Rhinodiagnost: Morphological and Functional Precision Diagnostics of Nasal Cavities

In this project, globally recognized research centers and market-leading medical technology companies are working on coordinated morphological and functional diagnostics for ear, nose and throat (ENT) physicians. Services are organized as a fast-working network in which important new decision aids, such as 3D models and flow simulation results, are made available to ENT specialists.

The nose is one of the most important organs of the human body and its functions are essential for the comfort of the individual patient. It is responsible for olfaction, supports degustation, filters the air of harmful particles, and tempers and moisturizes the inhaled air to create optimal conditions for the lung. Diseases and discomfort in the nasal cavity as they occur, for example, in chronic rhinosinusitis, nasal septal deviation, after surgery, or in polyp diseases, often lead to a reduction in one or more of these functionalities. Such a reduction frequently results in a limitation of the respiratory capacity, the formation of inflammatory foci in the nasal cavity, and lung diseases. A meaningful rhinological diagnosis is therefore key in evaluating the effectiveness of patient-specific nasal functionalities, taking into account the respective pathology.

The diagnostic quality is currently primarily based on the quality of the training of the practicing physician and his or her experience

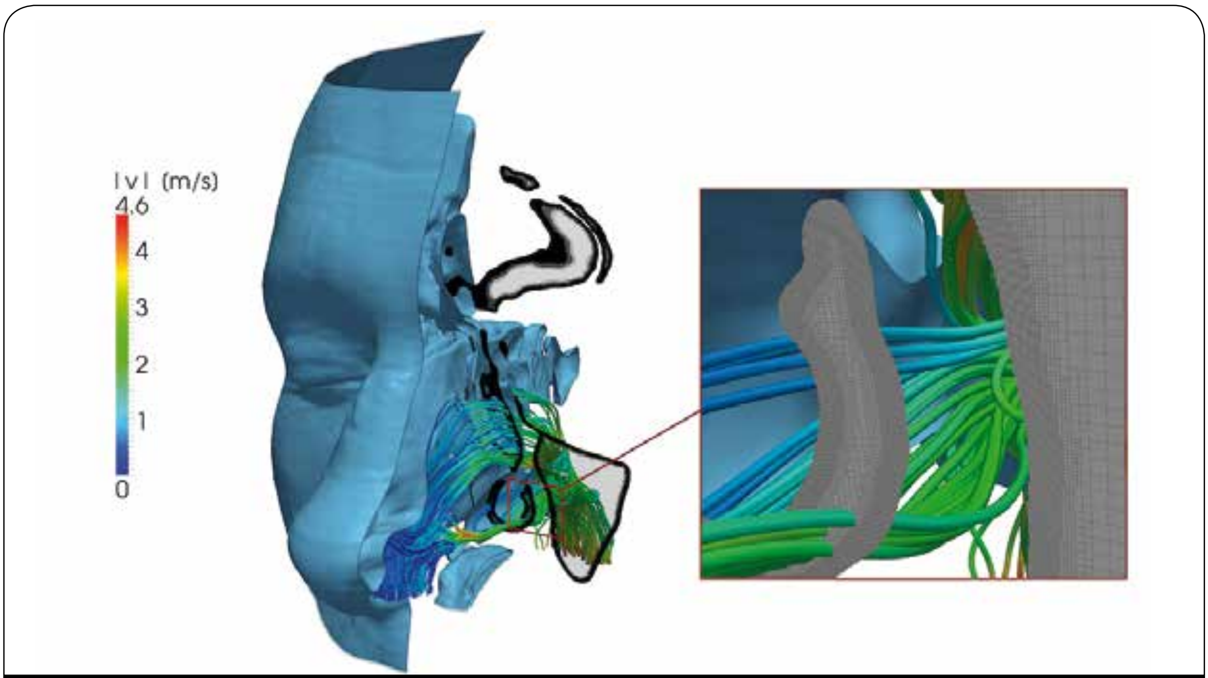

Fig. 1: Inspiratory flow in the human nasal cavity. The streamlines are colored by the velocity magnitude. The inset on the right shows a magnification of the boundary-refined computational mesh. © Institute of Aerodynamics, RWTH Aachen University.

