Improving dynamic response of respiratory models: a simulation study

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Abstract—This paper presents a comparative study of dynamic responses of three respiratory models under exercise, which one of them is proposed in this study in order to be included in an integrative model that simulates mechanical ventilation. Transients of the proposed model matches better with the known response from physiological point of view.

I. INTRODUCTION

Mechanical ventilation (MV) is a life support treatment used to replace total or partially the patient’s ventilatory function. Some computational systems based on respiratory models [1], [2] have been designed to predict treatment results and to aid physicians in choosing the right treatment.

We have developed an interactive tool based on mathematical models called MV-TRAINER [1] that allowed to simulate steady state responses of patients under MV. In order to improve its performance, two known dynamic respiratory models [3], [4] were analyzed under exercise stimuli. A third model, that integrates key features of [3] into [4], was also proposed in this study with the purpose of including the dynamic respiratory response in the MV-TRAINER. All models were implemented in SIMULINK/MATLAB®.

II. METHODOLOGY

The first respiratory system model [3], RS1, allows to analyze the effects of changes in the cardiac output and cerebral flow and lung mechanical factors. It includes a self-adaptive and discrete controller, which self-adjust the ventilation (V_E), cycle by cycle, through different afferent pathways and regulates of respiratory frequency (f_R) by using an optimization criteria based on the minimizing the work of breathing (WOB) [5].

The second model [4], RS2, is a model more detailed that simulates the interaction between respiratory and cardiovascular systems during wakefulness and sleep. It includes a proportional controller that adjusts V_E in function of brain and tissues pressure of CO_2 and O_2 (P_{ACO_2}, P_{ACO_2}, and P_{AO_2}).

The third model, RS3, includes key features of RS1 into RS2. It has been proposed in order to get a model with a more properly dynamic response under ventilatory stimulation: a) estimating V_E on depending P_{ACO_2}, P_{ACO_2}, P_{AO_2} and subject metabolic activity (MRV), and b) adjusting the breathing pattern by the optimization criteria set by [5].

REFERENCES

[6] John E. Hall, “Respiration: regulation respiration (see Fig. 41-9),” in Guyton and Hall Textbook of Medical Physiology, 2010.