SPIV of natural breathing in Neonatal Airways

J. Aplin 1, P. H. Geoghegan1,*, C. J. T. Spence 2, N. Kabaliuk 1, M. C. Jermy 1

1: Dept. of Mechanical Engineering, The University of Canterbury, New Zealand
2: Fisher & Paykel Healthcare Ltd, Auckland, New Zealand

* Correspondent author: patrick.geoghegan@canterbury.ac.nz

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HIGHLIGHTS

- The flow field in a model of a neonate (new-born baby)’s upper airway has been mapped with SPIV.
- The flow field differs from that in adults in some aspects which relate to flow resistance.
- A recirculation region was observed on expiration at the rear of the nasal cavity. This will trap CO₂ to be rebreathed subsequently, as the vortex is absent during inspiration.

ABSTRACT

The mechanics of airflow through the upper respiratory system is complex and has been studied in adults using both experimental and computational methods. However, the velocity field within the airways of neonates (new-born babies) have been little studied. Neonates are particularly susceptible to illness and respiratory issues. A scaled transparent silicone model of the neonatal airway was developed and **Stereoscopic Particle Image Velocimetry (SPIV)** was used with a physiologically accurate breathing waveform to determine the velocity field during natural breathing. In the model studied, which represents one individual at one stage in the congestion/decongestion cycle, and despite some small asymmetry in the left and right nasal cavity shape and volume, the same gross flow features existed in both sides. In general the bulk of the flow passed through the Middle Airway with a portion of the flow branching into the Superior Meatus and Middle Meatus. The **maximum velocity** during both inspiration (5.2 ms⁻¹) and expiration (6.1 ms⁻¹) was observed to occur within the right Nasal Valve. On expiration the Nasopharynx was found to have well distributed flow whereas during inspiration flow through the Nasopharynx was in the form of a jet which follows the posterior wall. These features have a bearing on the resistance to flow, which influences the work of breathing i.e. the metabolic cost and physical effort required to breathe at a given rate. Also, during expiration a region of recirculation is present in the **Superior Meatus** which is predicted to trap carbon dioxide and decrease the effectiveness of carbon dioxide removal during breathing. During inspiration, **non-quasi steady flow behavior** was found posterior to the Nasal Valve. The velocity fields obtained share a number of gross flow features observed in adults as well as some areas of difference. Furthering understanding the physics of air flow through the upper respiratory system will contribute towards the development of improved medical care for patients with respiratory illnesses or those in critical condition.