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Flow Pattern Comparison between LES and Unsteady Reynolds-Average Navier-Stokes Modeling for the Upper Airway Model with Obstructive Sleep

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Extended Abstract

Obstructive sleep apnea (OSA) is a common disorder characterized by partial or complete narrowing of the pharyngeal airway during sleep (Mihaescu, et al., 2011) resulting in repetitive airflow cessation, blood oxygen desaturation and sleep disruption (Christian, Ara, & William, 1976). The upper airway surgery aims to widen the volume of the airway, is usually performed to treat this disorder. However, the success rate of this surgery is limited. To increase the success rate of surgery, it is crucial to understand the flow features in the upper airway. Invasive method to study the upper airway flow characteristics of OSA subjects is generally not applicable in the clinical practice. Due to the non-invasive nature, the computational fluid dynamics (CFD) technique has been widely utilized to characterize the fluid flow in the upper airway. Since the complex morphology of the upper airway region is very complex, the flow is expected to be turbulent, and the turbulent model is usually involved in such simulation. It is crucial to select the proper turbulence model for accurate CFD simulation in OSA upper airway.

In this study, we compared the large eddy simulation (LES) and Unsteady Reynolds-Average Navier-Stokes (URANS) approaches in four human OSA upper airway models. The URANS models are unsteady k-ε, unsteady standard k-ω, and unsteady k-ω Shear Stress Transport (SST). The results show that the URANS models and LES model can obtain the same pressure drop across the airway in all the four OSA upper airway models, proved that the URANS models has the same capability for the mean pressure simulation compared with the LES model. Due to the anatomic narrowing for the OSA upper airway model before surgery, a strong jet flow was induced and resulted in several complex recirculation zones downstream of the minimum cross-sectional area. LES model can capture much more recirculation zones, while unsteady standard k-ω and k-ω SST can usually capture two recirculation zones, but only one of these recirculation zones can be captured by unsteady k-ε model. For OSA upper airway model after surgery, the airway is widened and the jet flow is attenuated, consequently the separation induces a main recirculation flow downstream of the minimum cross-sectional area. All the four turbulent models can capture this main recirculation zone. Flow oscillation may play an important role to evaluate the OSA severity. LES model can well simulate the flow oscillation, while only little flow oscillation can be captured by the URANS models. The purpose of CFD simulation in OSA upper airway is to predict the surgery outcome and help the surgery planning based on the correct and accurate flow features obtained. LES model is capable of capturing the flow patterns and flow oscillation and is good for prediction of OSA surgery. Even URANS can get the correct pressure distribution along airway, it may not be appropriate to be used for surgery prediction.

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