Computational fluid dynamics in idiopathic subglottic stenosis

Idiopathic subglottic stenosis (ISGS) is a rare condition with an estimated prevalence of 1:400,000.[1,2] ISGS occurs mainly in middle-aged women.[3] Chronic inflammation (with no known cause) leads to a concentrically growing scar at the site of the cricoid (transition from the subglottis to the trachea). The stenosis causes a restriction of airflow, which leads to complaints of shortness of breath with exertion, coughing and sputum retention.[4] The diagnosis is made by establishing a stenosis and excluding other known causes such as tuberculosis or granulomatosis with polyangiitis (GPA). Lung function examination usually shows both an obstructive inspiratory and expiratory flow, a so-called fixed airway obstruction (figure 1).

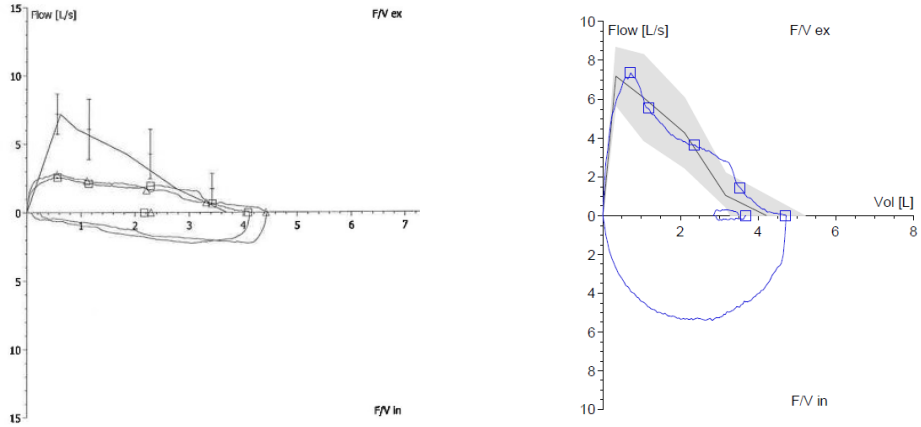

Figure 1. Flow-volume curve before (left) and after (right) the bronchoscopic incision and dilation.

Initial treatment of ISGS consists of bronchoscopic incision and dilation to restore the tracheal lumen (Figure 2). In the clinical practice a CT scan and lung function examination of the patient is performed. Based on static CT images it is not possible to make statements regarding air flow. Therefore, lung function is necessary to determine the degree of flow restriction and to improve airflow after treatment. With the help of computational fluid dynamics (CFD) it may be possible to calculate the flow and resistance in the airways. In addition to ISGS, CFD has been used in many other (more complex) diseases in the central airways to estimate the impact of a stenosis. The advantage of the ISGS syndrome is that it involves a relatively simple stenosis of the trachea, with virtually no dynamic component (variation of the airway lumen during inhalation and exhalation). Because lung function data are also available, this setting is ideal to investigate the usefulness of CFD.

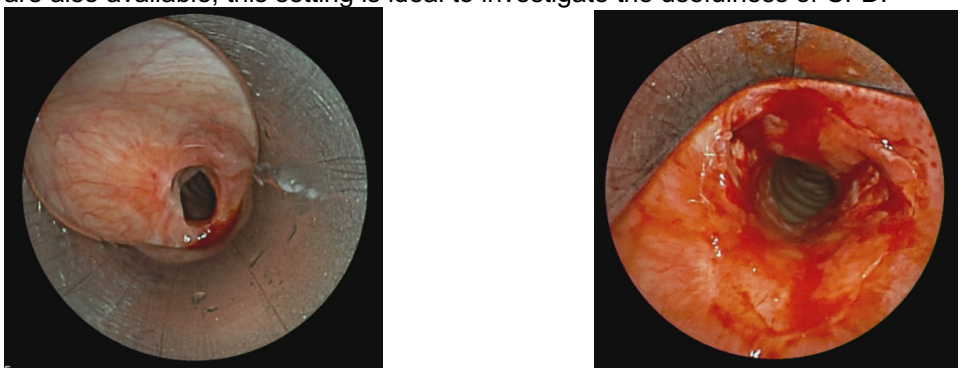

Figure 2. Bronchoscopic view before (left) and after (right) incision and dilation

Aim of the study: To simulate airflow over the trachea of patients with ISGS by means of CFD and to compare the results with the measured flow in lung function examination, both before and after the treatment.

