IN VIVO EVALUATION OF RESPIRATORY MUSCLES MECHANICS

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Introduction

Respiratory muscle weakness (RMW) commonly occurs in acute or chronic illness as well as in primary neuromuscular diseases. Currently, global diagnosis of RMW is established by mouth pressure measurements during quasi-static maneuvers (Black and Hyatt, 1969, Ratnovsky \textit{et al.}, 1999) or imaging. Differentiation between the contributions of major muscle groups can be achieved by electromyogram (EMG) studies. The EMG of human respiratory muscles has been measured for many years with needle or surface electrodes, and was found to range from 50 to 500µV (Cala \textit{et al.}, 1992; McKenzie \textit{et al.}, 1988). However, these studies were mostly basic physiological ones and the resulting data were not utilized in the clinical setting. The objective of this study was to quantitatively explore the relative contribution of four major groups of respiratory muscles to global lung ventilation throughout a range of maneuvers in healthy subjects.

Methods

A computerized experimental system was designed for simultaneous noninvasive measurement of inspired/expired airflow, mouth pressure and up to 8 channels of EMG surface signals from major respiratory muscles during various respiratory maneuvers. Measurements were done on 8 healthy subjects. An example of the sampled signals of mouth pressure, airflow and EMG is shown in Fig. 1. Lung volume values were calculated by integration of the airflow data. The EMG signals were fully rectified and filtered with a low pass filter (Butterworth with a cut-off of 6Hz) to yield a linear envelope of the signal. Hills muscle model was utilized to calculate the forces generated by the muscles from the acquired EMG data.

Results & Discussion

A full set of the measured data from a 33-year-old female is depicted in Fig. 1. It clearly demonstrates an increase in muscle activity in parallel with an increase in the breathing efforts: EMG amplitudes ranged from 30 to 150µV at flow rates of 3L/s and increase to 150-300µV for the inspiratory muscles and to 30-100µV for the expiratory muscles at flow rates of 5-8L/s. Both the linear envelope and the muscle forces followed the trend of the EMG signals and increased with an increase in breathing volume. The inspiratory muscles (sternomastoid and internal intercostal) were recruited at low lung volumes between 40-60%VC and increased their activity with an increase in lung volume. The expiratory muscles (rectus abdominis and external oblique), on the other hand, were recruited only at a higher range (20-80%VC) of vital capacity. Peak values of EMG signals of the sternomastoid and external intercostal muscles vary, depending on the effort, in the range of 0.03-0.5mV and 0.03-0.2mV, respectively, while peak values of the forces computed to be 20N and 120N, respectively. Peak values of EMG signals of the rectus abdominis and external oblique muscles vary in the range of 0.05-0.15mV while the peak forces computed to be 60N and 120N, respectively (Fig. 2). All subjects showed symmetric performance of their respiratory muscles on both side of the chest wall. The results of this study show the potential of these noninvasive methods to provide early diagnosis of muscle weakness, and to be used for follow-up of performance during disease progression or in monitoring the improvement of the muscle function after intervention or rehabilitation.
References