J. Duffin

Cardiovascular-Respiratory System Modeling and Applications.

Introduction

This series of talks is intended to provide students with the necessary physiological knowledge and a practical approach to constructing models simulating the control of breathing. Clinical examples that use these modeling concepts are presented as appropriate. The talks begin with an introduction to simulation programming and then develop a conceptual graphical model of the chemoreflex control of breathing in the steady state. The experiments that produced the model and the parameter estimation from those experiments are reviewed next.
To convert the model to handle the effects of acid-base changes on respiratory control, models of oxygen and carbon dioxide carriage in blood are presented after reviewing the relevant physiology. The Stewart approach to modeling acid-base is presented and the steady state chemoreflex control of breathing and acid-base is developed. This model is incorporated into a dynamic simulation of the chemoreflex control of breathing and acid-base. If time permits, the Campbell diagram approach to modeling pulmonary mechanics will be discussed as a possible approach to simulating the action of ventilators on patients. The last talk will focus on a current modeling challenge; the control of breathing during exercise, detailing current theories.

The topics covered are as follows:

1. Programming Simulation Models with LabVIEW
   (a) Basic ideas
   (b) Simulation solutions
   (c) Material balance equations
   (d) Time delays
   (e) The state-machine approach to programming
   (f) An example program step-by-step
2. The Chemoreflex Control of Breathing (Steady State)

(a) System physiology
(b) Chemoreflex feedback
(c) The central chemoreflex
(d) The peripheral chemoreflex
(e) The controlled system
(f) Graphical steady state model
(g) System stability
(h) Clinical Example (Mahamed et al., 2005)

3. Measuring the Chemoreflex Parameters

(a) Rebreathing method
(b) Rebreathing results
(c) Parameter estimation (Duffin et al., 2000)
(d) Model assumptions Chemoreflex model equations

4. CO_2 & O_2 carriage and Acid-Base

(a) Physiology of CO_2 and O_2 carriage in blood
(b) O_2 dissociation curve models (Lobdell, 1981; Chiari et al., 1997; Longobardo et al., 2002)
(c) CO_2 carriage equation (Douglas et al., 1988).
(d) The Stewart approach to acid-base balance (Stewart, 1983)
(e) The Stewart-Watson equations. (Watson, 1999)
(f) CO_2 dissociation curve model.
(g) Modelling the steady state chemoreflex control of breathing and acid-base (Duffin, 2005).
(h) Clinical Example

5. The Chemoreflex Control of Breathing (Programming a Dynamic Model)

(a) Overview
(b) Blood flow control

(c) Pulmonary ventilation
(d) Pulmonary gas exchange
(e) Tissue gas exchange
(f) Chemoreflexes
(g) Determining default values
(h) Demonstration

6. Pulmonary Mechanics: the Campbell diagram

    (a) Introduction (Moscovici da Cruz et al., 2002)
    (b) Simple conceptual models
    (c) Lung and thoracic wall compliances
    (d) Two compliance graphical model
    (e) Airway resistance
    (f) The Campbell diagram
    (g) Work of Breathing
    (h) Model equations
    (i) Demonstration

7. Exercise: a modeling challenge

    (a) The human system as an endurance athlete (Noakes, 2006)
    (b) The respiratory control system
    (c) The response to exercise
    (d) Exercise drives to breathe
    (e) Central command and afferent feedback measurement (Bell, 2006)
    (f) Sine wave exercise experiments (Wells et al., 2007)
    (g) Vascular distension theory (Haouzi, 2006)
    (h) The drive to breathe in heavy exercise (Mateika and Duffin, 1995)
    (i) The possible role of carotid chemoreceptors

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