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SIMULATION OF SWALLOWING INCLUDING ANATOMICAL STRUCTURE AND FOOD BOLUS FLOW USING FLUID-STRUCTURE INTERACTION METHOD

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Summary: Swallowing is the process of transporting food masticated in the mouth through the pharynx to the esophagus. The transported food is often a mixture of solid and liquid. Organs involved are multiple soft tissues such as tongue, soft palate, pharyngeal wall, epiglottis, arytenoid, vocal cord and esophagus.

Therefore, swallowing simulation essentially needs a model of solid and liquid mixture for food and an elastic model for living body. In this study, we apply a method of coupled analysis of fluid and elastic body using newly developed fluid-structure interaction (FSI) technique in particle method. The technique leads us to analyze the interaction between organs or between organs and bolus.

In the structural analysis, the behavior of particles arranged in organs was analyzed by elastic force, artificial force, force of viscosity, and contact force.

The elastic force was analyzed using Hamiltonian Moving Particle Simulation (HMPS) method usually applied to non-linear elastic body. In the HMPS method, displacement mode with specificity and local vibration of particles are likely to occur, thereby providing artificial potential as a stabilizer. The viscous force was introduced not to reproduce strict visco-elasticity but to stabilize the calculation. The contact force consists of a normal force and frictional force. The wall surface represented by particles was smoothed by the metaball technique and then the repulsive force was calculated by the penalty method. The soft tissue was applied nearly incompressible Mooney-Rivlin model.

From the medical CT image and the video-fluorography of swallowing, the tongue, soft palate, pharyngeal wall, epiglottis, arytenoid, vocal cord and esophagus were modeled to make it anatomically refined form. For foods, the solid part was analyzed as an elastic body, and the liquid part was analyzed as a fluid using the Explicit MPS method. Physical property values were determined based on actual measurement data.

This study made it possible to model not only accurate anatomical structures and movements but a mixture of solid and liquid of food for simulating swallowing. In the future, we plan to develop it for swallowing simulation to elucidate the mechanism of swallowing and aspiration.