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Scientific Paper:

Progress in Molecular and Environmental Bioengineering - From Analysis and Modeling to Technology Applications, Angelo Carpi (Ed.), ISBN: 978-953-307-268-5, 2011

A Liquid Ventilator Prototype for Total Liquid Ventilation Preclinical Studies

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Abstract:

Mechanical ventilation is a life-saving procedure used for treating acute respiratory distress, when the respiratory system is no longer capable of regulating blood gases via pulmonary gas exchange. While conventional mechanical ventilation (CMV) is often sufficient to transiently replace lung function until recovery, the most severe respiratory distress syndromes must be treated either by non conventional mechanical ventilation such as high frequency ventilation or even non ventilator strategies such as extracorporeal gas exchange (Raoof et al., 2010).
Large literature data suggest a radical change in ventilator support by replacing the traditional gas mixture with a breathable liquid. This method, called liquid assisted ventilation, leads to the replacement of the air-liquid interface in the alveoli by a liquid-liquid interface. Since the 70s, perfluorocarbon liquids (PFC) have been identified as the best candidates to be used in liquid ventilation due to their high oxygen and carbon dioxide solubility (Wolfson & Shaffer, 2005). In addition, they are biochemically stable and bio-inert molecules, available as medical grade products including for respiratory use. Liquid assisted ventilation can be performed either as partial or total liquid ventilation. During partial liquid ventilation, only a fraction of the lungs are filled with perfluorocarbon liquid and a conventional mechanical gas ventilator ensures lung ventilation. In contrast, during total liquid ventilation (TLV), the lungs are completely filled with perfluorocarbon liquid while a dedicated device, called a liquid ventilator, must be used to periodically renew a liquid tidal volume in the lungs. A large number of preclinical studies involving various animal models of acute respiratory distress syndrome have demonstrated clear benefits from total liquid ventilation as compared to all other tested ventilation strategies, including partial liquid ventilation, conventional and high frequency gas ventilation (Hirschl et al., 1996; Wolfson et al., 2008). Among its several theoretical advantages over CMV, TLV is considered less aggressive for the lungs due to lower positive inspiratory pressures and lower respiratory rates. This is felt to be beneficial in both pediatric and adult respiratory distress syndromes, where repeated alveolar overdistension during CMV contributes to acute and chronic lung injury (Chan et al, 2007; Hayes et al., 2010; Speer, 2009). Moreover, it offers a new means to clean the lung of inflammatory debris (Richman et al. 1992; Foust et al., 1996; Avoine et al., 2011).

Key-words: total liquid ventilation, perfluorocarbon liquids, respiratory distress syndrome, pressure control, oxygenator, oxygen fraction concentration