Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

Dynamic Imaging Method of Trachea's Oscillations in Total Liquid Ventilation - Preliminary Findings

Symon Vanackere[1], Kevin Le Duc[2], Malo Guémas[1], Éric Lavallée[3], Gabriel Richard[3], Nathalie Samson[2], Sébastien Poncet[1], Etienne Fortin-Pellerin[2], Philippe Micheau[1]

[1]Université de Sherbrooke, Génie mécanique, Canada (Québec)
[2]Université de Sherbrooke, Pédiatrie, Sherbrooke, Canada (Québec)
[3]Université de Sherbrooke, Image Analysis and Visualization Platform (IAVP), Canada (Québec)

ABSTRACT

Total Liquid Ventilation (TLV) aims to replace air in conventional ventilation with perfluorocarbon (PFOB), a breathable liquid. This technique could serve as respiratory support to help babies born extremely premature breathe. The project focuses on developing a technology capable of managing both inhalation and exhalation of PFOB. However, exhalation presents significant challenges due to the compliance of the respiratory tract, which can completely close by folding onto itself. This phenomenon, know as collapsus, may occur when the ventilator's flow rate exceeds the maximum expiratory flow. It could be associated with chocked flow, a condition arising when the liquid's velocity exceeds the local speed of sound.

Using a CT-Scan, the objective is to capture the dynamic of the trachea's closing and opening during TLV when the exhalation flow rate oscillates around the chocked flow conditions.

The Inolivent-10 liquid ventilator was modified to automatically induce tracheal oscillations. Moreover, a pressure-based feedback controller was implemented to regulate the exhalation flow rate, with an adjustable gain (Kp) based on the error function. Beyond a detection threshold, this error detects a pressure drop which may imply an excessive airway's deformation.

The measures were obtained from a 2.3 kg piglet under general anesthesia for 1 hour using a dynamic CT-scan at 10 Hz. Data were collected during exhalation and inhalation pauses (to measure local sound speed) and forced oscillations. After stabilizing the animal with a tidal volume of 40 ml, oscillations ranging from 1.2 to 4.9 Hz (induced by different controller settings) were recorded via dynamic CT imaging. The 3D images allowed visualization of the tracheal deformations. At a constant flow rate of -15 ml/s and a low gain (Kp = 1/20), large, low-frequency oscillations (1.2 Hz) were observed, with clear cyclic tracheal deformation in sync with pressure fluctuations. Conversely, at – 8mL/s with a high gain (Kp = 1/5), smaller, high-frequency oscillations (4Hz) were present, but no cyclic tracheal deformation was visible in the images.

Future works will focus on numerical modeling and interpreting the observed dynamics. Moreover, a study is needed to confirm that prolonged oscillations do not pose a risk to the trachea.