SIGNAL PROCESSING AND EVALUATION IN ARTIFICIAL LUNG VENTILATION MONITORING

K. Roubík, R. Grünes, M. Rožánek

CTU in Prague, Faculty of Biomedical Engineering, nám. Sítná 3105, 272 01 Kladno

Background

Introduction of novel unconventional ventilatory regimens into the clinical practice brings together the necessity of adequate measurement and monitoring of the ventilatory parameters. As behaviour of the respiratory system is significantly different from that during conventional ventilation, the only acceptable method for intrapulmonary conditions monitoring is a mathematical modelling of the respiratory system with subsequent simulations of the important parameters present in the alveolar space inside lungs.

High-frequency oscillatory ventilation (HFOV) belongs to unconventional techniques of artificial lung ventilation attracting interest of clinicians recently. Despite the fact that HFOV becomes routinely used in neonates and young paediatric patients, there are many problems connected with HFOV application in adults. There is no doubt about positive effects of HFOV in neonates, while results of several large multicentric clinical studies do not prove the definite benefit of this ventilatory regimen in adults. The resolution of the problem will be connected most likely with different aetiology of acute respiratory distress syndrome (ARDS) having also very different clinical manifestations and different requirements for treatment. Several studies [1, 2, 3] describe inhomogeneity of ARDS group of adult patients resulting in different mechanical properties of the respiratory system and dependently different ventilatory strategies required for ARDS treatment.

Methods

The designed system for HFOV monitoring and measurement of the lung mechanics consists of two basic parts: hardware and software. The hardware part records pressure changes in the respiratory system and measures airflow by a pneumotachograph. In addition, the system records oesophageal pressure by an oesophageal balloon catheter and measures also intraabdominal pressure by Foley's transurethral catheter. Signals from the sensors are filtered and digitized by A/D transducer and digital data are transferred for analyses and calculations into a computer using Ethernet.

The practical realization of the hardware (Figure 1) is designed so that quite high number of used measuring lines and transducers does not complicate access to the patient and does not complicate medical care.

The software part of the system consists of two basic subsystems. The first subsystem has a function of a classical monitor for artificial lung ventilation with a possibility to display standard parameters, curves and trends including special curves of oesophageal and intraabdominal pressures (Figure 2). The programme contains all basic display modes commonly used in commercial ventilators, including trends (Figure 3) and ventilatory loops.

The other part of the software is unique and it encompasses a special set of algorithms for separate evaluation of the mechanical parameters of lungs and chest wall allowing distinguishing between ARDSp and ARDSexp. All the numerical algorithms were originally designed and tested in MATLAB environment. The final software has been written in Borland C++ language.

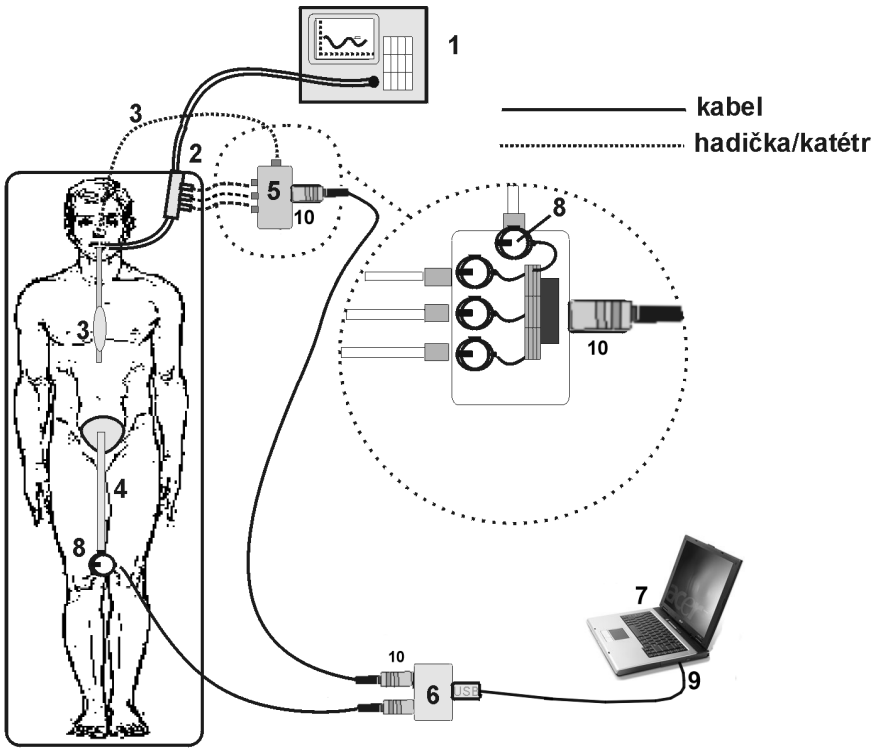

Figure 1: Design of the monitoring and diagnostic tool. 1—ventilator, 2—airway pressure and airflow sensors, 3—oesophageal balloon catheter, 4—Foley's transurethral catheter, 5—pressure/voltage transducers, 6—microprocessor-controlled measuring device, 7—computer, 8—individual pressure sensors, 9—Ethernet connection cable, 10—safe and coded electric connectors.

