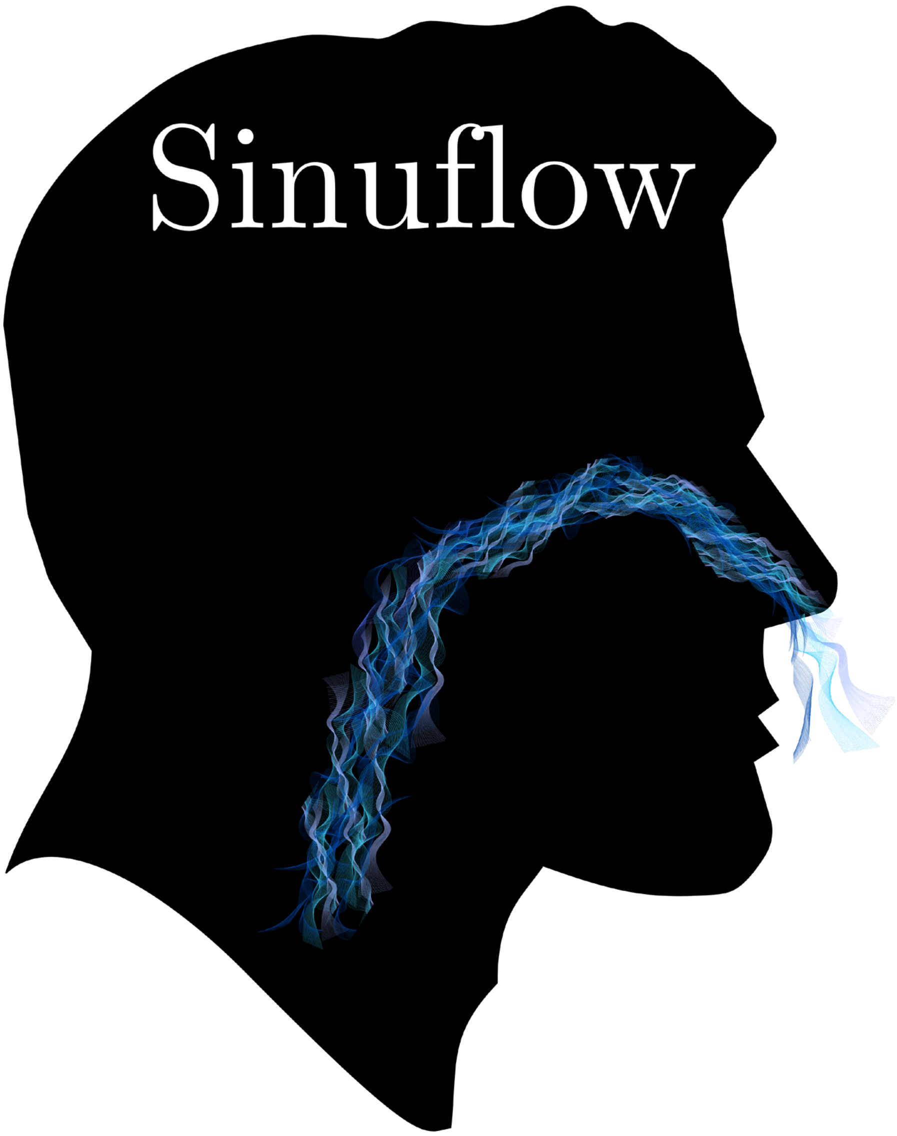

Sinuflow

Comprehensive Report Before and After Simulated Surgery

Contents

1.0| Introduction

This report is compiled using Computational Fluid Dynamics (CFD) tools. CFD is a division of fluid mechanics that employs the techniques of numerical analysis to find solutions to problems involving fluid flow, and as such should be regarded as an engineering tool alone and not a medical tool. This report does not contain medical claims.

CFD can be used to analyse airflow parameters such as air pressure, air velocity, air distribution and many more airflow characteristics in the nasal cavity. It is suggested that such parameters are evaluated by a medical specialist to identify the causes, if any, of nasal obstruction, bearing in mind that CFD although accurate, presents margins of error. Sinuflow advises to always accompany this study with thorough physical examinations including nasal endoscopy.

Sinuflow uses a patent pending method to analyse airflow distribution in different partitions of the nasal cavity. Studies suggest that nasal obstruction can be caused by localised abnormalities in airflow rather than a complete lack of airflow in the entire nasal cavity. This highlights the need to investigate airflow parameters in different sections of the nasal cavity separately.

2.0| Patient Nasal Airway Anatomy

2.1| Nasal Airway Anatomy

A 3D reconstruction of the nasal anatomy allows doctors to visualise all areas of the nasal cavity some of which are not easily accessible through conventional methods due to the narrow nasal passages. Nasal airway reconstruction often provides an effective way to visualise nasal abnormalities such as nasal valve stenosis, deviated septum, nasal polyps and many more. Note in the figures below sinuses are excluded for clarity.

2.1.1| Before Simulated Surgery

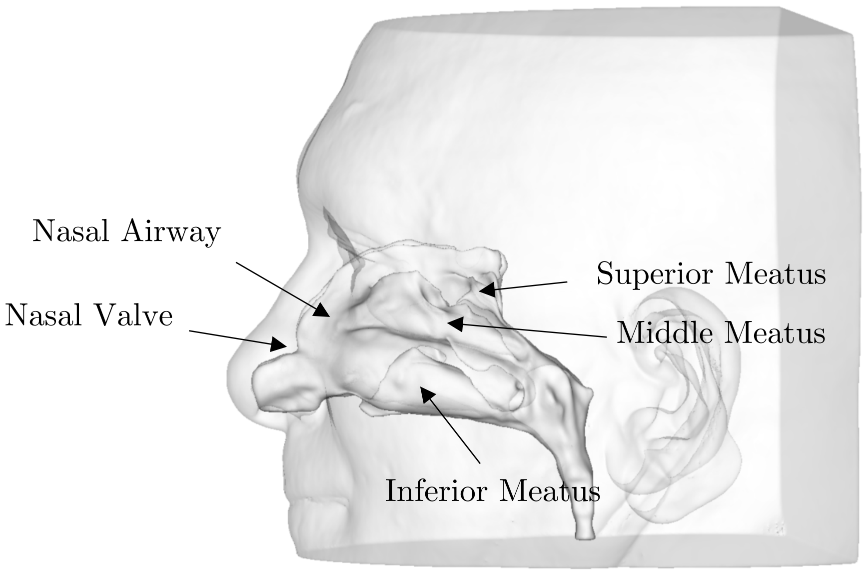


Figure 2.1.1.1: Reconstruction of nasal airway including face

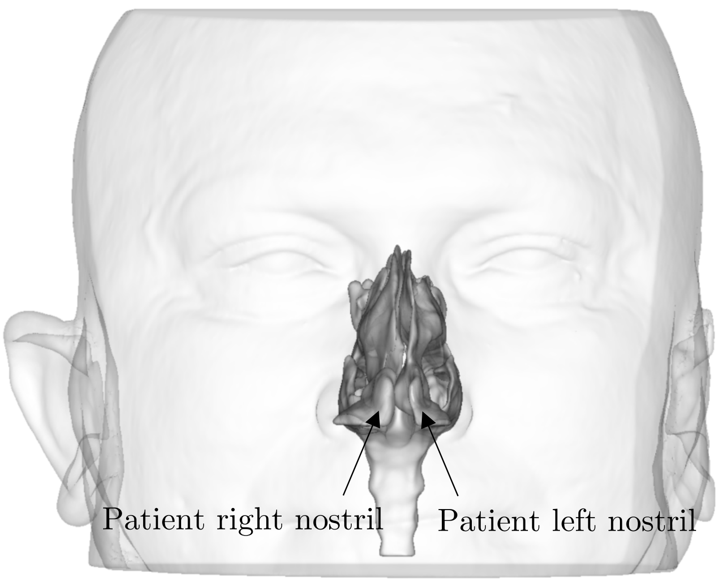


Figure 2.1.1.2: Reconstruction of nasal airway frontal view including face

Figure 2.1.1.3: Reconstruction of nasal airway frontal view

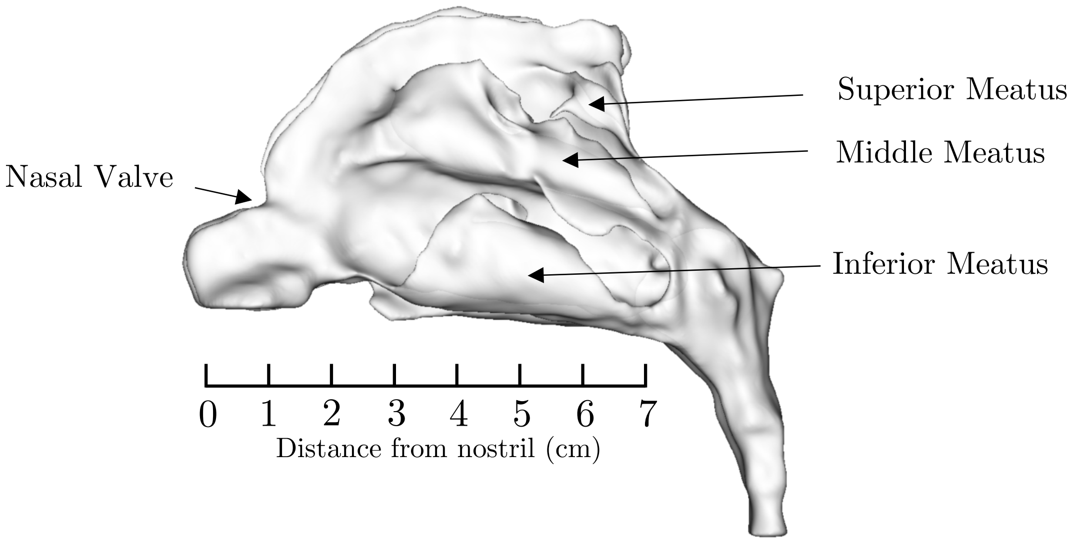


Figure 2.1.1.4: Reconstruction of nasal airway sagittal view (left airway)

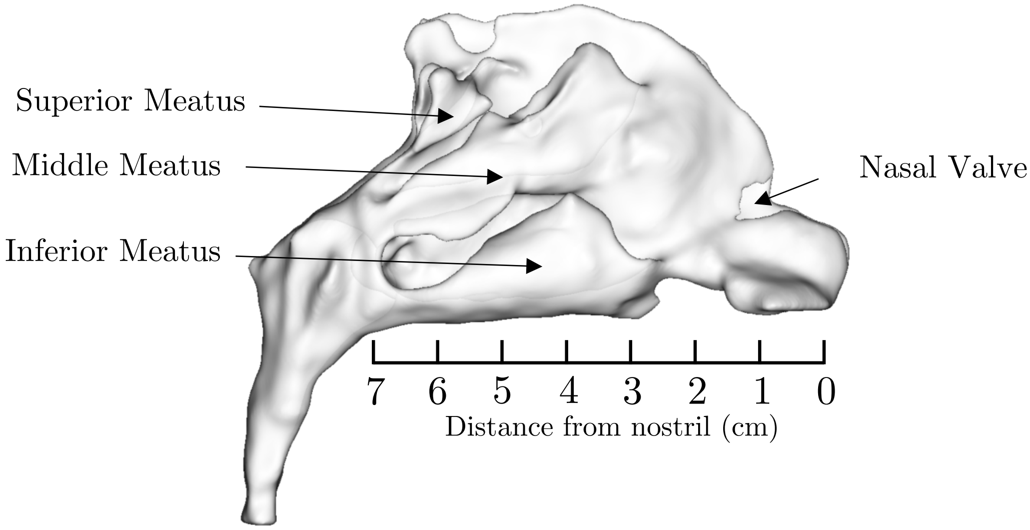


Figure 2.1.5: Reconstruction of nasal airway sagittal view (right airway)

2.1.2| After Simulated Surgery

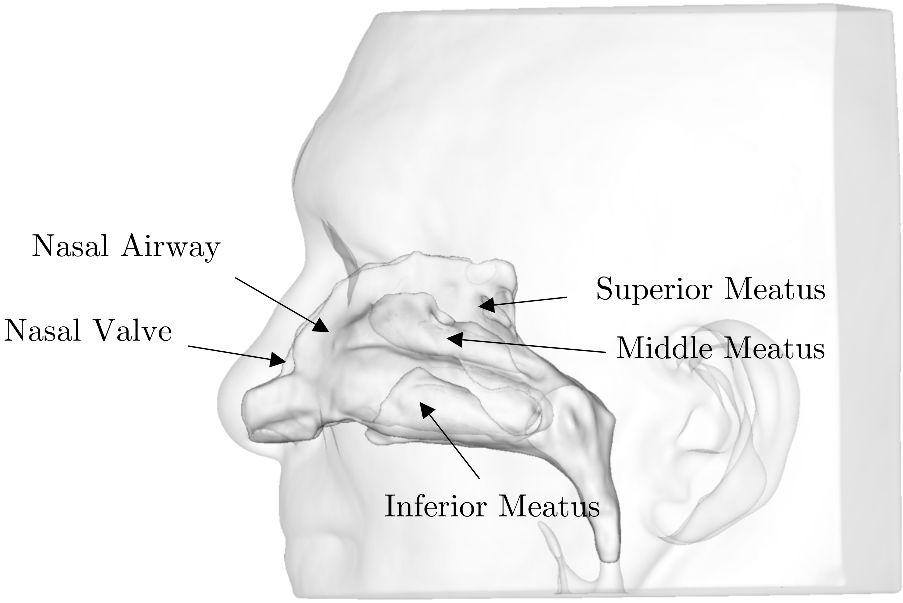


Figure 2.1.2.1: Reconstruction of nasal airway including face

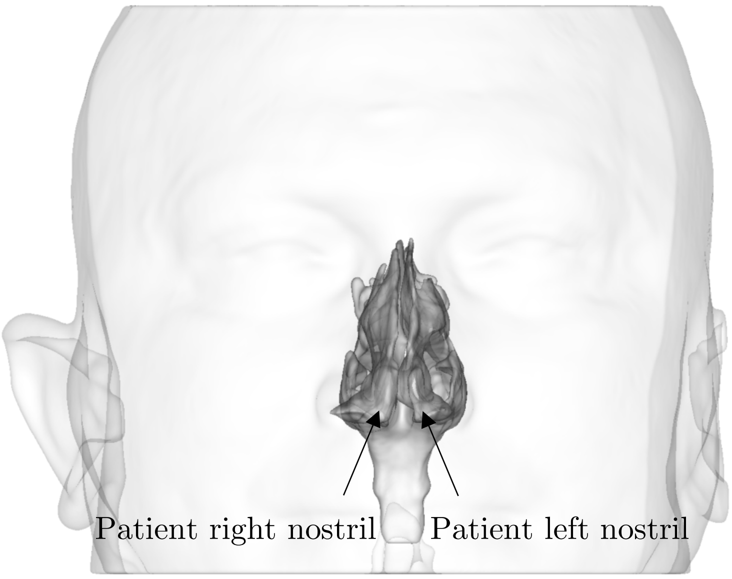


Figure 2.1.2.2: Reconstruction of nasal airway frontal view including face

Figure 2.1.2.3: Reconstruction of nasal airway frontal view

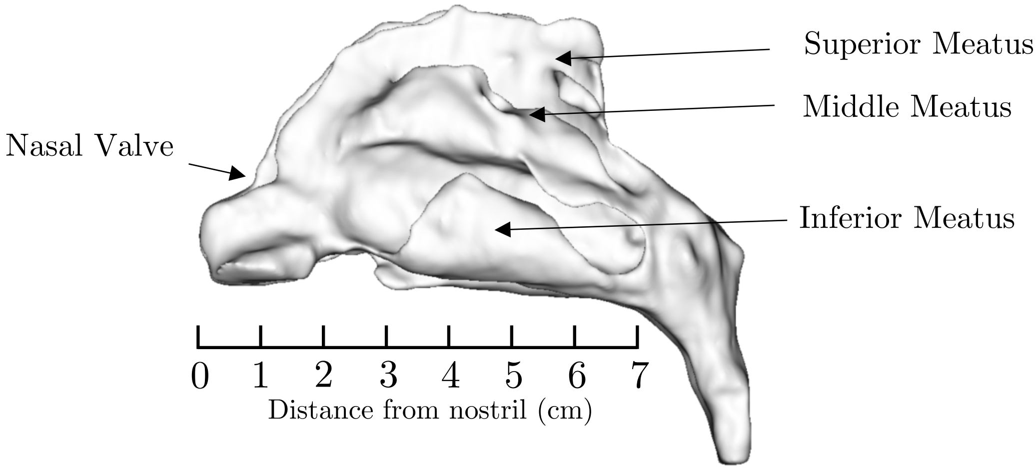


Figure 2.1.2.4: Reconstruction of nasal airway sagittal view (left airway)

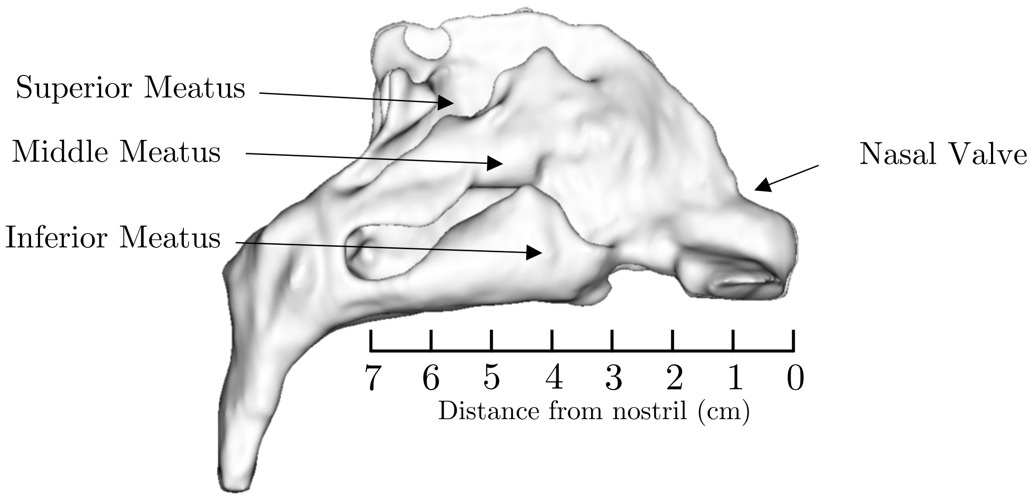


Figure 2.1.2.5: Reconstruction of nasal airway sagittal view (right airway)

2.2| Nasal Airway Video Before Simulated Surgery

2.3| Nasal Airway Video After Simulated Surgery

3.0| Airflow

3.1| Airflow Streamlines

Airflow streamlines provide a visual image of the airflow in the nasal cavity. Generally, in a healthy nasal cavity, streamlines are uniformly distributed. Uniformly distributed streamlines ventilate the inferior, middle and superior meatus alike. In unhealthy nasal cavities streamlines are localised in few areas leaving other areas unventilated.

