Simultaneous Parameter and Input Estimation of a Respiratory Mechanics Model

F. Vicario[1], A. Albanese[1], D. Wang[1], N. Karamolegkos[1], and N. W. Chbat[1]

Abstract: This paper presents a solution to the simultaneous parameter and input estimation of a respiratory mechanics model by infusing physiological knowledge into the estimation algorithm in order to overcome the original underdeterminacy of the problem.

The complex dynamics of air through the respiratory system can be approximated by a first-order dynamical system. Its electrical analogue is given by the series arrangement of a resistance R (mainly related to the upper airways) and a compliance C (primarily due to the lungs and chest wall). The system is driven by the pressure gradient at the two ends of the R-C analogue, given by the difference between mouth pressure and the pressure generated by the respiratory muscles (P_{mus}). This pressure gradient causes air to flow through the system, letting the lungs inflate during inhalation and deflate during exhalation. In a mechanically ventilated patient, knowledge of R and C is very useful to guide clinicians in optimizing the therapy. Air flow and pressure at the mouth can be easily and non-invasively measured when a patient is connected to a mechanical ventilator. On the contrary, the respiratory muscle pressure P_{mus} can only be inferred from invasive measurements of esophageal pressure. Therefore it is not routinely available at the bedside and, making the input to the dynamic model not completely known. As a result, the estimation of R and C from mouth pressure and flow measurements is an underdetermined problem.

In previous work we showed how the underdeterminacy of the non-invasive estimation problem can be overcome by adding constraints to the profile of the respiratory muscles pressure over a breath. The constraints are based on physiological considerations. The estimation problem is then written as a quadratic program that can be solved via well-established numerical techniques. In this paper we improve the computational efficiency of the approach by replacing the above mentioned constraints with pre-defined templates for P_{mus}, whose parameters are estimated simultaneously with R and C using the ordinary least-squares method. The solution of the parameter estimation problem is then given by the combination of R, C and P_{mus} that provides the best least-squares fit to the measured airflow and pressure data. The resulting algorithm has been successfully proven on-line during an animal test.

[1] Acute Care Solutions Department
Philips Research North America, Briarcliff Manor, NY 10510, USA
francesco.vicario@philips.com, antonio.albanese@philips.com, dong.wang@philips.com, nikolaos.karamolegkos@philips.com, chbat@philips.com