study of breathing in anxious patients.

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