3.1.1| Left Airway

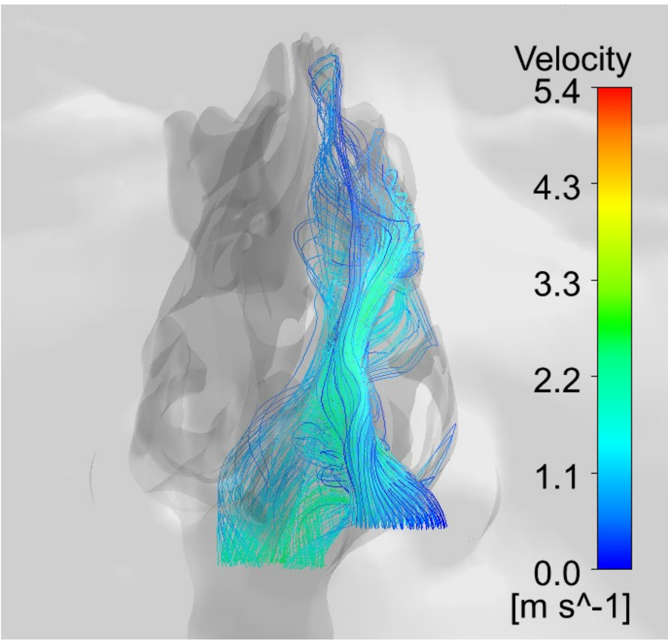


Figure 3.1.1.1: Coronal view streamlines (before simulated surgery)

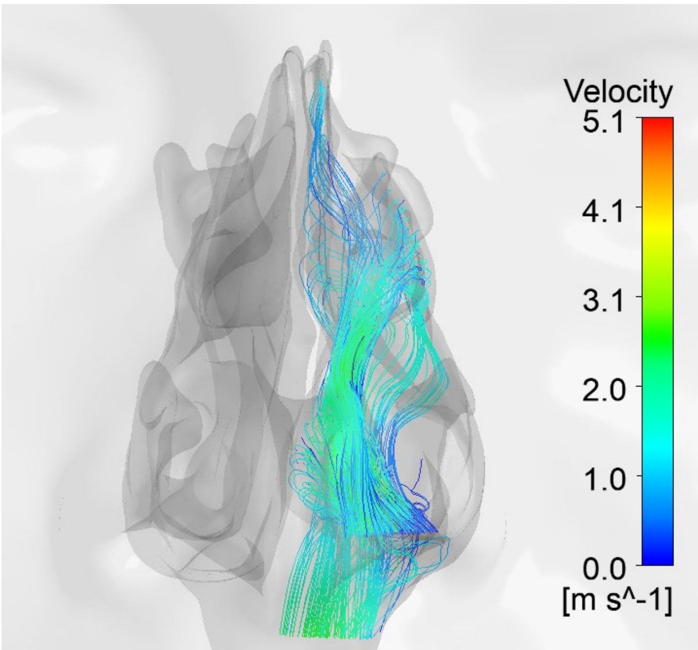


Figure 3.1.1.2: Coronal view streamlines (after simulated surgery)

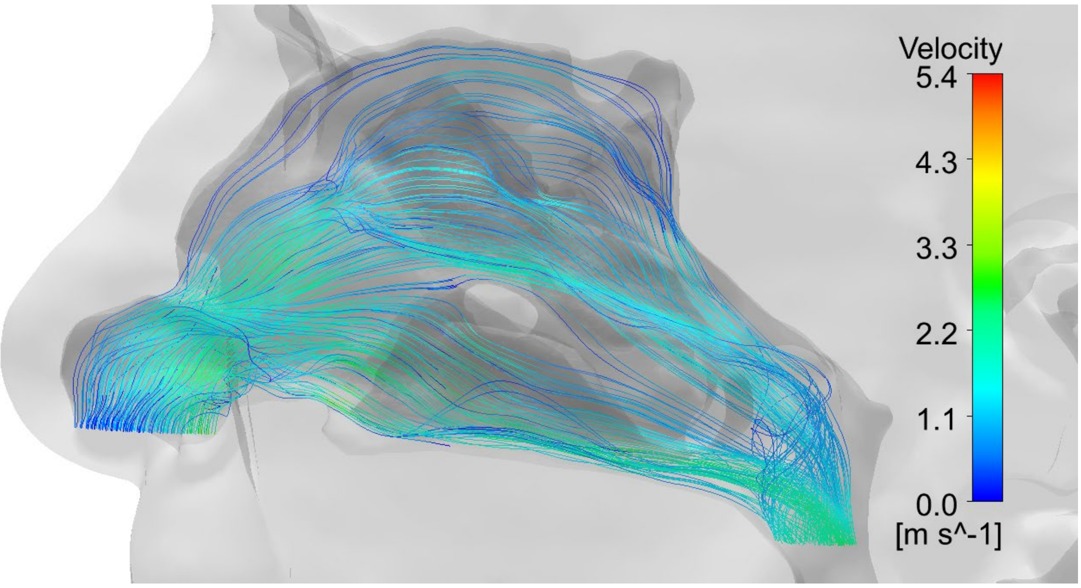


Figure 3.1.1.3: Sagittal view streamlines (before simulated surgery)

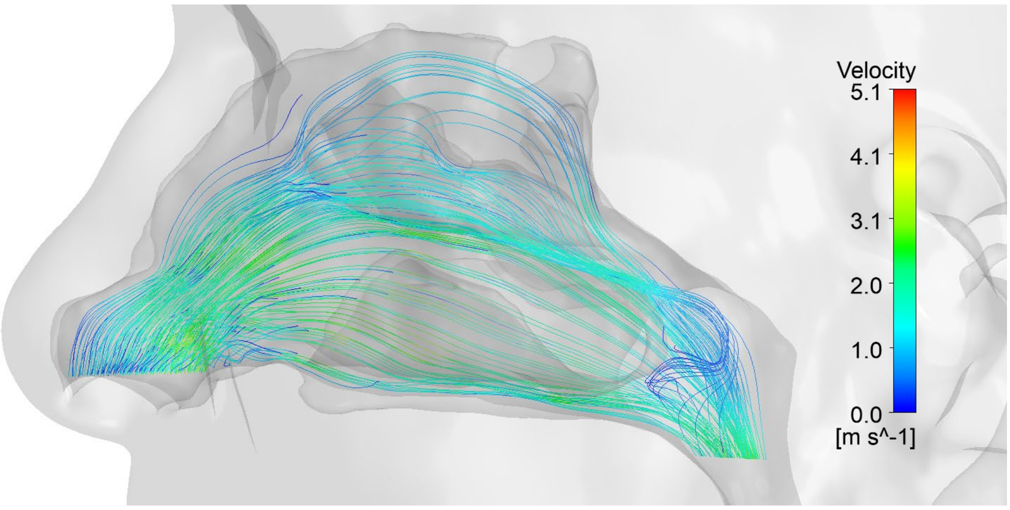


Figure 3.1.1.4: Sagittal view streamlines (after simulated surgery)

3.1.2| Right Airway

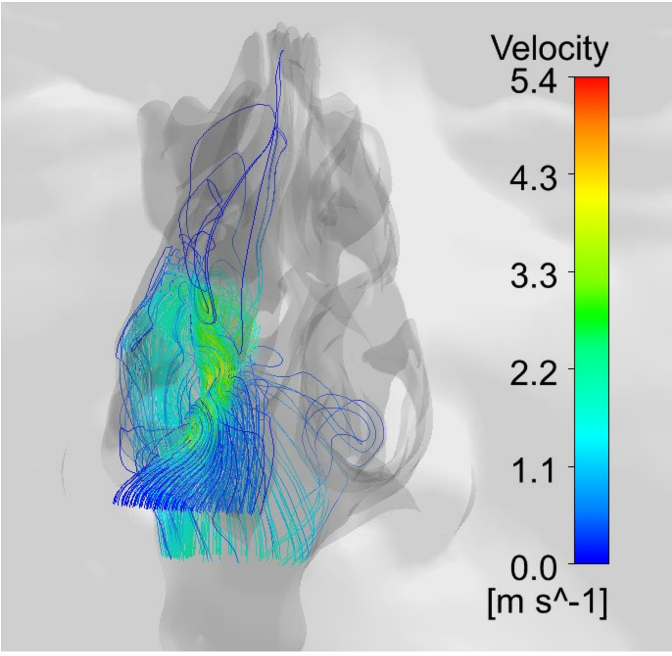


Figure 3.1.2.1: Coronal view streamlines (before simulated surgery)

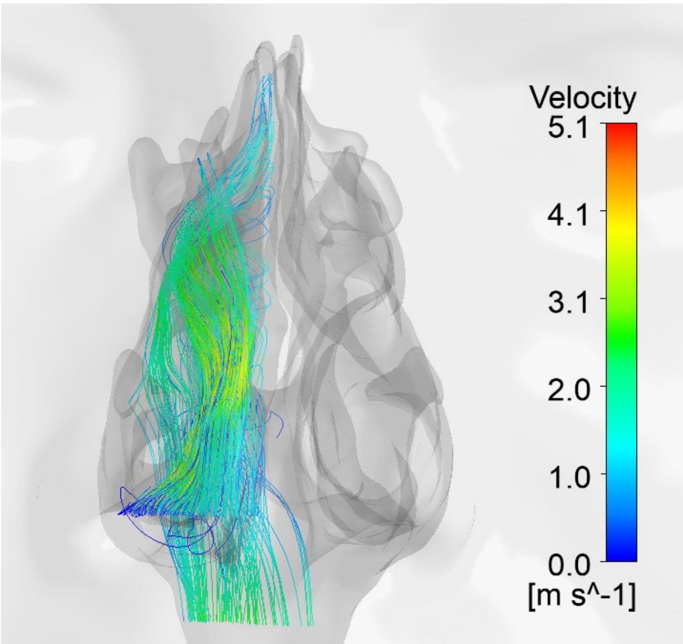


Figure 3.1.2.2: Coronal view streamlines (after simulated surgery)

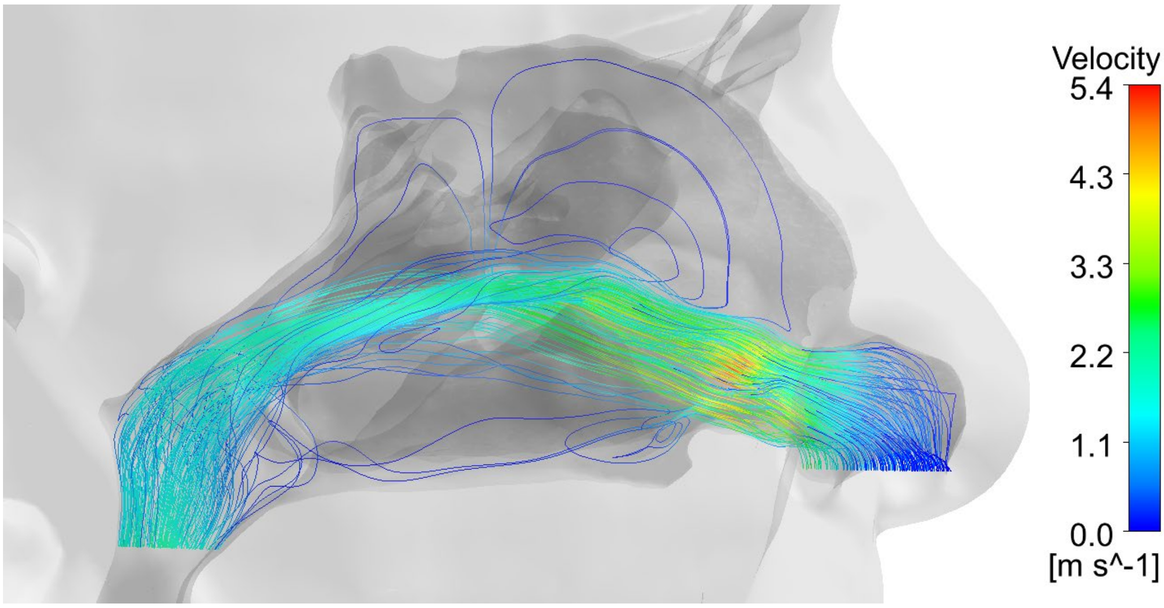


Figure 3.1.2.3: Sagittal view streamlines (before simulated surgery)

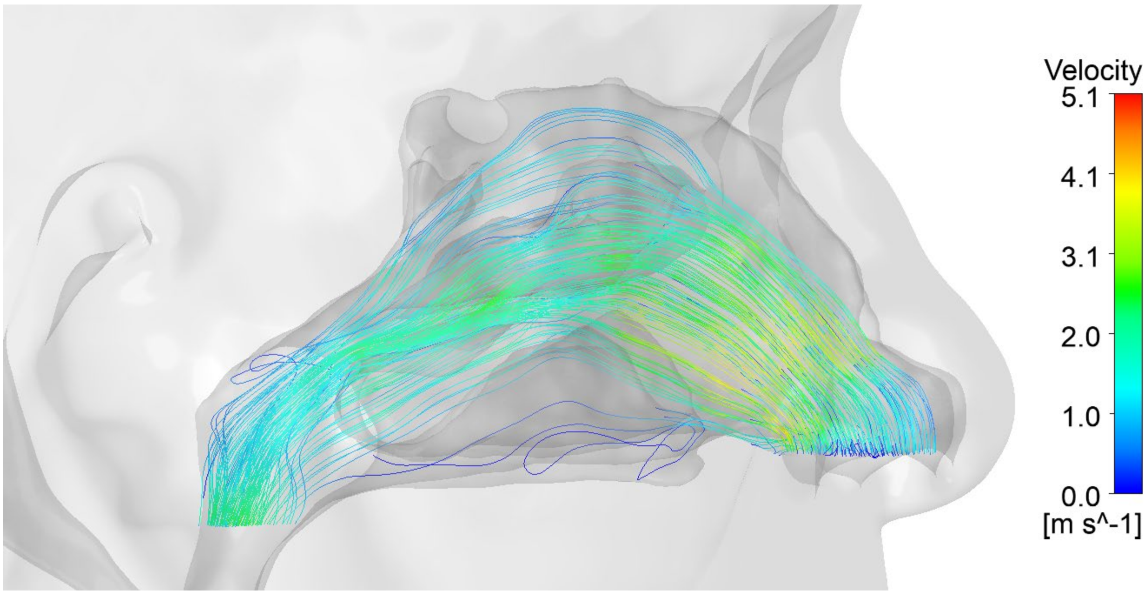


Figure 3.1.2.4: Sagittal view streamlines (after simulated surgery)

3.2| Airflow Distribution

Sinuflow uses a patent pending method to divide the nasal cavity in 5 partitions. This is done to analyse the airflow distribution in each partition. As a rule of thumb, due to the parabolic airflow in healthy individuals, at a distance of 3cm to 5cm from the nostril, airflow in partitions h_1, h_2 and h_3 generally is between 1L/min to 5L/min each. Airflow in partition h_4 is generally between 1L/min to 3L/min, and airflow in partition h_5 is generally between 0.2L/min to 0.5L/min. This can vary from individual to individual but if any partitions is ventilated by airflow well above or well below the indicated amounts nasal endoscopy is suggested.

