Introduction
Tracheomalacia is the collapse of the trachea during expiration. The prevalence of tracheomalacia is 1 in 2100 children and it is higher in patients with lung diseases such as bronchopulmonary dysplasia.

Methods - Computational Fluid Dynamics

- Each CFD simulation was performed using the commercial package, Star-CCM+ 14.04.011 and the large eddy simulation (LES) mathematical model was applied as the turbulence model.
- The CFD mesh was about 2 million cells constructed with polyhedral cells in the interior and with nine prism layers on the wall. The temporal resolution was 0.8 ms.
- The first boundary condition for the CFD simulation was airway motion during the breathing cycle. It was obtained for each subject by registering airway surfaces which were segmented from MR images at 4 different time-points (end inspiration, peak inspiration, end expiration, and peak expiration) during the breathing cycle.
- The second boundary condition was the airflow rates of the left and right bronchi during the breathing cycle. It was obtained using the total lung volume and the median respiratory waveform of each subject.
- The total pressure along the airway of each subject was calculated at peak expiration and measured the total pressure loss across the glottis.

Results

- Figure 5 illustrates the glottis motion during the breathing cycle of two subjects with tracheomalacia (purple) and without tracheomalacia (yellow).
- On average, the glottis cross-sectional area at peak expiration in the subjects with tracheomalacia was 3.63 mm² and without tracheomalacia was 11.43 mm² (p = 0.016, Figure 6).

Conclusions

- This is the first study that demonstrates auto-PEEP in newborns.
- The total pressure loss at the glottis during peak expiration in the subjects with tracheomalacia was more than 11 times higher than subjects without tracheomalacia, suggesting auto-PEEP due to the narrowing of the glottis.
- Respiratory gated MRI allows reconstruction of UTE MR images at multiple points during the breathing cycle, providing a means for UTE MRI to be generated and visualized.
- The combination of UTE MRI and CFD enables modeling of airflow in the airway with dynamic motion to obtain clinically relevant information that can be used to improve patient care and health.
- The imaging method is a free-breathing, non-invasive and non-ionizing technique to assess tracheomalacia.

Future studies will be focused on quantifying the entire airway starting from nostrils to lungs.

References


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