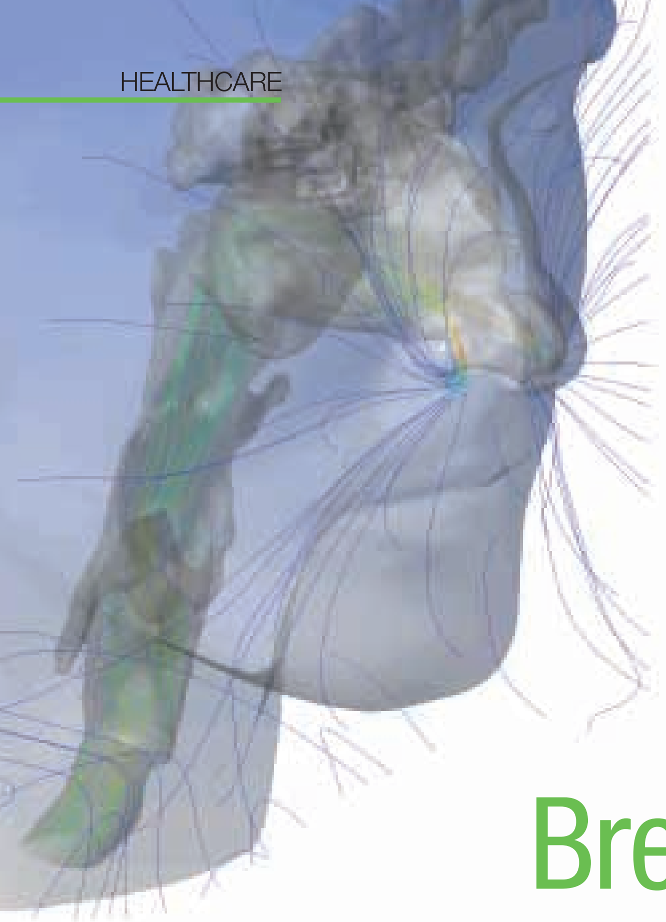

Pathlines for air flow during inhalation, colored by velocity

Breathing **Easily**

Simulation of airflow in human noses can become a useful rhinosurgery planning tool.

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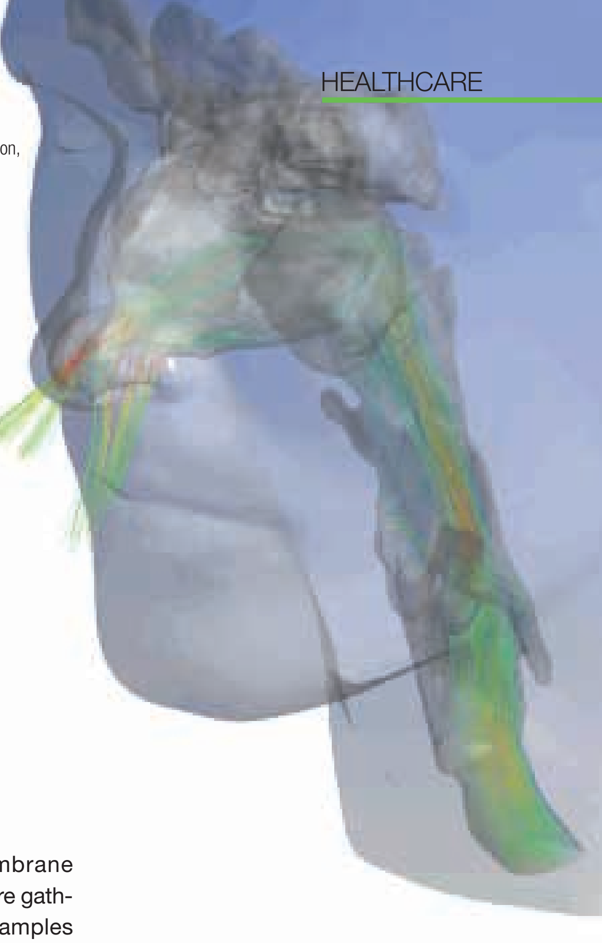
A requirement for normal breathing through the nose is an undisturbed passage through the nasal airways. If this condition is not fulfilled due to any obstruction or deformation, surgical correction of the nasal airways might be required. Rhinosurgery is a reconstructive surgical approach that reshapes the nose and/or nasal structure and often is used to correct birth defects or other breathing problems.

To understand the effects of nasal anatomy on normal breathing, a team in Germany composed of members from the Zuse-Institute Berlin, Asklepios Clinic Birkenwerder and CFX Berlin Software GmbH carried out simulations using ANSYS CFX computational fluid dynamics (CFD) software. The research team based the analysis models on highly detailed internal and external nasal anatomy. The ability to simulate complex airflow characteristics with regard to individual anatomy enables the study of the physiology and pathophysiology of nasal breathing on a per patient basis. As a result, fluid flow simulations can become an extremely useful tool in treatment planning for functional rhinosurgery.