3.2.1| Nasal Cavity Partitioning

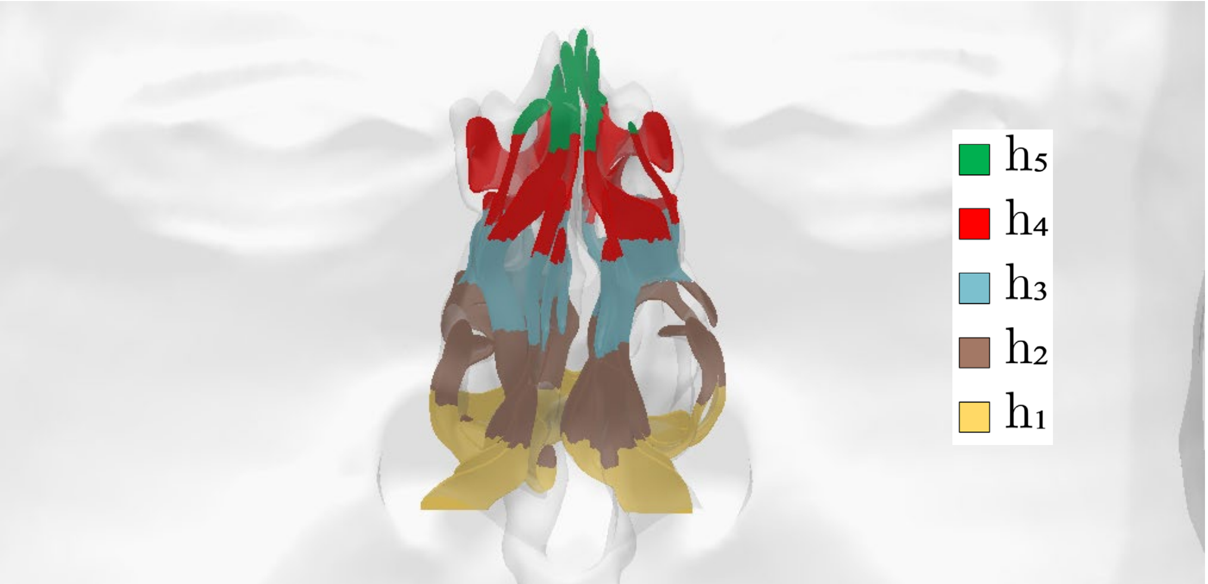


Figure 3.2.1.1: Nasal cavity partitioning frontal view (before simulated surgery)

Figure 3.2.1.2: Nasal cavity partitioning frontal view (after simulated surgery)

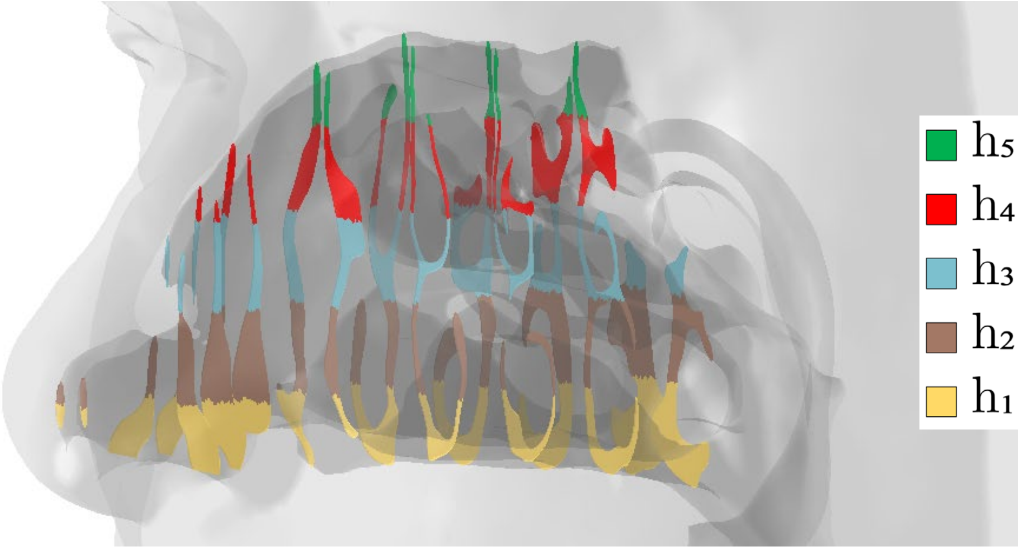


Figure 3.2.1.3: Nasal cavity partitioning side view (left airway before simulated surgery)

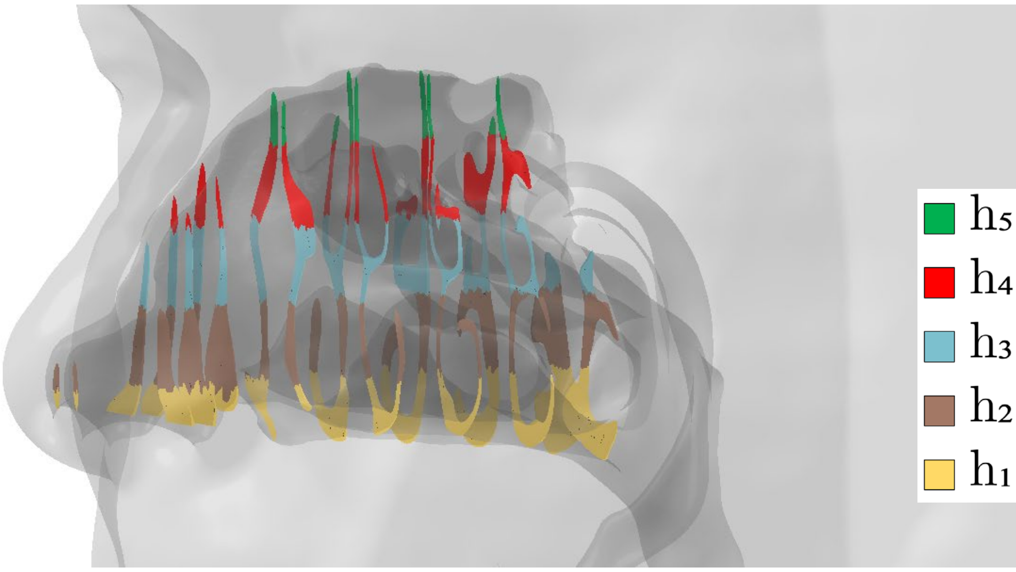


Figure 3.2.1.4: Nasal cavity partitioning side view (left airway after simulated surgery)

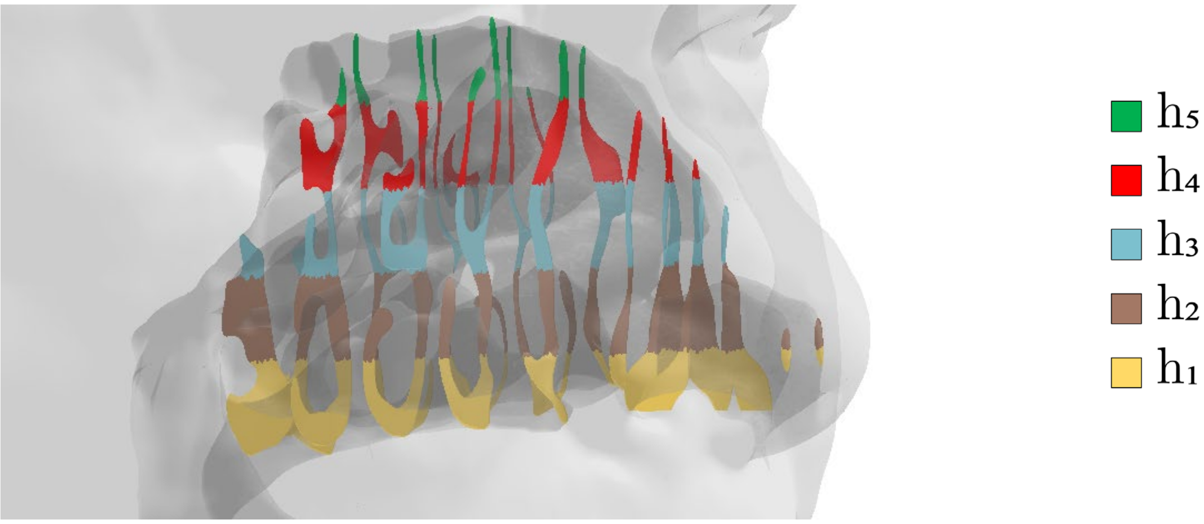


Figure 3.2.1.5: Nasal cavity partitioning side view (right airway before simulated surgery)

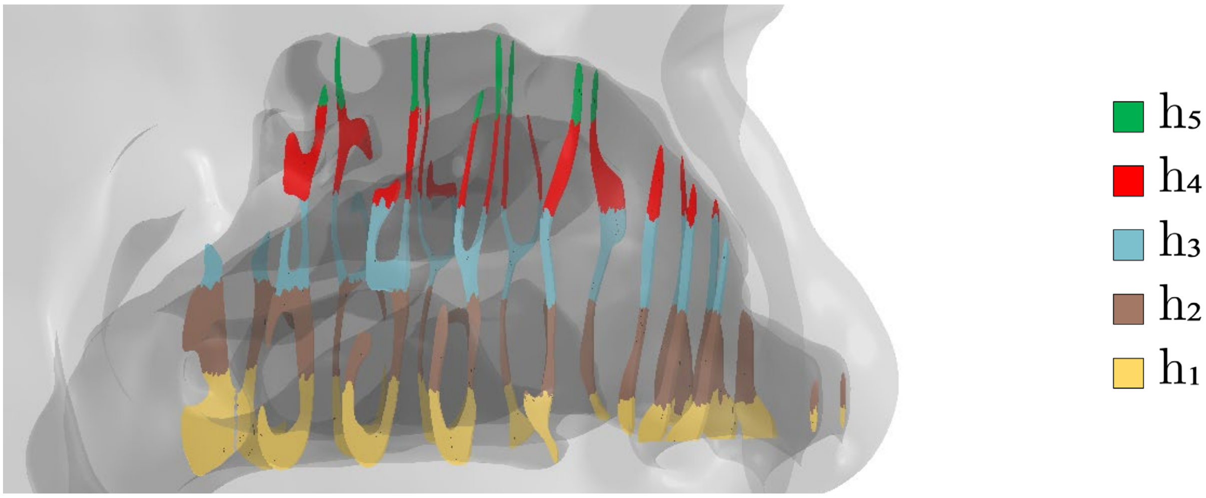


Figure 3.2.1.6: Nasal cavity partitioning side view (left airway before simulated surgery)

3.2.2| Airflow Distribution (Absolute)

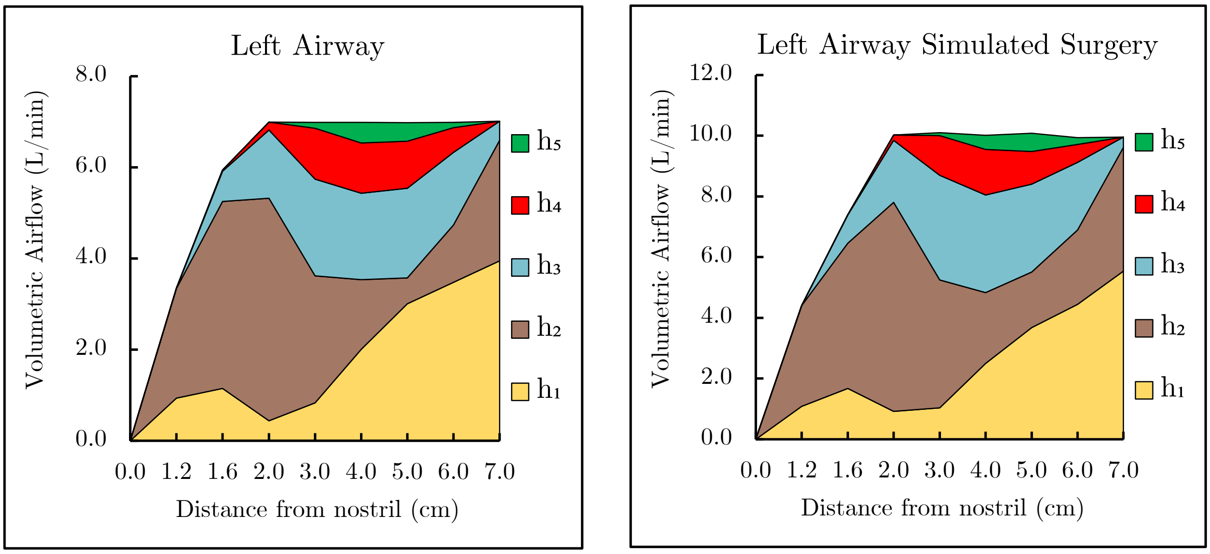


Figure 3.2.2.1: Nasal airflow distribution (left airway)

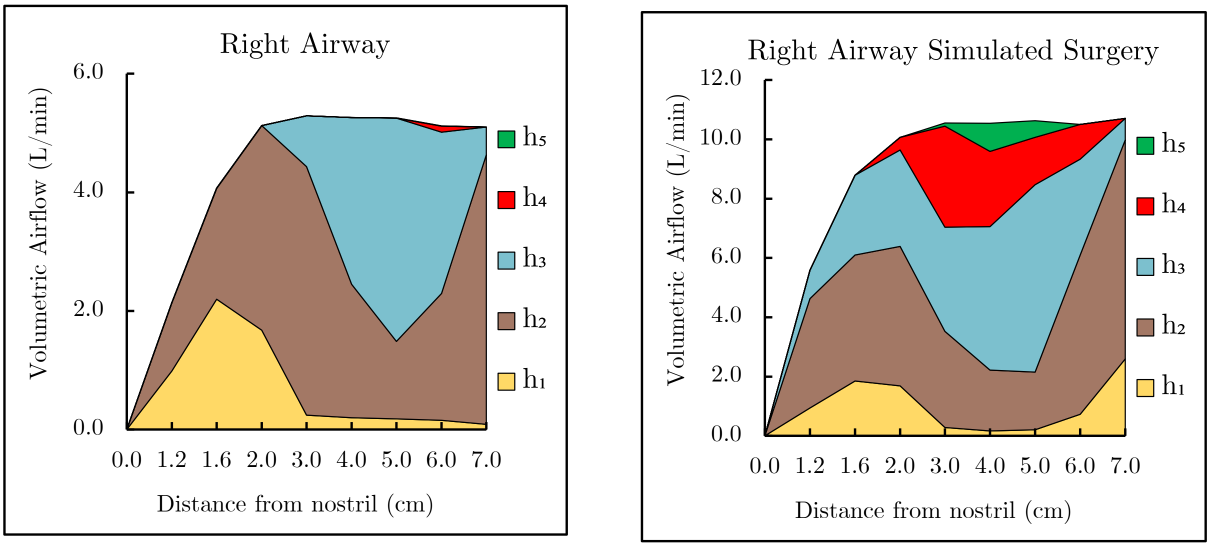
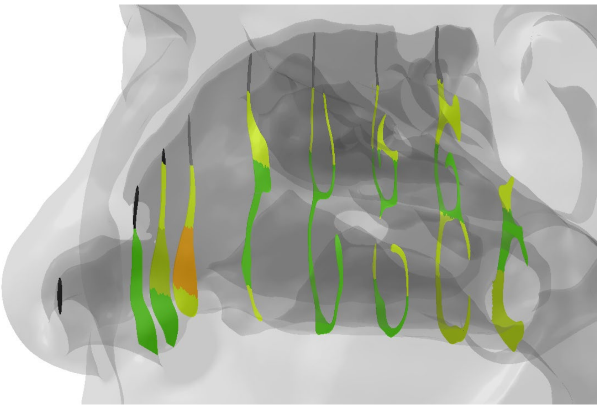
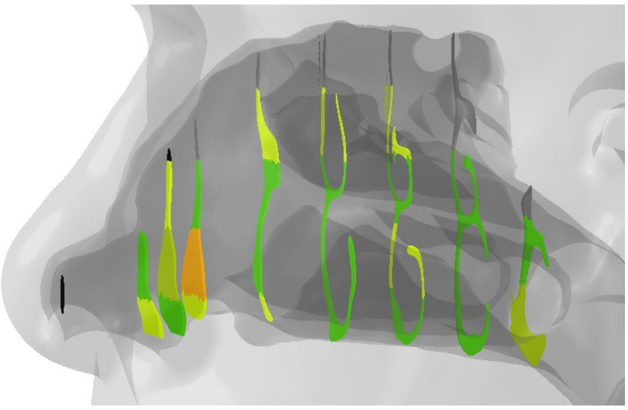