Methods: A database with clinical imaging of patients before and after treatment is already available. Based on available CT scans of the neck, 3D reconstructions of the airways will be made (larynx to main carina). Initially, 10 patients will be analyzed using the open source VMTK image processing tool. Simulations will be carried out using the lattice Boltzmann method (LBM) based flow solver *Musubi*[5]. The Dutch national supercomputer Snellius will be deployed for the detailed CFD calculations (example

simulations shown in figure 3). The data generated by the simulations (estimated flow, resistance, pressure drop and turbulent intensities) will be compared with lung function data (peak expiratory flow % predicted, forced inspiratory value in 1 second/vital capacity % predicted) from the same patients. The sample size can be expanded based on the spread of variables.

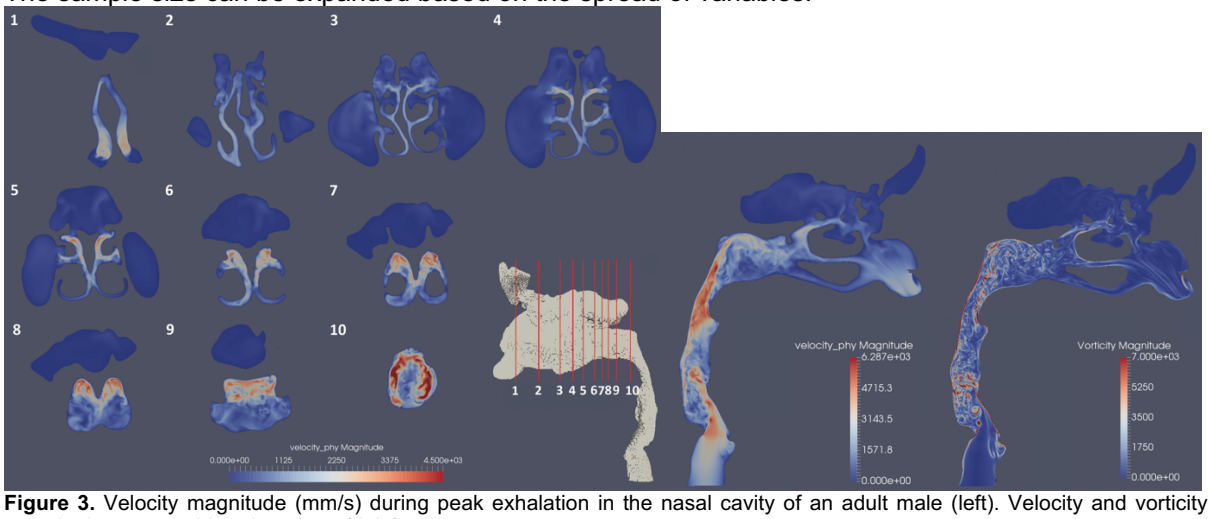

Figure 3. Velocity magnitude (mm/s) during peak exhalation in the nasal cavity of an adult male (left). Velocity and vorticity magnitude across a bisecting plane (right).

Expectations: This project will provide novel insights into the intrinsic flow dynamics that affect the pathophysiology of the ISGS using CFD. The candidate will have exposure to state of the art computing facilities and clinical data from a leading Dutch hospital. We expect a motivated student with TechMed or Engineering related background with a strong interest in CFD and its application in the biomedical field, with a will to make a difference in the health care through interdisciplinary research.

Supervision: Supervision on the clinical aspects of the studies will be provided by **Dr. J.M.A. (Johannes) Daniels,** Pulmonologist at the Amsterdam UMC. The CFD side will be supervised by **Dr. K. (Kartik) Jain**, Assistant Professor at the University of Twente (UT). **Dr. R. (Rob) Hagmeijer**, Associate Professor at the UT will act as the chair person for the examination. Scientists from AMC and UT will be available for discussions thus ensuring a good working atmosphere.

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References

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