For this study, the research team based their investigations on a reference model of the nasal airways created from actual human anatomy without obvious pathologic symptoms. To develop a geometric model for this case, researchers first acquired a helical computed tomography (CT) scan of a male volunteer following local administration of a decongestant. High-resolution tomography with an almost isotropic spatial resolution of 0.37 x 0.37 x 0.4 millimeters allowed for the representation of internal anatomical structures with sufficient detail. This provided the team with three-dimensional geometric information that they used to create a simulation model of the nasal and paranasal cavities.

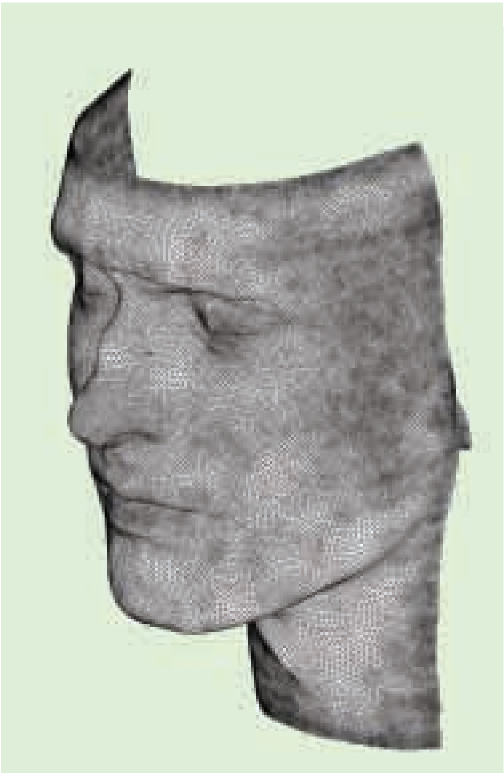
The research team then used AMIRA®[4] software to reconstruct and



Pathlines for air flow during exhalation, colored by velocity

mesh the flow domains based on the CT scan information. In addition to creating the volumetric grid of inner airway structures, the research team reconstructed the facial soft tissue. To accomplish this, they generated a grid for the anterior inflow region in order to simulate the effect of the nose and face external surface geometry on the inhalation flow behavior. Finally, the team exported the meshed model, with locally refined resolution and suitable element quality, in computational fluid dynamics (CFD) General Notation System (CGNS) format for import into ANSYS CFX software.

The CFD simulation involved calculating the transient flow behavior over seven breathing cycles. The researchers applied a pressure difference between the inlet and outlet (lung) as a boundary condition. The lung pressure was represented as a function of time and was derived from a series of active anterior rhinomanometry (AAR) measurements, recorded from the same subject from whom the geometry model was derived in a comparable mucous membrane swelling condition. Samples were gathered at a rate of 2,000 samples per 15-second measurement. Finally, researchers measured air volume flow for validation of the simulation results and found that there was appropriate agreement between the experimental and numerical data.



Mesh for external facial geometry

To gain a better understanding of the relationship between nose morphology and respiration, the research team is currently investigating the effect of anatomical changes to the external nose geometry. Using an advanced biomechanical tissue model, they can vary the shape of the external nose in a realistic manner, increasing or decreasing the nasolabial angle or the cross section of the nasal valve, for example. Such variations may disturb the inspiratory inflow due to an increased resistance, an impaired airflow distribution or a pathological turbulence behavior. In this way, interactive geometry alteration of the nasal airways in combination with a simulation analysis of the resulting fluid flow using ANSYS CFX technology can provide a basis for a sophisticated virtual rhinosurgery planning tool. Conclusions drawn from simulation could have an important impact on future surgical and conservative therapeutic concepts, thus driving clinical research.

In further investigations, the research team will study the humidification of nasal airflow as a multi-fluid flow with an additional transport equation for water vapor. In those studies, the humidity charge of the nasal mucosa will be modeled, and humidity transfer between mucosa and air will be considered by appropriate boundary sources at the fluid walls. To accomplish this, researchers will introduce dense layers of pentahedral prism elements at the air–mucosa interface to ensure accurate numerical calculations for fluid shear stresses, such as changes of air velocity at the mucosal walls. In addition, this simulation methodology will enable the study of pharmacokinetic issues, such as the effective application of drug delivery via the respiratory system. In these simulations, the medication particles and inspired air will be regarded as a multiphase flow consisting of liquid droplets (dispersed distributed particle flow) in a continuous air stream; a heat transfer mechanism will also be included. ■

References

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