Figure 3.2.2.2: Nasal airflow distribution (right airway)



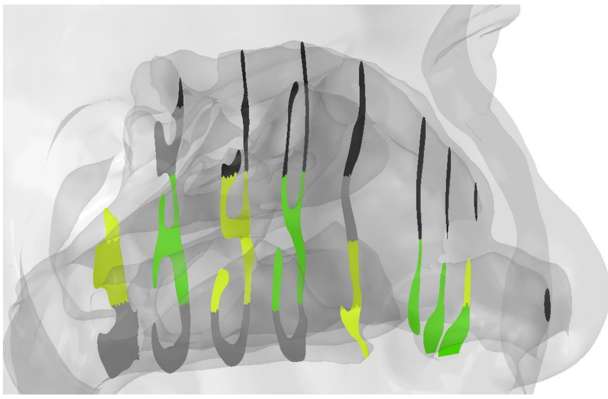
No Airflow
0.00 L/min < Airflow < 0.50 L/min
0.50 L/min < Airflow < 1.50 L/min
1.50 L/min < Airflow < 3.50 L/min
3.50 L/min < Airflow < 5.00 L/min
5.00 L/min < Airflow < 7.00 L/min
7.00 L/min < Airflow

Figure 3.2.2.3: Nasal airflow distribution (left airway before simulated surgery)



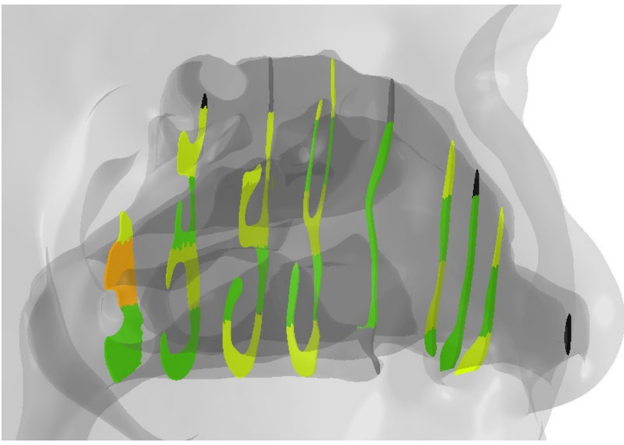
No Airflow
0.00 L/min < Airflow < 0.50 L/min
0.50 L/min < Airflow < 1.50 L/min
1.50 L/min < Airflow < 3.50 L/min
3.50 L/min < Airflow < 5.00 L/min
5.00 L/min < Airflow < 7.00 L/min
7.00 L/min < Airflow

Figure 3.2.2.4: Nasal airflow distribution (left airway after simulated surgery)



No Airflow
0.00 L/min < Airflow < 0.50 L/min
0.50 L/min < Airflow < 1.50 L/min
1.50 L/min < Airflow < 3.50 L/min
3.50 L/min < Airflow < 5.00 L/min
5.00 L/min < Airflow < 7.00 L/min
7.00 L/min < Airflow

Figure 3.2.2.5: Nasal airflow distribution (right airway before simulated surgery)



No Airflow
0.00 L/min < Airflow < 0.50 L/min
0.50 L/min < Airflow < 1.50 L/min
1.50 L/min < Airflow < 3.50 L/min
3.50 L/min < Airflow < 5.00 L/min
5.00 L/min < Airflow < 7.00 L/min
7.00 L/min < Airflow

Figure 3.2.2.6: Nasal airflow distribution (right airway after simulated surgery)

3.2.3| Airflow Distribution (Percentage)

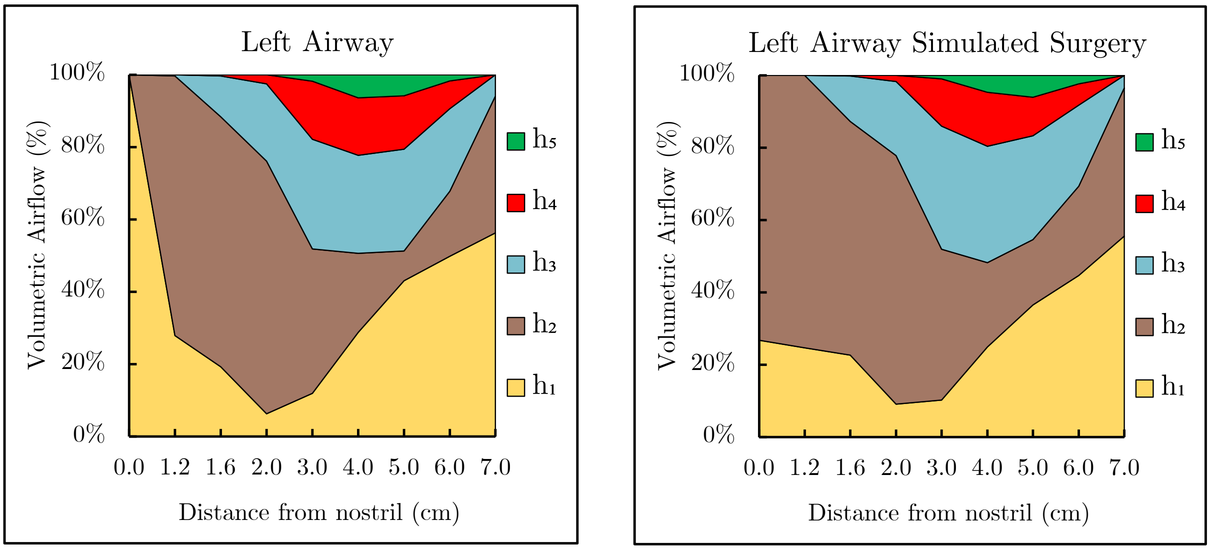


Figure 3.2.3.1: Nasal airflow distribution (left airway)

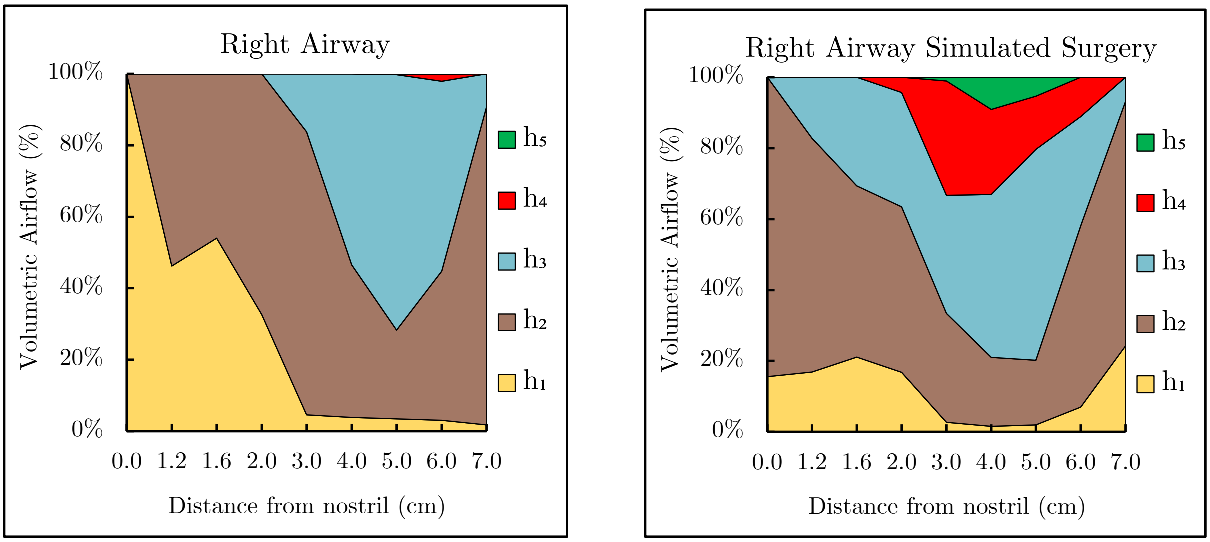


Figure 3.2.3.2: Nasal airflow distribution (right airway)

4.0| Area

4.1| Area Distribution (Absolute)

The area of each partition is analysed. Area is often the limiting flow factor at the nasal valve (around 1cm to 2cm from the nostrils). A very small area at the nasal valve can be a cause of obstruction and nasal valve stenosis. However small airspace can also be caused by other conditions such as turbinate hypertrophy and other factors. Nasal endoscopy should be performed to verify the presence or lack thereof of any abnormality.

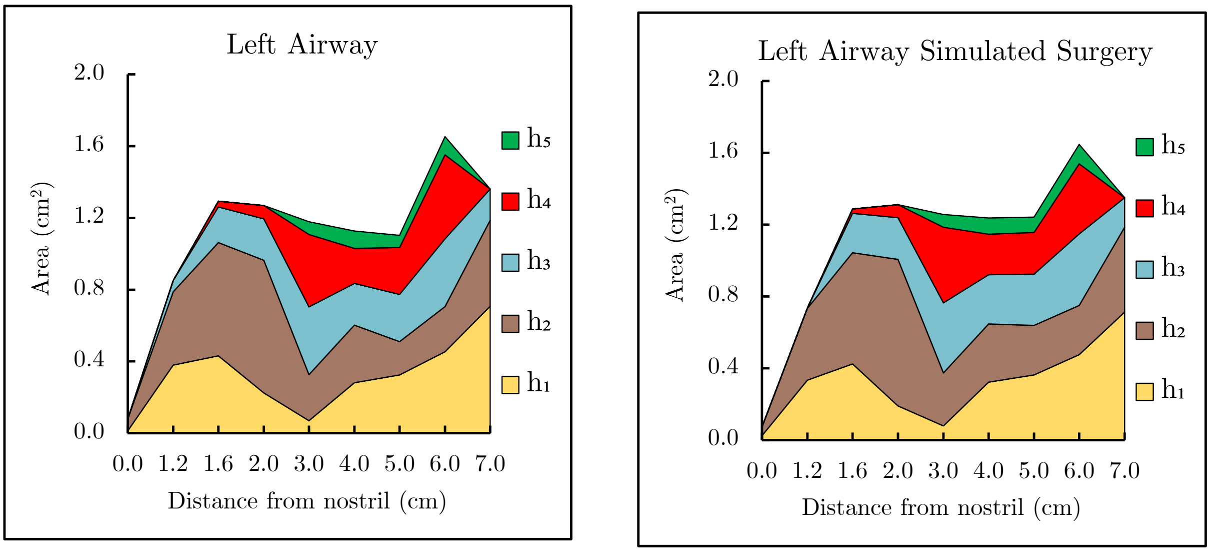


Figure 4.1.1: Coronal area by partition (left airway)

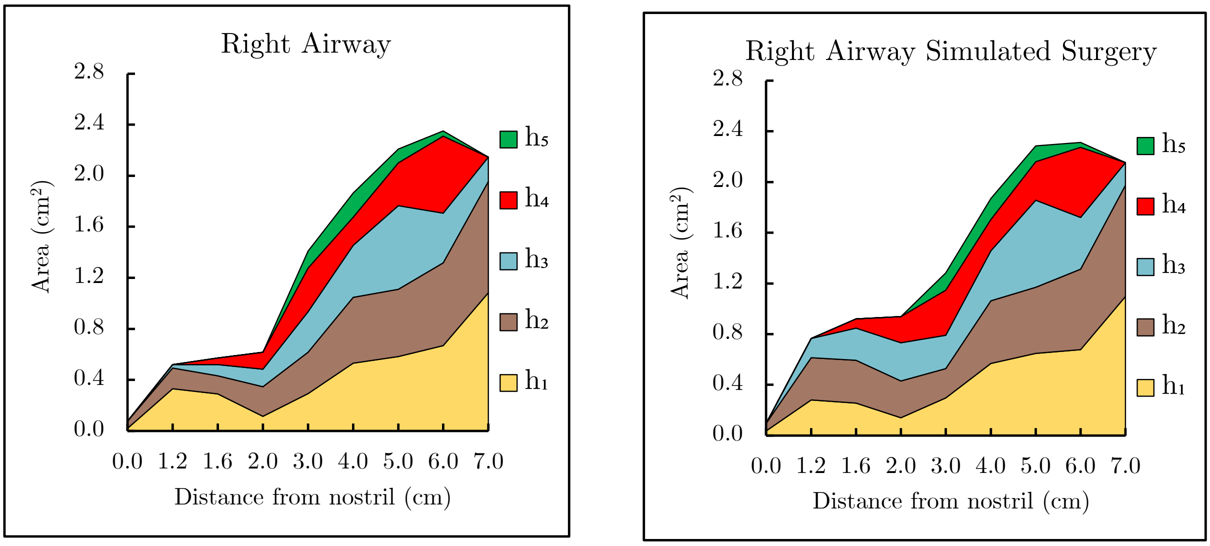


Figure 4.1.2: Coronal area by partition (right airway)

4.2| Area Distribution (Percentage)

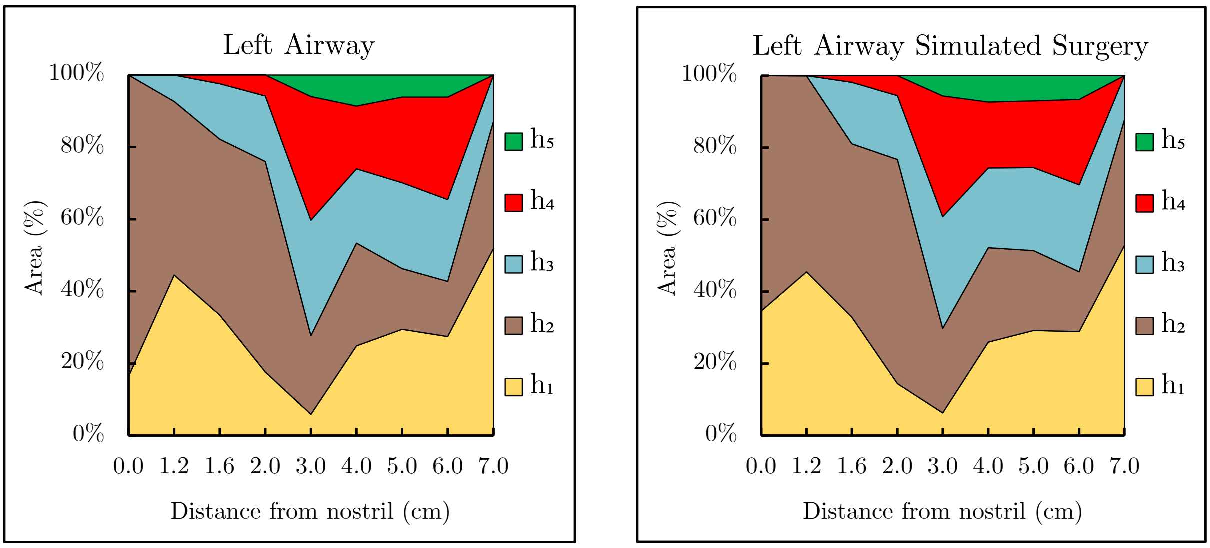


Figure 4.2.1: Coronal area by partition (left airway)

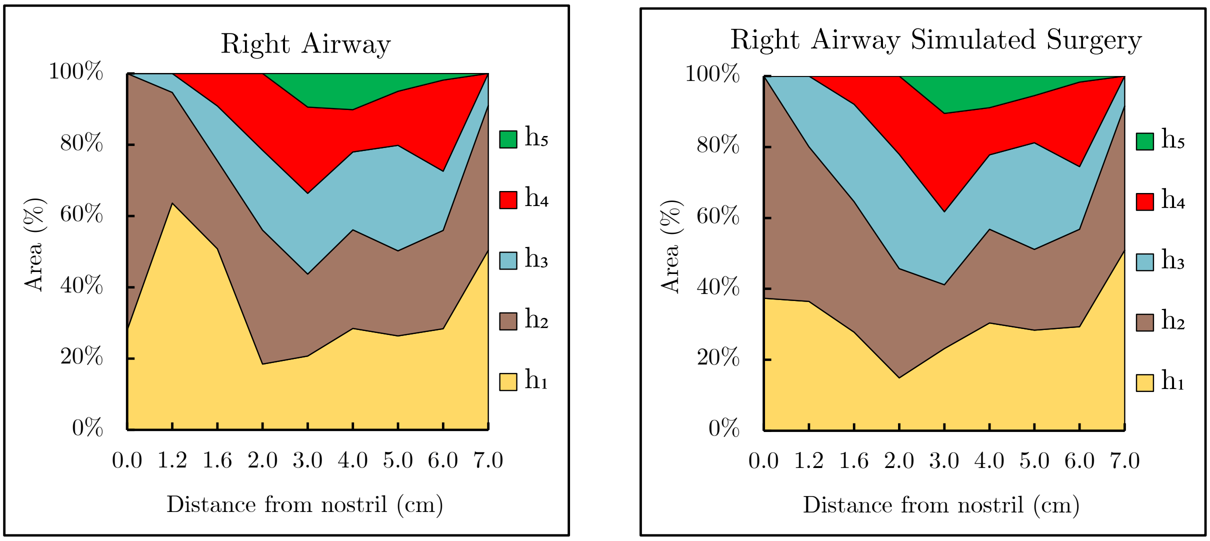


Figure 4.2.2: Coronal area by partition (right airway)

5.0| Velocity

5.1| Velocity Distribution

The air velocity in each partition is analysed. Low velocity can either be an indicator of obstruction and poor ventilation or of excessive area due to turbinate atrophy or resection. However other factors may be involved.