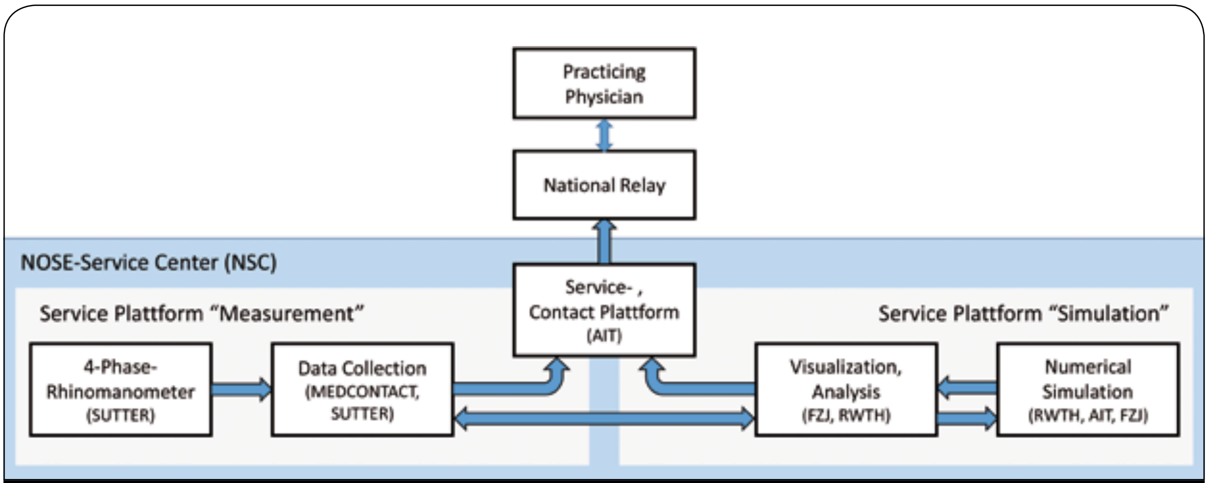

Fig. 2: NOSE-Service Center (NSC).

in the treatment of specific clinical pictures. The according functional diagnostics employ methods of medical imaging, such as computer tomography (CT) or magnetic resonance tomography (MRT), to enable a well-founded diagnosis. Unfortunately, such analyses do not include any information on the respiratory comfort of a patient defined by the fluid mechanical properties of respiration.

Project goals

Current developments in the field of computational fluid dynamics (CFD) and high-performance computing (HPC) allow for patient-specific prediction of the flow in a human nasal cavity by means of numerical simulations [1, 2] (see Fig. 1), enabling identification of anatomical locations of pathologies. In addition, advanced rhinomanometry methods [3, 4] allow medical professionals to determine respiratory resistance in order to provide extended information on the patient's respiratory capacity. Hence, results from CFD and rhinomanometry can be used to a-priori determine optimal surgery strategies for an individual patient in order to increase surgery success rates and to adapt treatment therapies.

Unfortunately, such methods have not made their way into everyday clinical practice due to their complexity and costs. In order to improve this situation, the implementation of a NOSE Service Center (NSC) is to be prepared within this project, offering extended possibilities of functional diagnostics, and providing a network of service points. Fig. 2 shows schematically the structure and interaction chain within the NSC.

Project consortium and tasks

To reach the project goals, two German medical device companies, namely Sutter Medizintechnik GmbH (SUTTER) and Med Contact GmbH (MEDCONTACT), jointly proceed with the Austrian partner Angewandte

Informationstechnik Forschungsgesellschaft mbH (AIT), and the two research facilities Institute of Aerodynamics (AIA), RWTH Aachen University, and Jülich Supercomputing Centre (JSC), Forschungszentrum Jülich, to implement the NSC.

In more detail, the partners will perform the following tasks to reach the overall project goals:

- **SUTTER** has developed the 4-phase rhinomanometer (4PR, 4RHINO), which was declared a standard in functional diagnostics in November 2016. SUTTER carries out optical examinations in an in-vivo nasal model and performs in-vitro analyses using 4PR to validate the numerical methods. In addition, the influence and the physical properties of the nasal valve, which can produce an airway collapse during accelerated flow, will be investigated by means of elastography methods.

- **MEDCONTACT** expands the 4PR with wireless data transmission functions for automated data collection. NSC compatibility will be ensured in cooperation with SUTTER and the 4PR will be clinically tested and introduced to the market.

- **AIT** sets up a service and contact platform, which is to serve as an interface between the practicing physician and the service platforms behind it. Additionally, AIT evaluates an established CFD method in terms of cost, efficiency and accuracy.

- **AIA** evaluates high-fidelity CFD methods in terms of cost, efficiency and accuracy. Furthermore, in-situ computational steering will be implemented to allow for online modification of the geometry at simulation run time and for an up-to-date fluid mechanical interpretation of the geometrical changes. Therefore, automatic analysis tools for expert analysts as well as tools retrieving key information relevant for direct clinical use will be implemented.

- **JSC** develops software components making the analysis of the simulation data accessible to the physician interactively and purposefully on modern HPC systems. Beyond that, the possibility of using virtual operations with direct updating and analysis of the flow parameters are demonstrated in close cooperation with AIA.

Project funding

Rhinodiagnost is funded as a ZIM (Zentrales Innovationsprogramm Mittelstand) project by the Federal Ministry for Economic Affairs and Energy (BMWi) in Germany. The Austrian partner is funded by COIN (Cooperation and Innovation), Federal Ministry of Science, Research and Economy (BMWFW). The project runs under the auspices of IraSME (International research activities by SMEs).

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