Fluid-structure interaction in Obstructive Sleep Apnea: validation of numerical simulations using measurements on an in-vitro setup [invited lecture]

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1.CLINICAL CONTEXT

An obstructive apnea consists in brief cessation of respiratory airflow, caused by soft tissue collapsus within the upper airway (1). Numerical simulations of the fluid-structure interaction involved during this phenomenon are of interest for clinical applications (2). In this context, simulations must be validated using experimental data.

2.MATERIAL AND METHODS

a. Numerical simulations

Within the framework of continuum mechanics, simplified assumptions have been considered so as to allow computation time compatible with clinical applications. Linear elasticity in association with small perturbations assumption have been chosen for the soft tissue. An asymptotic simplification of the full Navier-Stokes equations, called Reduced Navier-Stokes / Prandtl (RNSP), has been used for the respiratory airflow (3). The complete set of equations is solved using a mixed finite differences / finite elements method, inside a fluid-structure interaction loop (4).

b. Experimental validation

Systematic comparisons between the simulations and measurements performed on an in-vitro replica of the tongue and of the oropharynx have been carried out. The setup consists in a deformable tongue made of latex, connected to a rigid pipe in which the airflow circulates (fig. 1) (4). Pressure distribution was measured at several places along the replica while its deformation was quantified using a digital camera. Computer simulations have been performed for similar configuration and confronted to the measurements.

3.RESULTS / DISCUSSION

a. Results of comparisons

The results of the systematic comparisons can be summarized as follows :

- partial obstruction (hypopnea) is observed both on the replica and from simulations,

- the prediction accuracy is within 30 % for the pressure distribution, and within 10 % for the deformation,

- above a given pressure difference (700 Pa), self sustained oscillations start, which can not be predicted numerically. However, it corresponds to snoring, not to an apnea.

b. Discussion

This study tends to prove the ability of our method to predict with accuracy a fluid-structure interaction, in conditions close to those of an apneic episode. In particular, simplified assumptions revealed to be sufficient for description of this interaction. This is interesting as it allows a considerable reduction of computation time.

Bibliography

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Figure

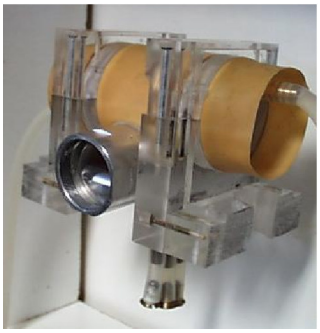

Fig. 1 - Photograph of the in-vitro setup.