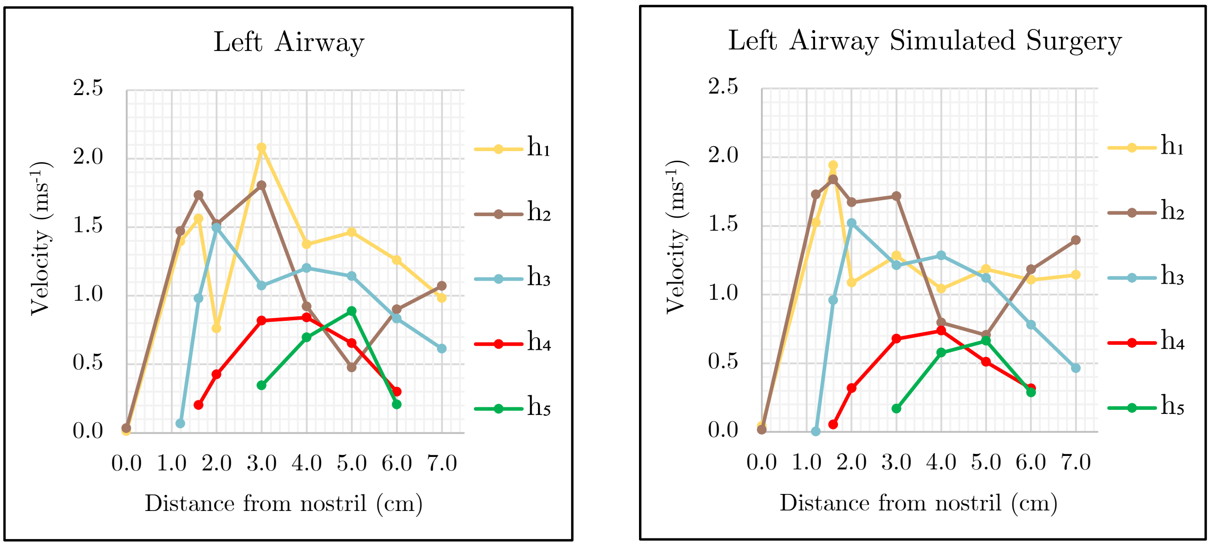


Figure 5.1.1: Velocity by partition (left airway)

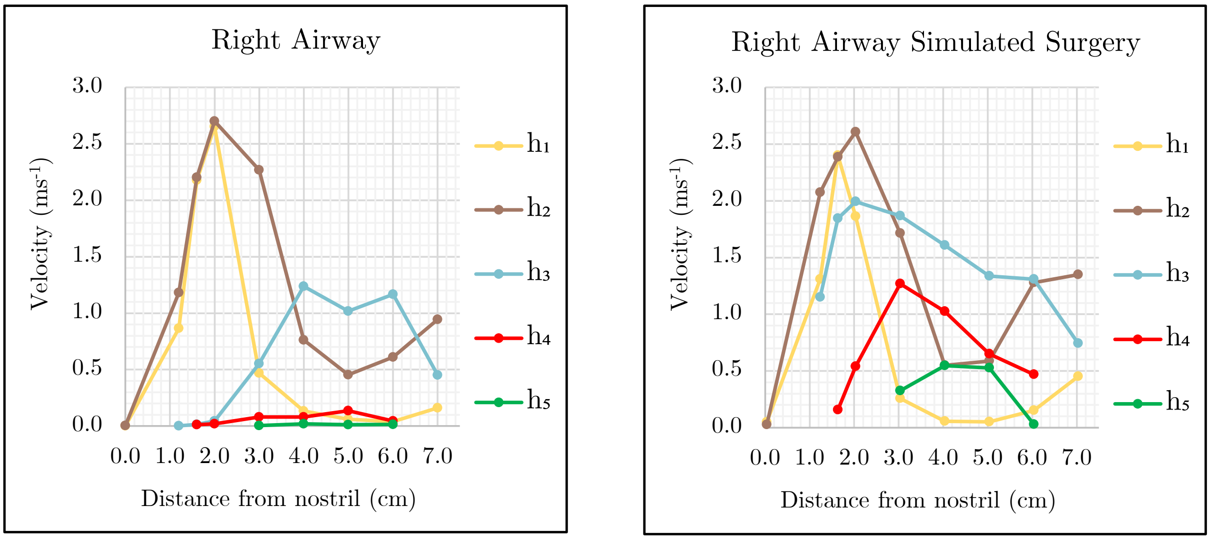


Figure 5.1.2: Velocity by partition (right airway)

5.2| Velocity (Average)

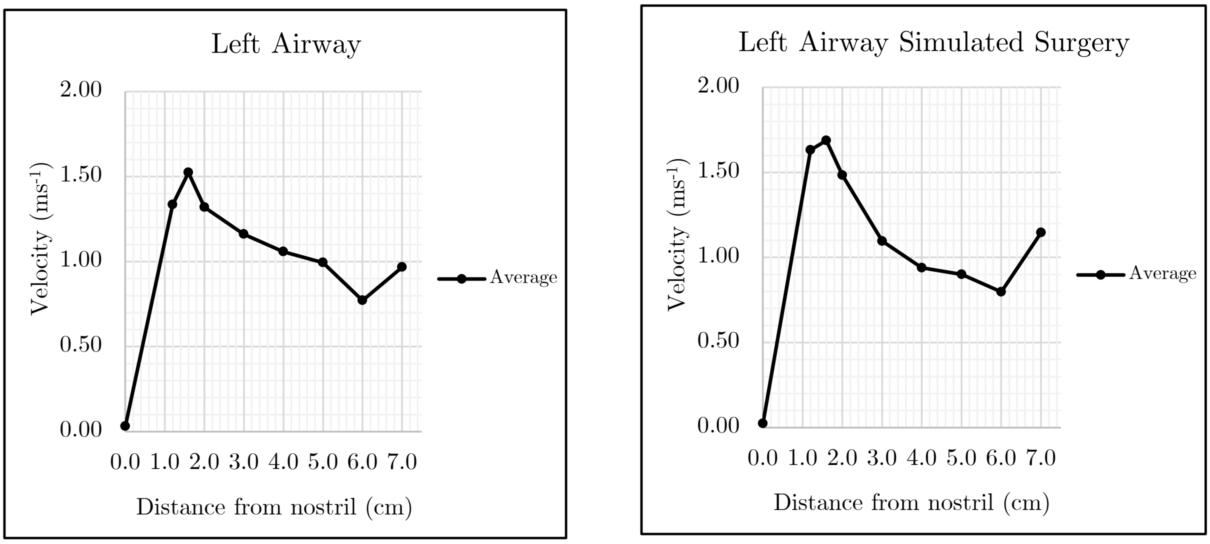


Figure 5.2.1: Average velocity of all partitions (left airway)

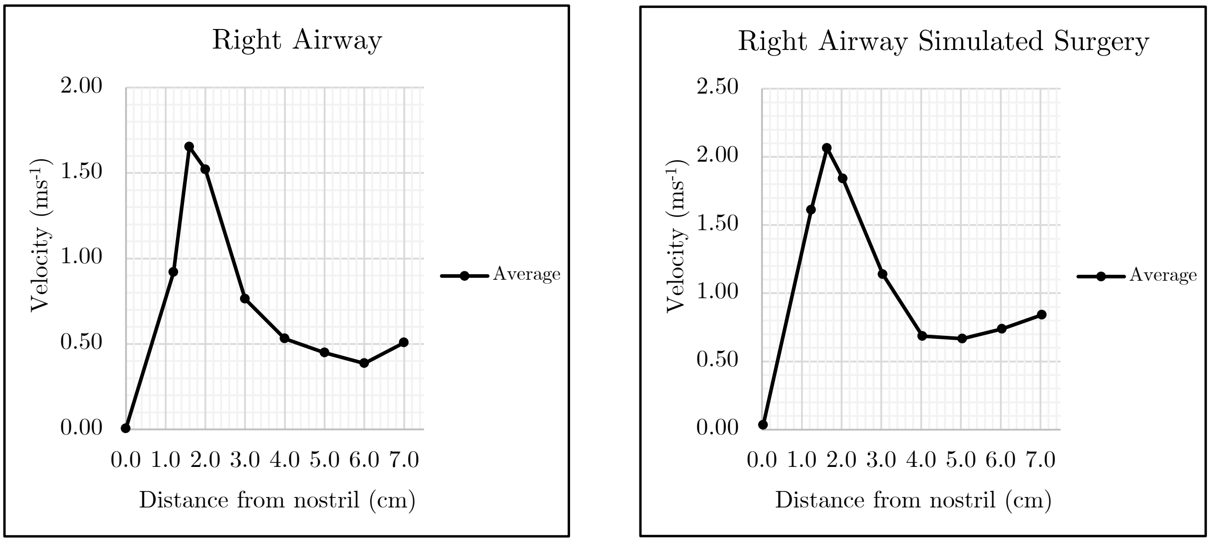


Figure 5.2.2: Average velocity of all partitions (right airway)

5.3| Velocity Field

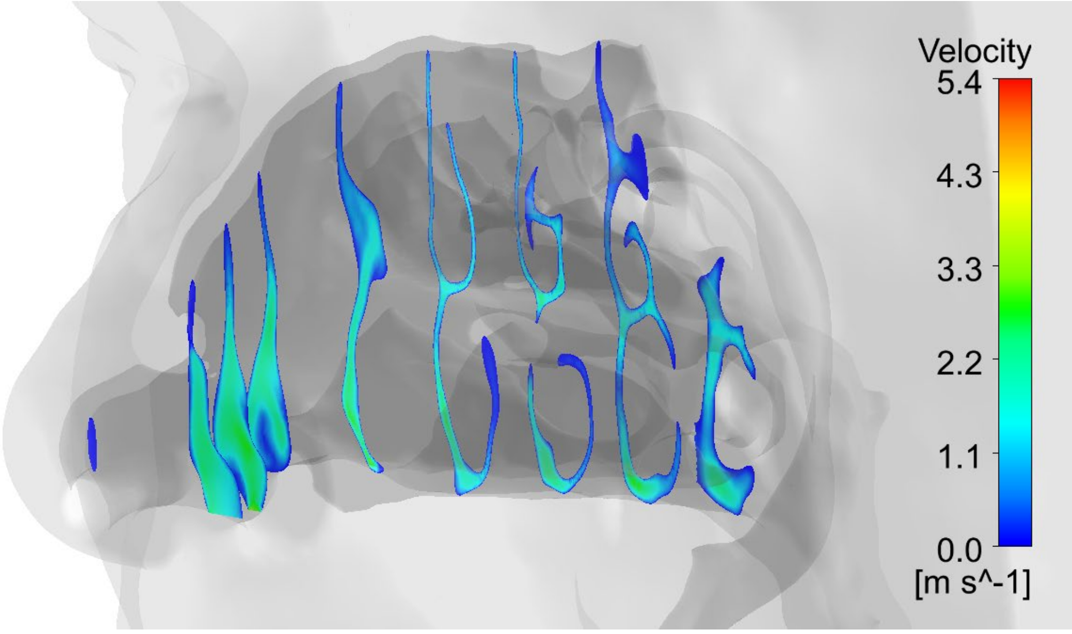


Figure 5.3.1: Velocity field (left airway before simulated surgery)

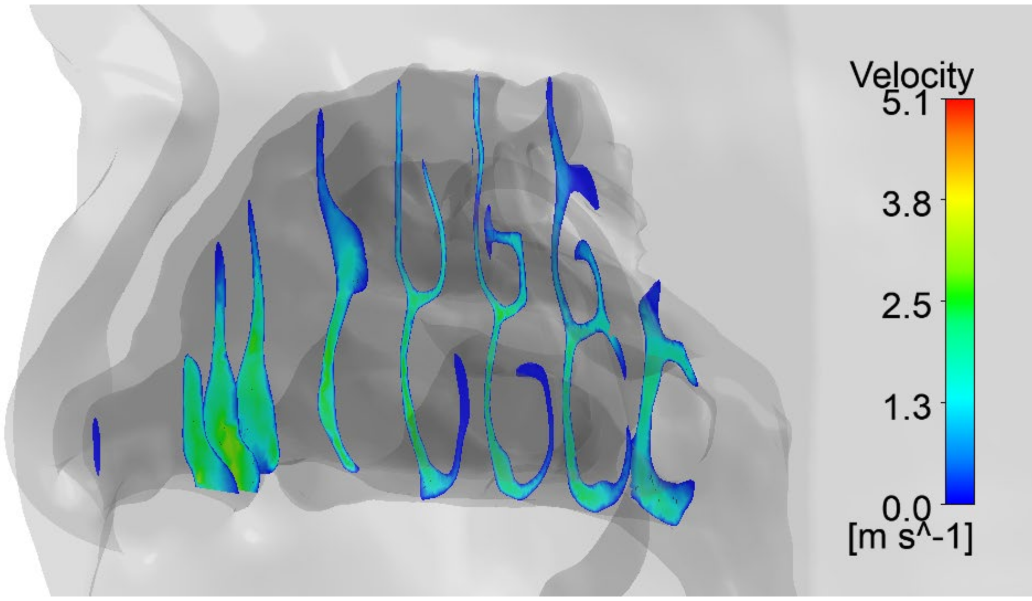


Figure 5.3.2: Velocity field (left airway after simulated surgery)

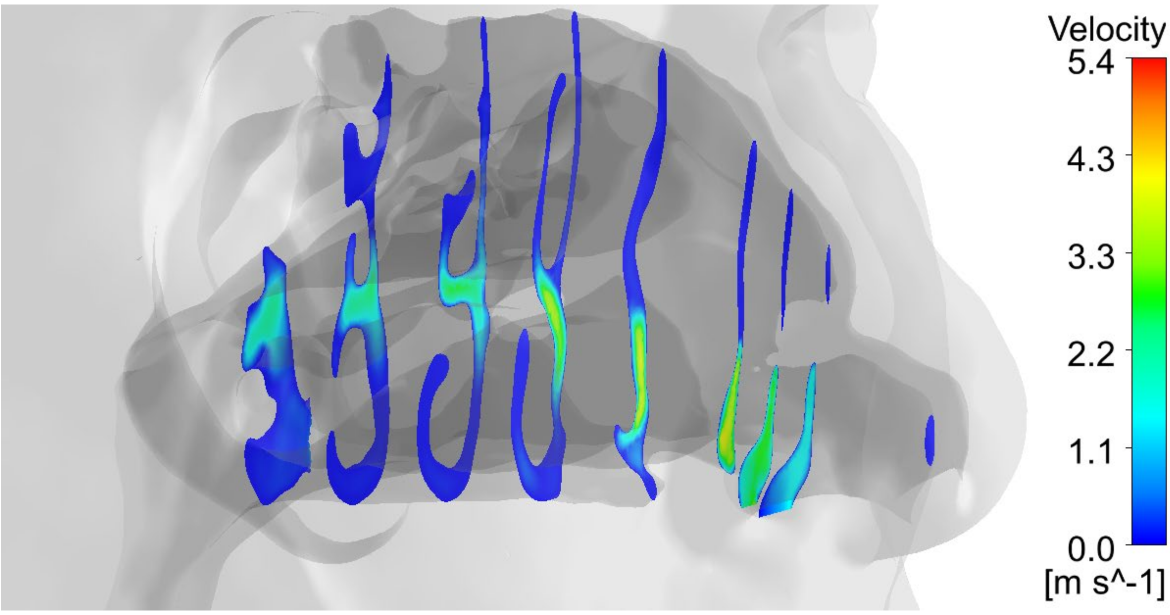


Figure 5.3.3: Velocity field (right airway before simulated surgery)

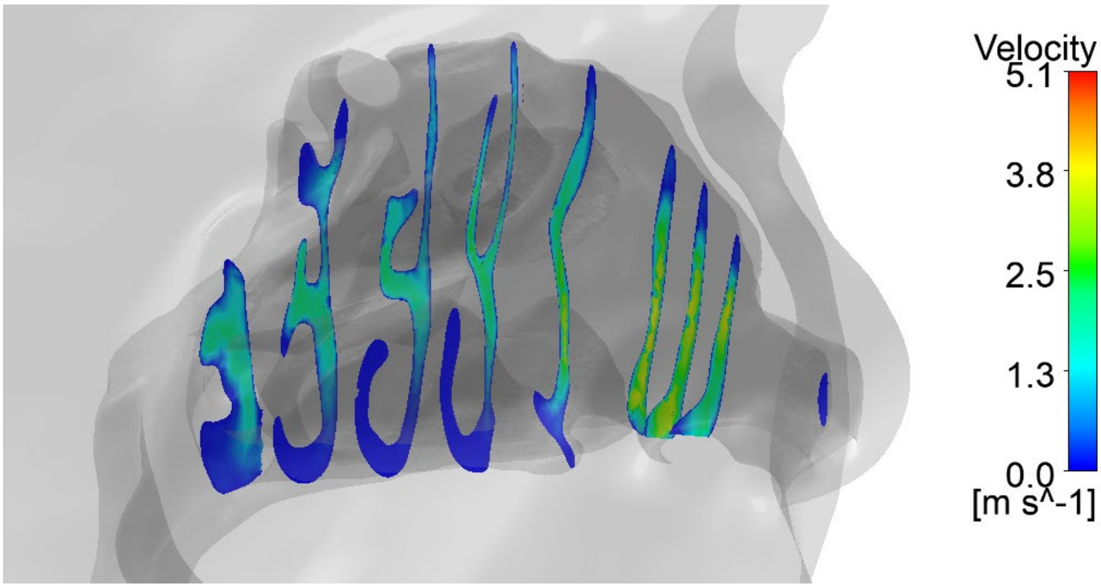


Figure 5.3.4: Velocity field (right airway after simulated surgery)

5.4| Velocity Field Video Before Simulated Surgery

5.5| Velocity Field Video After Simulated Surgery

6.0| Pressure

6.1| Pressure Distribution

In healthy nasal cavities there is a gradual decrease in pressure between the nostrils and the pharynx. Generally, if obstruction is present, it causes a sharp pressure drop, however this may vary. Note that gauge pressure in quoted. Gauge pressure is the difference between atmospheric pressure and the pressure in the nasal cavity. As air enters the nasal cavity it is at the same pressure as atmospheric pressure. As pressure reaches the pharynx where pressure is lower than atmospheric pressure, pressure decreases.