Accuracy of the system was tested during an animal experiment on a group of rabbits (N=15) while pulmonary and extrapulmonary forms of ARDS were invoked (by oleic acid administration in the dose of 0.08 ml/kg B.W. and stiffened chest by a pressure cuff inflated at 2 kPa, placed around the chest and abdomen). Parameters measured and evaluated from the designed system were compared with the values provided by Galileo ventilator (Hamilton Medical), which has standardized procedures of measurement and evaluation. In some cases, there were not corresponding parameters available, provided by Galileo. The missing parameters were calculated from the provided ones using standardized equations and algorithms [4].

Results

The system has been tested during animal experiments a results were compared with parameters obtained from Galileo ventilator. Pressure measurements accuracy was better than 5% and airflow and volume measurement accuracy was better than 10% in the whole range of Galileo settings. Compliance of the whole respiratory system from the designed device differed less than 10% from the Galileo value.

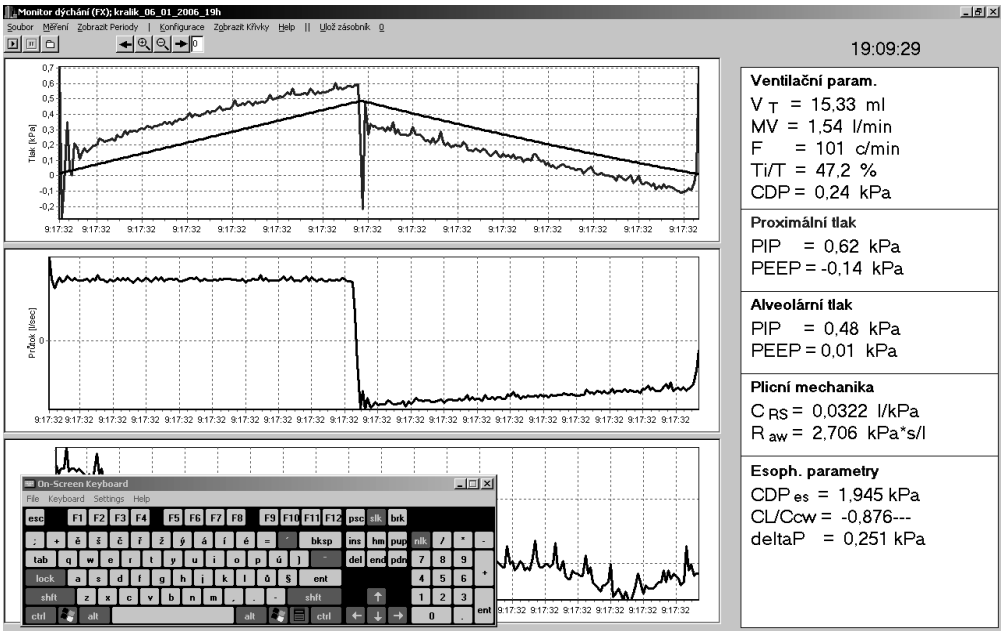

Figure 2: Example of a standard monitoring screen during high-frequency oscillatory ventilation of a rabbit.

