Doctoral School of Information and Biomedical Technologies
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SUBJECT: Development of optimal lung ventilation minimizing the risk of Ventilator-Induced Lung Injury (VILI)

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DESCRIPTION: The project is focused on investigations concerning mechanisms of artificial ventilation influence on inhomogeneous, pathologically changed lungs.

The project goals are clearly cognitive expanding the current state of knowledge on the risk factors of Ventilator Induced Lung Injury (VILI), caused by: barotrauma, high driving pressure, volutrauma, atelectasis, biotrauma and ergotrauma. VILI is the worst side effect of artificial ventilation of the lungs. The results of our investigations will indicate what ventilation methods or set of ventilation parameters could be the most suitable to avoid VILI, especially in patients with lung pathology. Different criteria for minimizing the risk of VILI will be taken into account (maximum alveolar pressure, work of breathing and respiratory power).

For more than the last 7 decades, artificial ventilation of the lungs has been realized utilizing mechanical ventilators, in most cases of the respiratory system inefficiency or during surgical operations. The ventilators perform automatically by generating intermittent positive pressure at the respiratory airways, which results in continuously changed positive pressure in the alveoli. In patients with lungs pathology or/and in cases of improperly adjusted ventilation parameters like too high inspiratory pressure or tidal volume the so-called Ventilator–Induced Lung Injury (VILI) may arise, that is a bad, serious side-effect of positive pressure ventilation. Lungs have viscoelastic properties so pulmonary stress and strain resulting in VILI depends on inspiratory pressure and its rate that is proportional to inspiratory flow. It implies that inspiratory ventilation power as a product of inspiratory pressure and flow, delivered to the lungs during inspiration is a good index of the risk of VILI. So, it was assumed in the project that the optimal ventilation method is the method to deliver a requested tidal volume to the lungs with a minimum inspiratory power. Thus, the research objectives in the project are the development of the optimal lung ventilation method minimizing the risk of VILI and the assessment of the efficacy of optimal lung ventilation on a model of pathologically changed lungs. Clinical investigations are expensive, time-consuming and many patients for investigations are needed to obtain statistically proven results of studies. Besides, such institutional authorities like European Commission or the US Food and Drug Administration encourage the researcher to diminish the number of animal experiments and replace them with in silico studies, especially in a preclinical phase. Contrary to clinical investigations, modelling of a ventilator-lungs system and usage of simulation to study their interaction is cheap, saves time and generally is easy to perform for experienced investigators equipped with proper experimental tools. It is also very

important that studies on virtual patients like lung models are devoid of ethical issues. To achieve the project objectives the simulation investigation will be performed on the hybrid (pneumatic–computer) simulator of the hybrid respiratory system (HRS) developed in the IBBE PAS that enables to connect of a mechanical ventilator pump with a computer model of lungs inserted in the simulator, using impedance transformers. The project result will be to find such inspiratory pressure and flow patterns to assure the minimization of mechanical power during lung ventilation and keeping it on a constant minimal level during inspiration. The results of the project will give new information to researchers, physicians and engineers working on the automation of ventilation therapy with the aim to improve its outcomes and speed up scientific investigations in this field by promoting the use of in silico simulation for ventilation strategy optimization. The method of investigation proposed in the project consists of ventilation of the lungs model that is a part of the hybrid respiratory simulator (HRS), employing an arbitrary ventilation pump (AVP) generating intermittent positive pressure of changeable patterns. As far as the risk of VILI is concerned, a potentially safe level of applied ventilation power for patients is not known up to now. So, the minimum value of ventilation power will be traced in the simulation study automatically through so-called an extreme controller.
Thanks to the unique features of the HRS-AVP system, an analysis of the possibility of test database generation will be carried out to assess the AI applicability for lung ventilation diagnostics. AI usage in cases of various lung pathologies and under conditions of limited availability of measurement data would be of great importance.

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