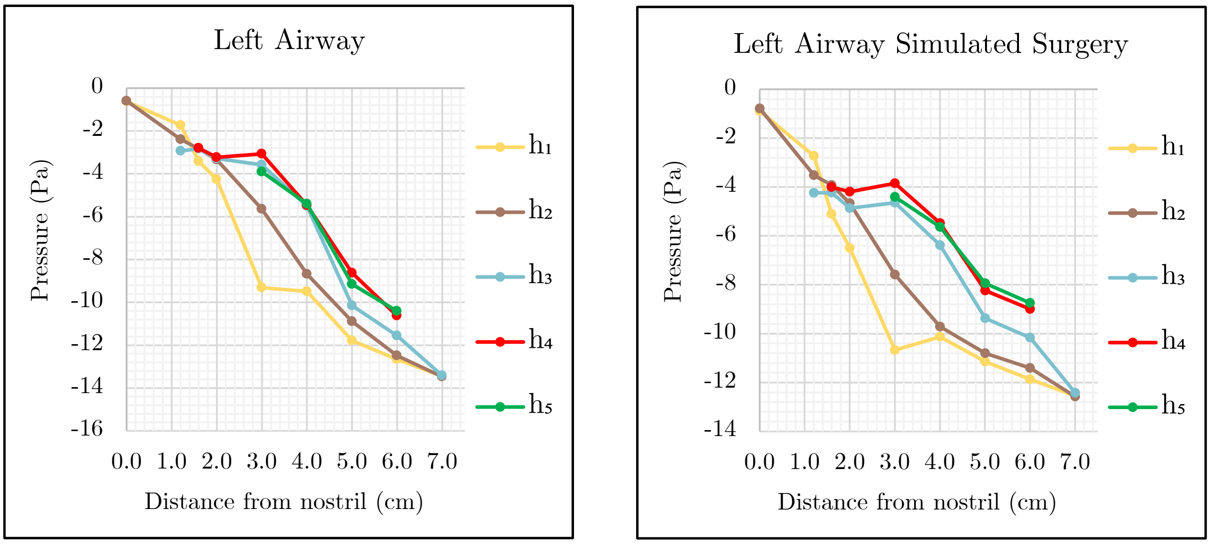


Figure 6.1.1: Pressure by partition (left airway)

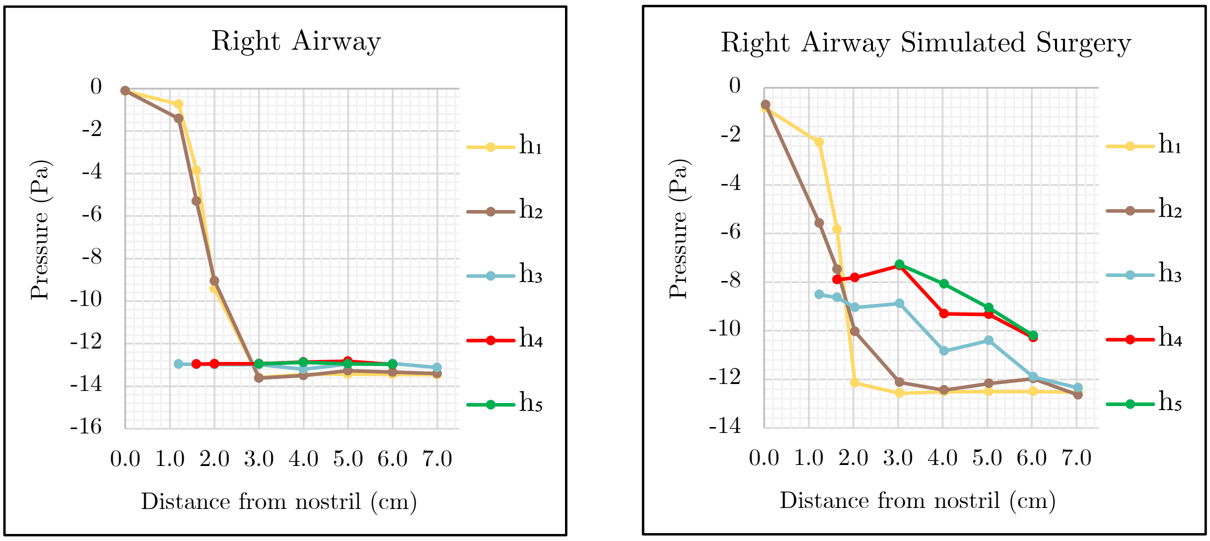
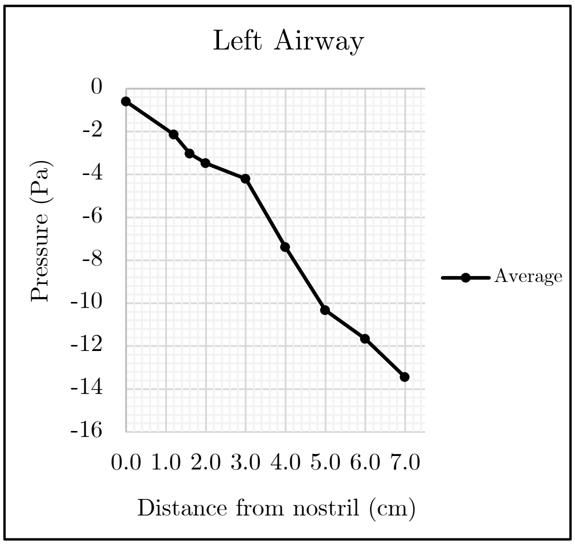


Figure 6.1.2: Pressure by partition (right airway)

6.2| Pressure (Average)



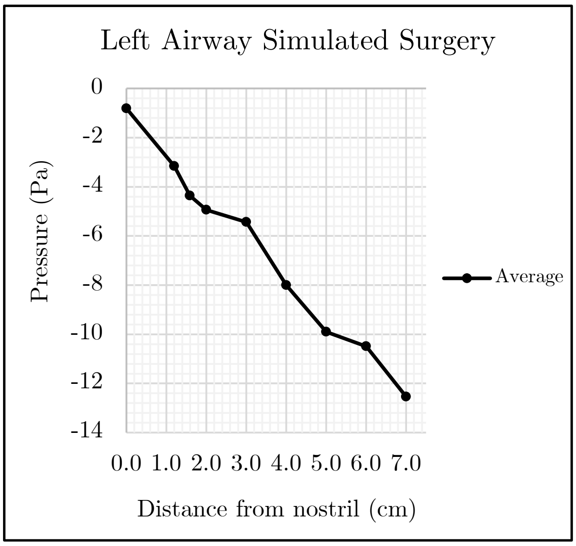
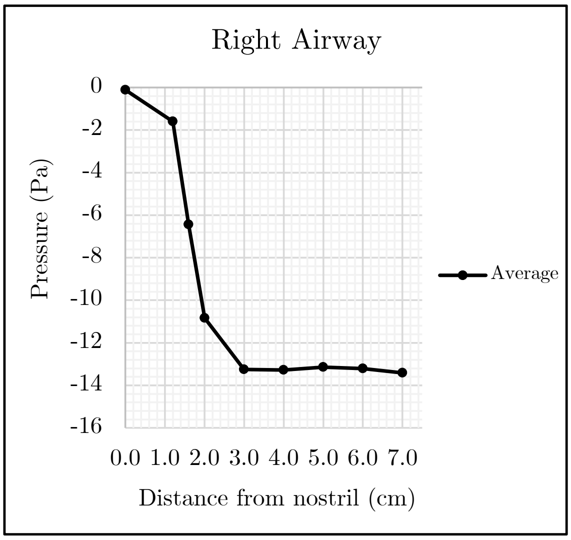


Figure 6.2.1: Average pressure of all partitions (left airway)



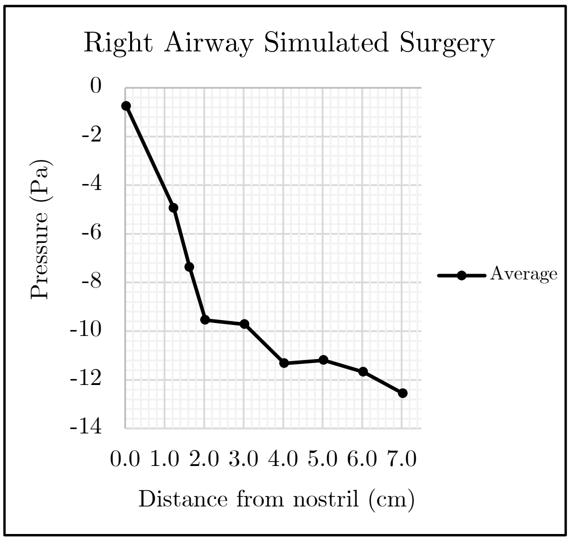


Figure 6.2.2: Average pressure of all partitions (right airway)

6.3| Pressure Field

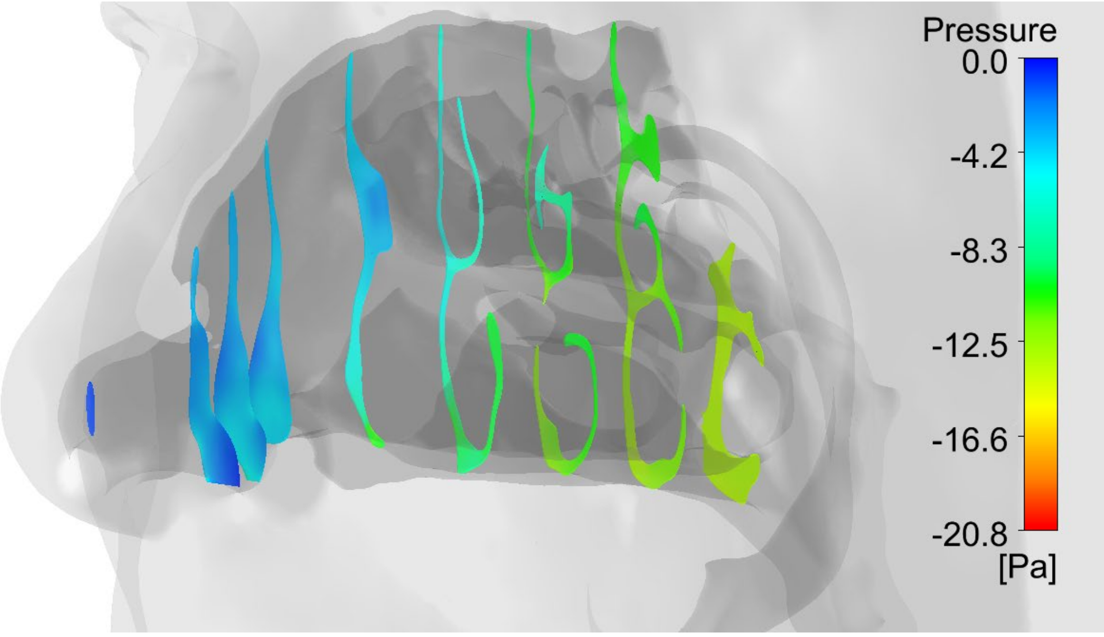


Figure 6.3.1: Pressure field (left airway before simulated surgery)

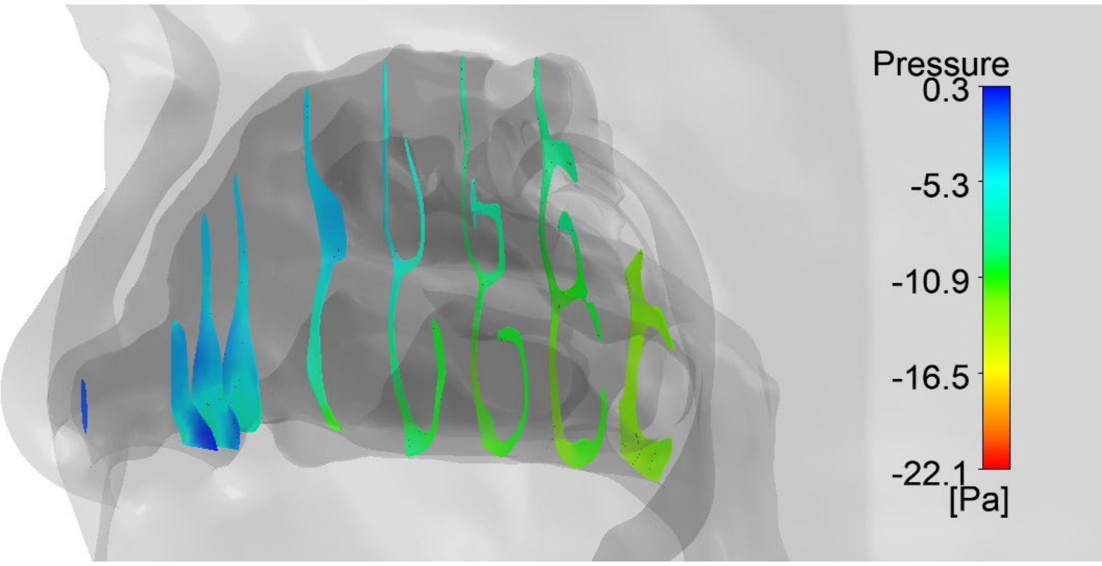


Figure 6.3.2: Pressure field (left airway after simulated surgery)

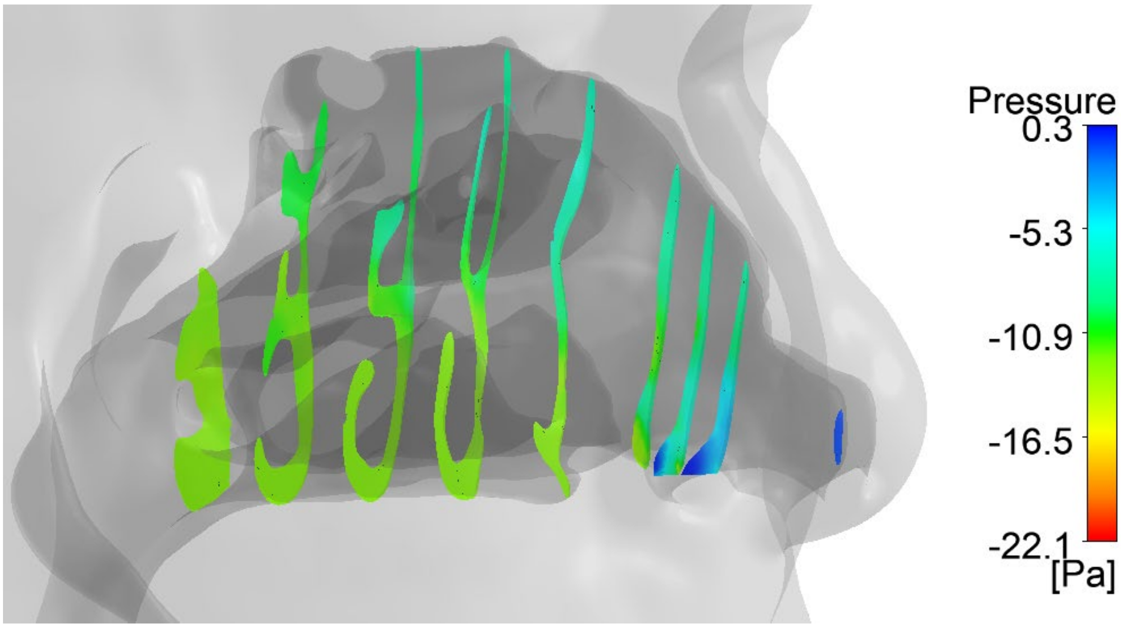


Figure 6.3.3: Pressure field (right airway before simulated surgery)