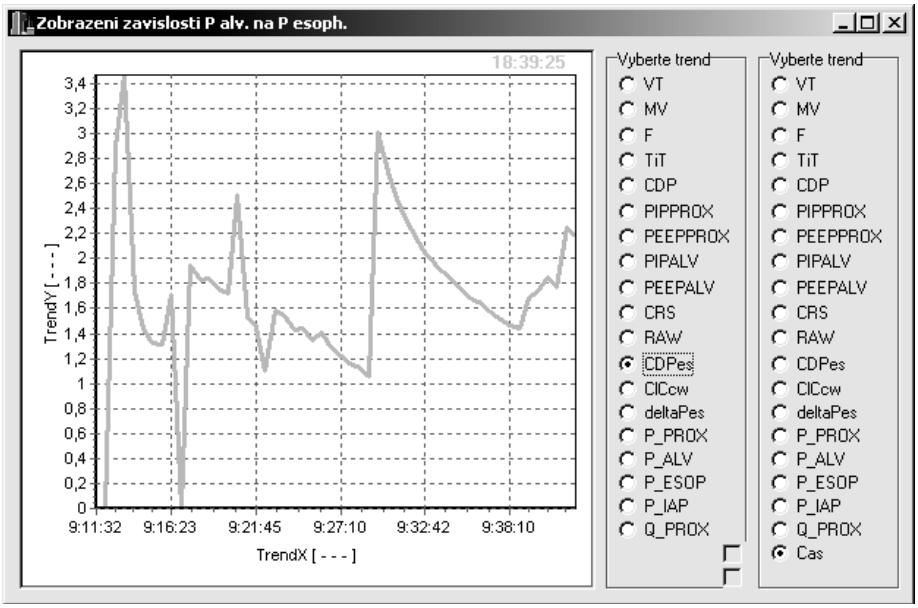

Figure 3: Example of depicting trends and selection of all the possible parameters recorded during the history of artificial ventilation.

The main advantage of the system is breath-to-breath analysis of the lung, chest wall and the respiratory system compliances, which makes the system unique. These parameters are used for making decision about ARDS type and consequently about the best ventilatory strategy. An example of the changes in compliances in a rabbit in dependency on positive end-expiratory pressure, measured by the designed system, is presented in Figure 4.

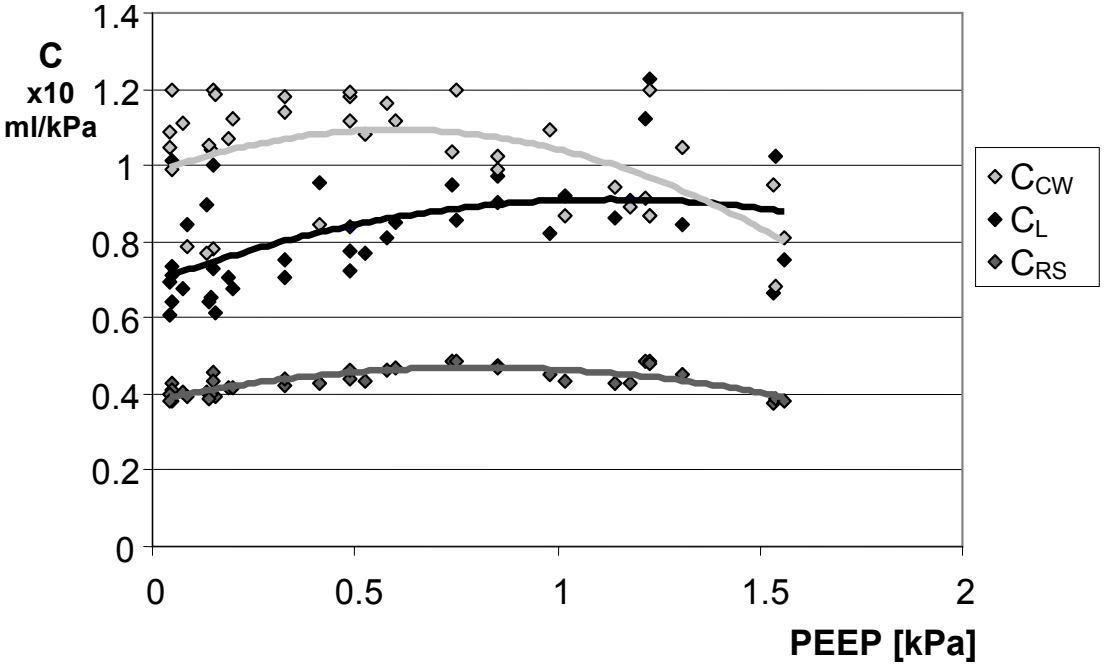

Figure 4: Dependency of chest wall, lung and the respiratory system compliances on increasing positive end-expiratory pressure (PEEP) in a rabbit.

Conclusion

The designed and tested system is able to analyze suitability of a patient for treatment of ARDS with high-frequency oscillatory ventilation, which is based on detail analysis of the respiratory mechanics.

The tests confirmed not only functionality of the designed system, but also its ability to distinguish between pulmonary and extrapulmonary ARDS forms. It gives the clinician a tool for efficient and reasonable application of progressive unconventional ventilatory technique—high-frequency oscillatory ventilation.

Acknowledgement

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Contacts:

Karel Roubík, Assoc. Prof., M.Sc., PhD
CTU in Prague
Faculty of Biomedical Engineering
nám. Sítná 3105, 272 01 Kladno
e-mail: roubik@fbmi.cvut.cz
phone: +420 603 479 901