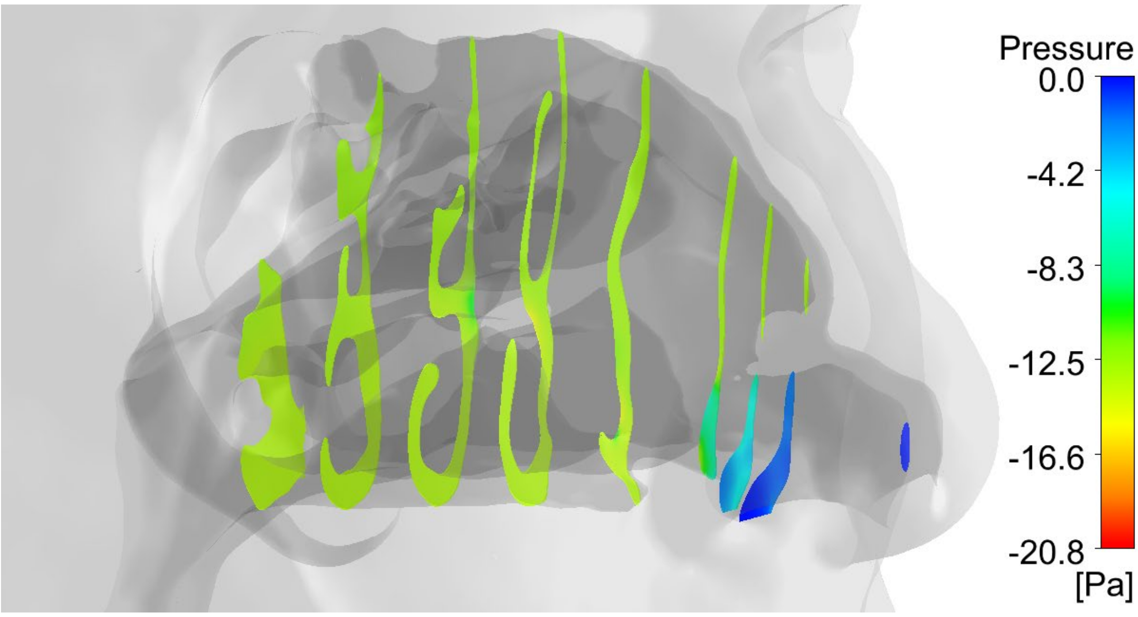


Figure 6.3.4: Pressure field (right airway after simulated surgery)

6.4| Pressure Field Video Before Simulated Surgery

6.5| Pressure Field Video After Simulated Surgery

7.0| Temperature

7.1| Temperature Distribution

Temperature is highly related with other factors such as room temperature, health of nasal mucosa and more factors. For this reason, a physical examination is suggested.

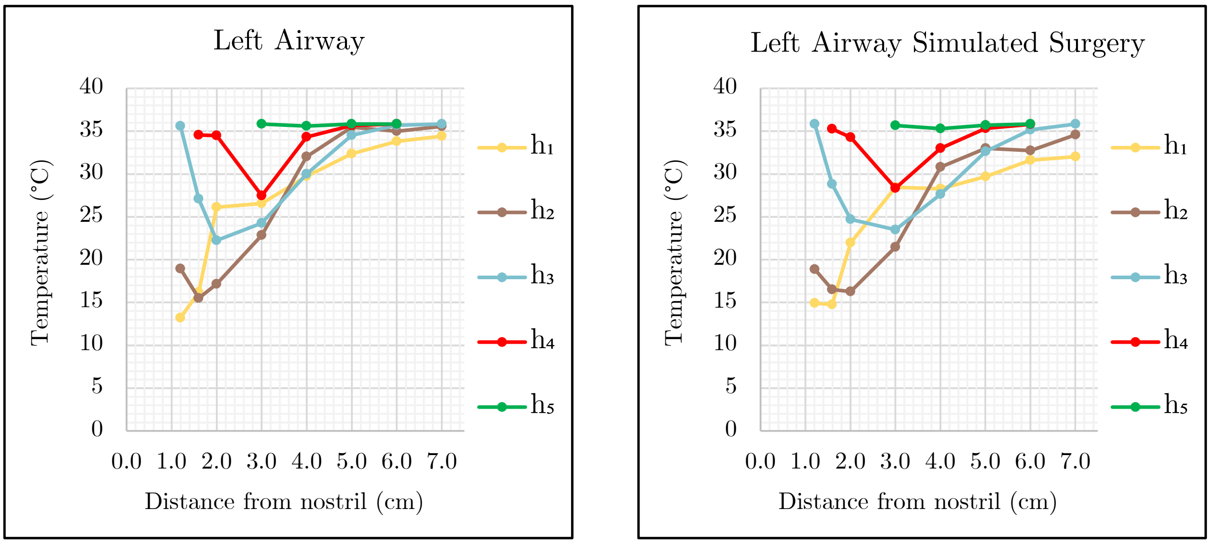


Figure 7.1.1: Temperature by partition (left airway)

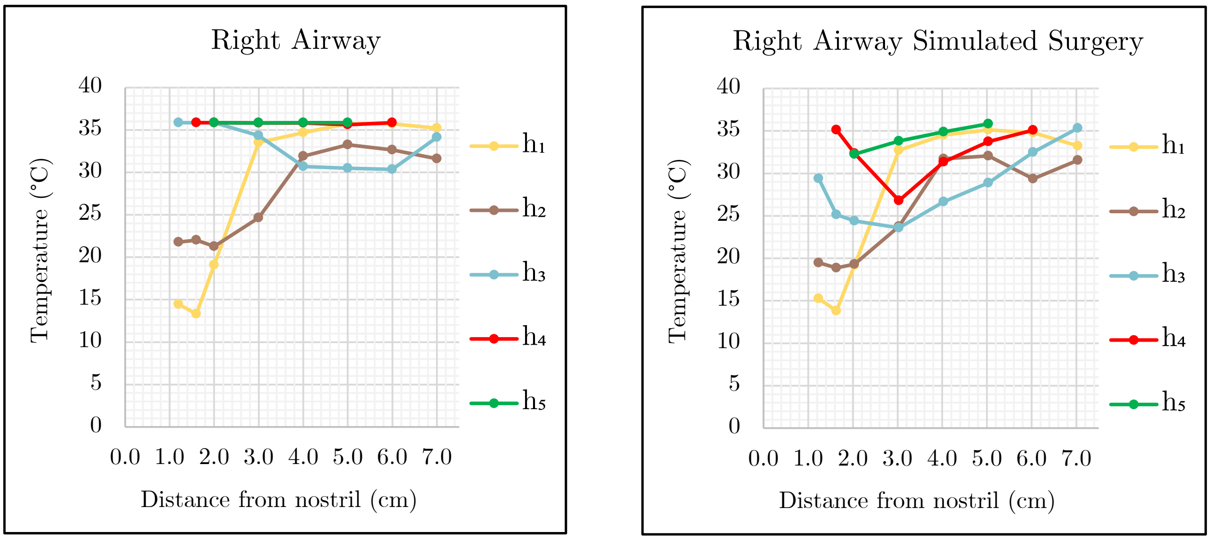
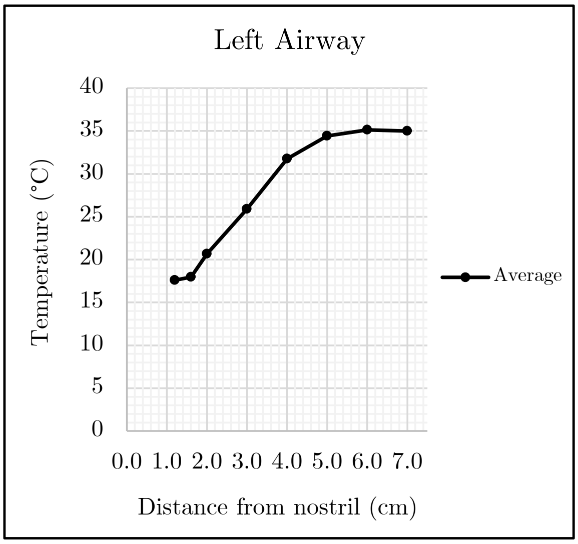


Figure 7.1.2: Temperature by partition (right airway)

7.2| Temperature (Average)



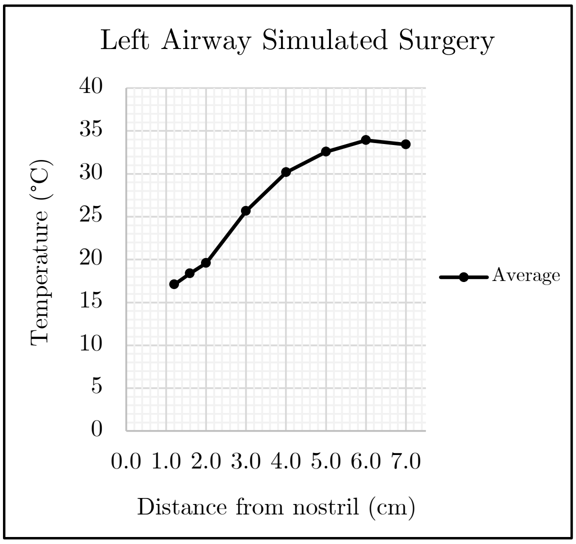
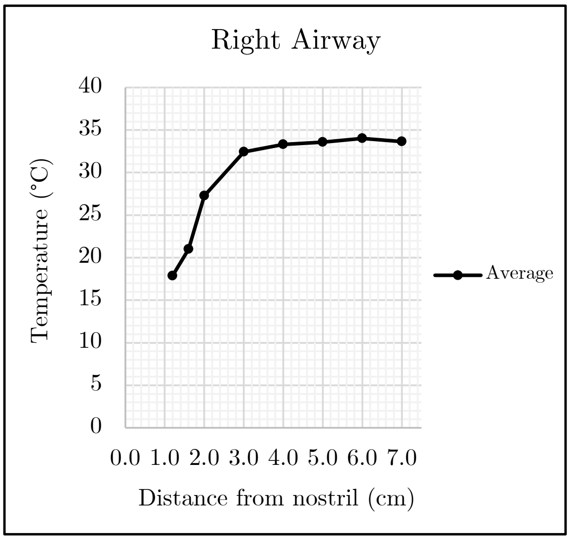


Figure 7.2.1: Average temperature of all partitions (left airway)



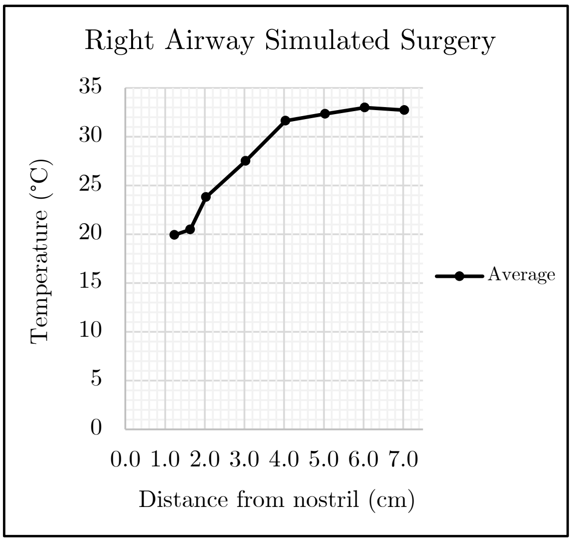


Figure 7.2.2: Average temperature of all partitions (right airway)

7.3| Temperature Field

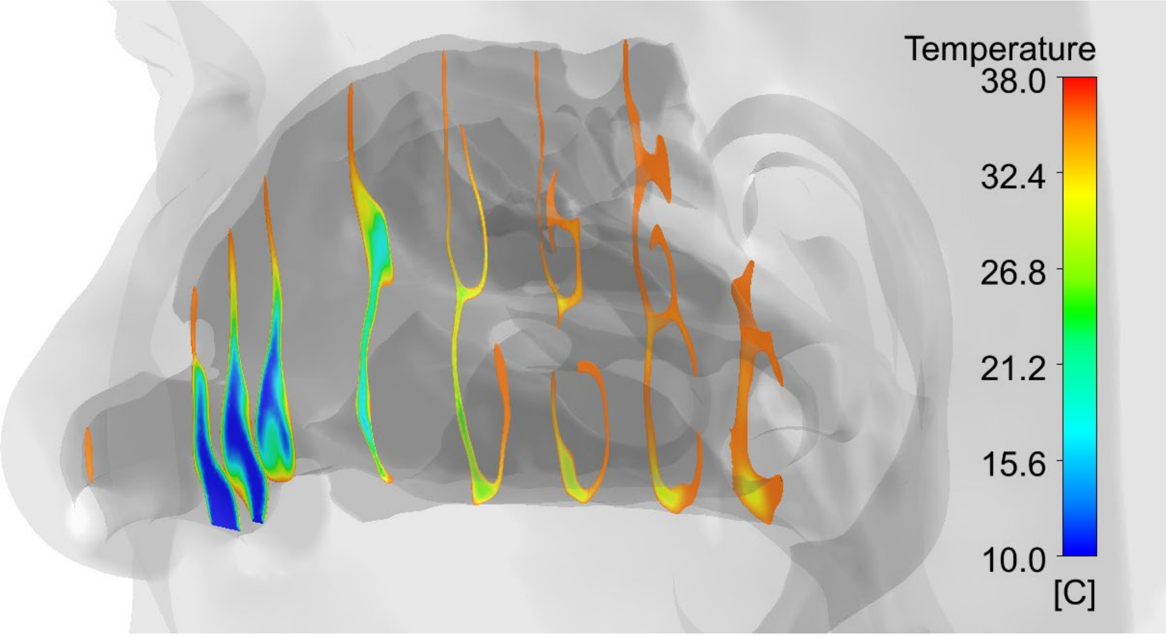


Figure 7.3.1: Temperature field (left airway before simulated surgery)

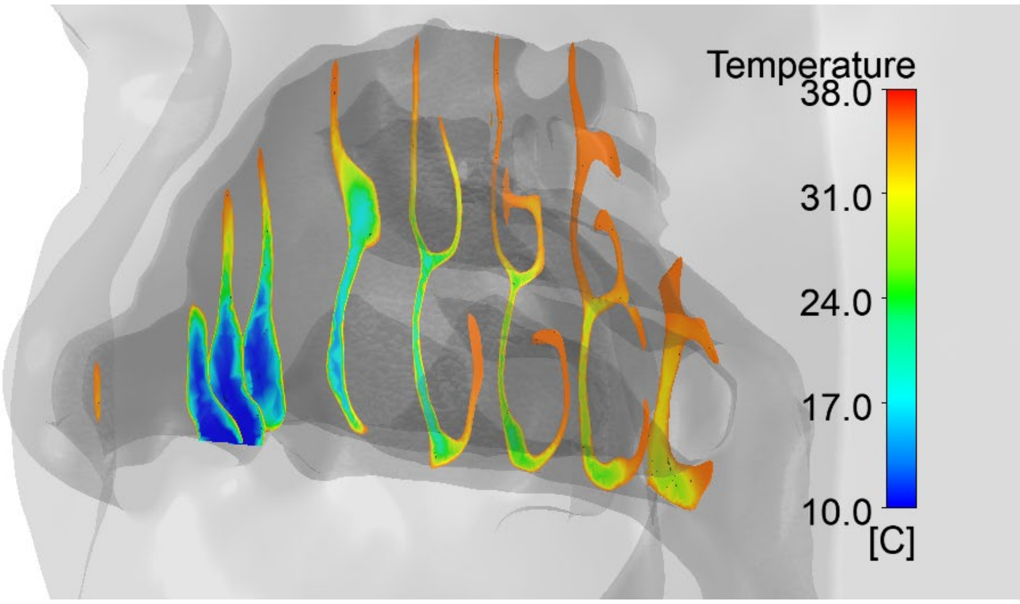


Figure 7.3.2: Temperature field (left airway after simulated surgery)

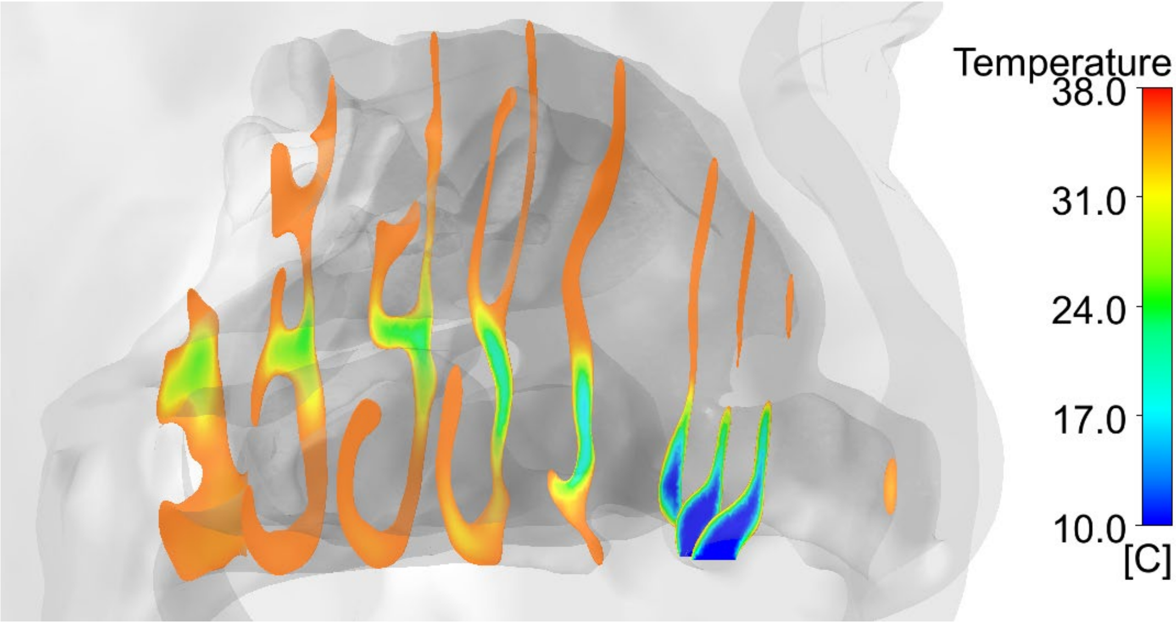


Figure 7.3.3: Temperature field (right airway before simulated surgery)

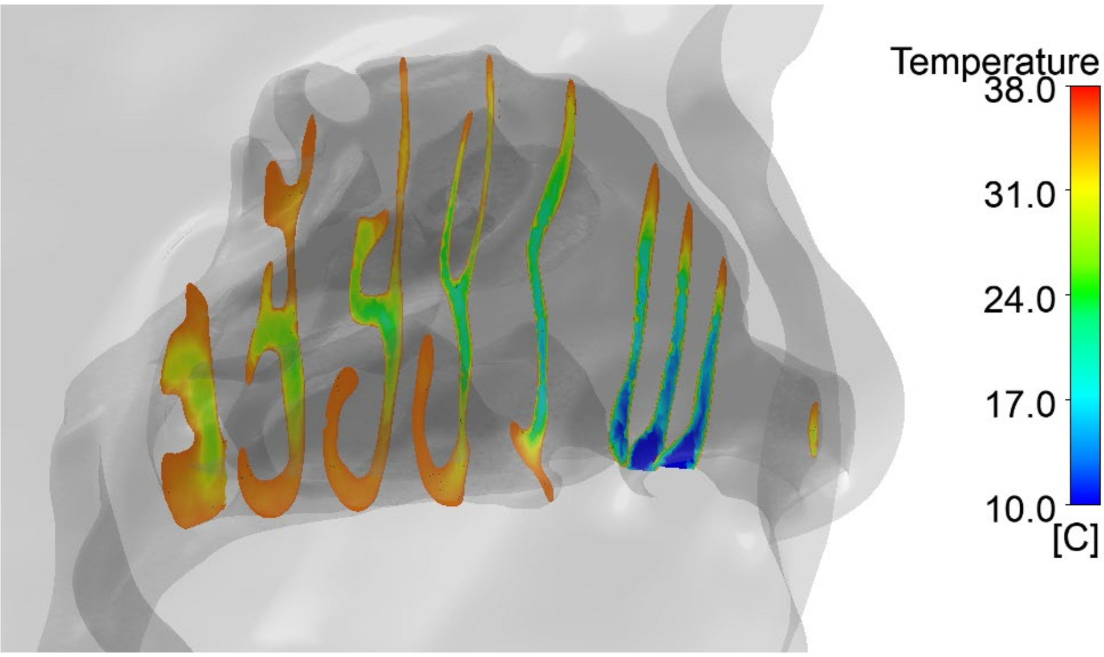


Figure 7.3.4: Temperature field (right airway after simulated surgery)

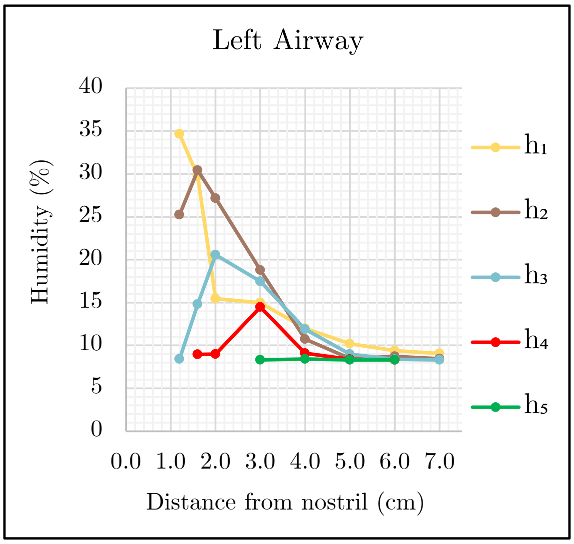
7.4| Temperature Field Video Before Simulated Surgery

7.5| Temperature Field Video After Simulated Surgery

8.0| Humidity

8.1| Humidity Distribution

Humidity is highly related with other factors such as room humidity, health of nasal mucosa and more factors. For this reason, a physical examination is suggested.



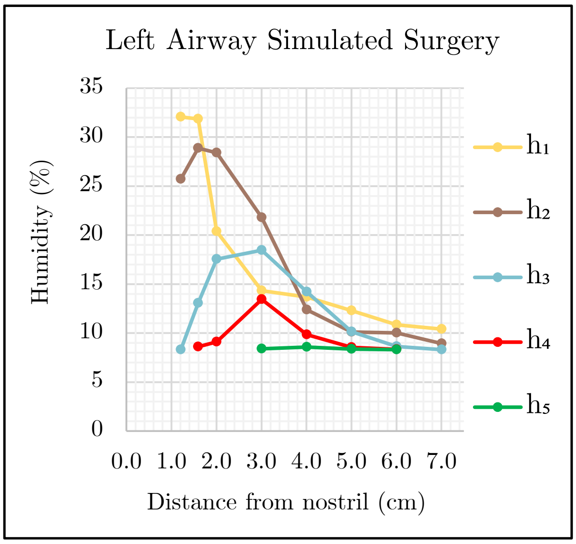
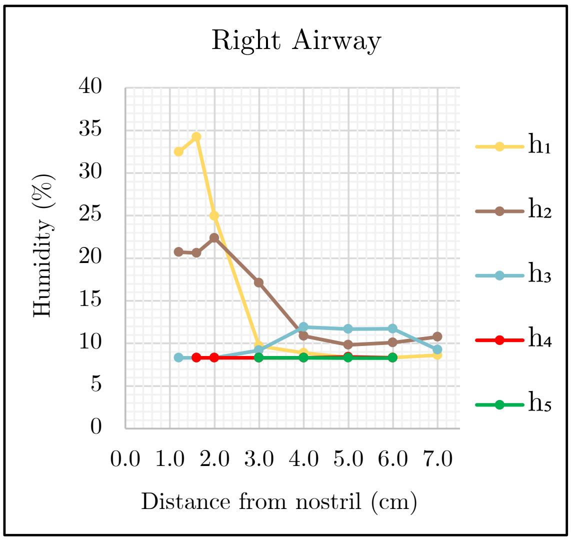


Figure 8.1.1: Humidity by partition (left airway)



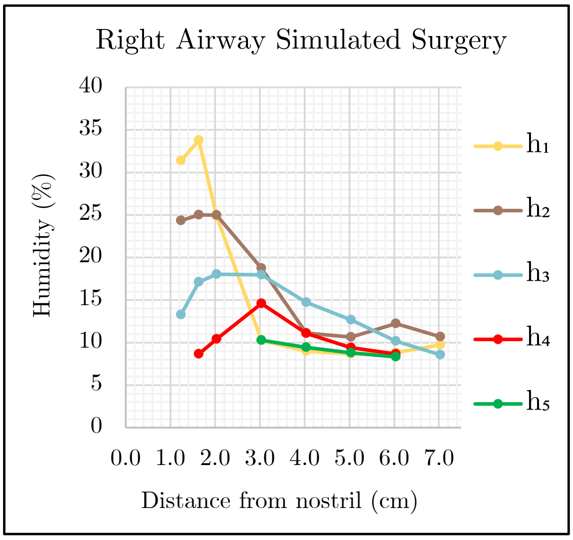
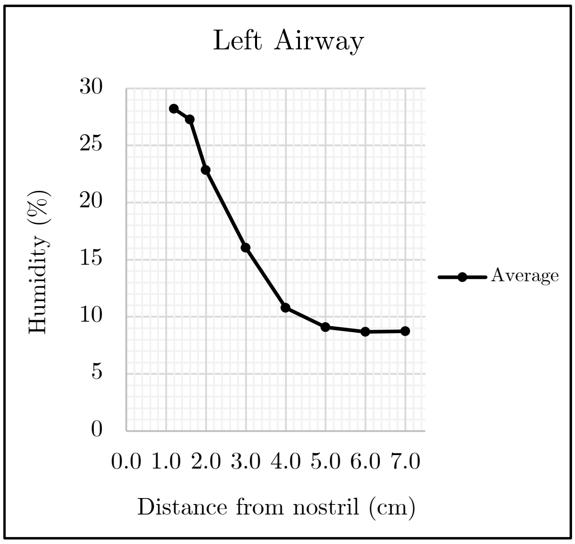


Figure 8.1.2: Humidity by partition (right airway)

8.2| Humidity (Average)



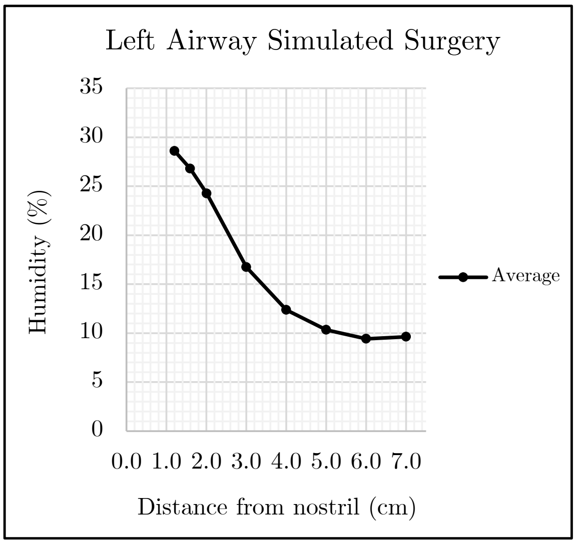
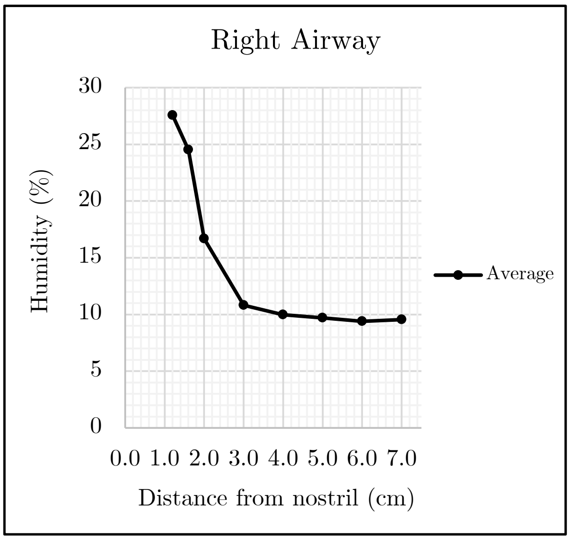


Figure 8.2.1: Average humidity of all partitions (left airway)



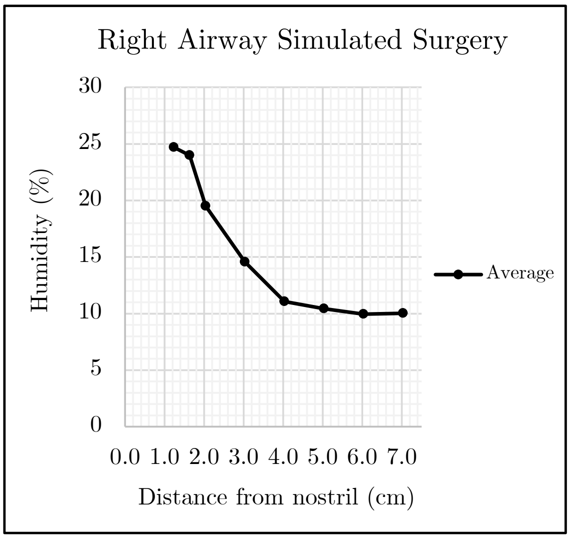


Figure 8.2.2: Average humidity of all partitions (right airway)

8.3| Humidity Field

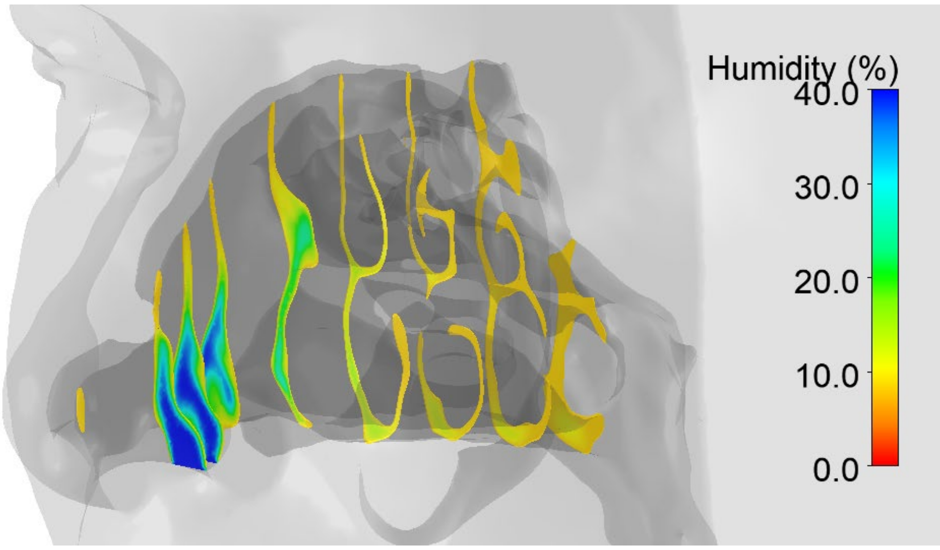


Figure 8.3.1: Humidity field (left airway before simulated surgery)

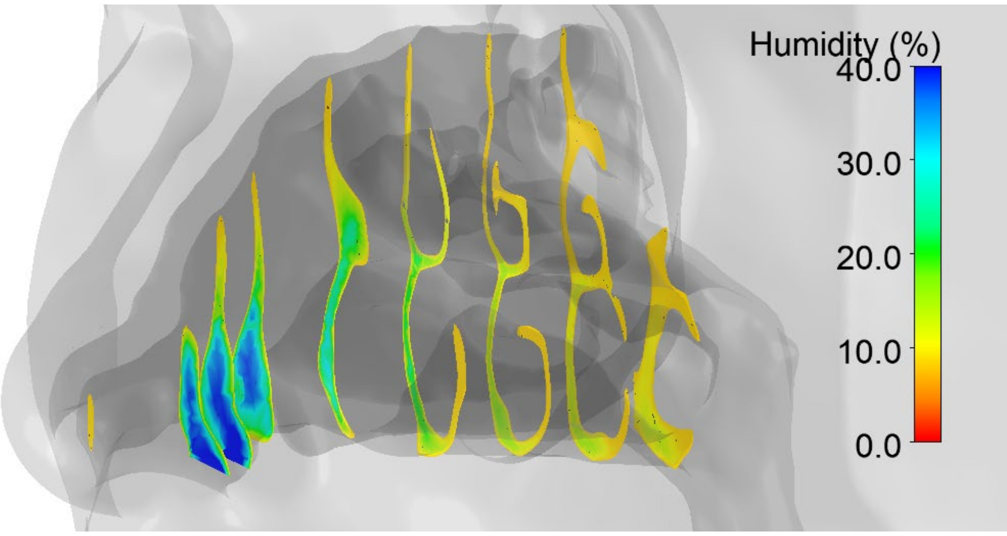


Figure 8.3.2: Humidity field (left airway after simulated surgery)

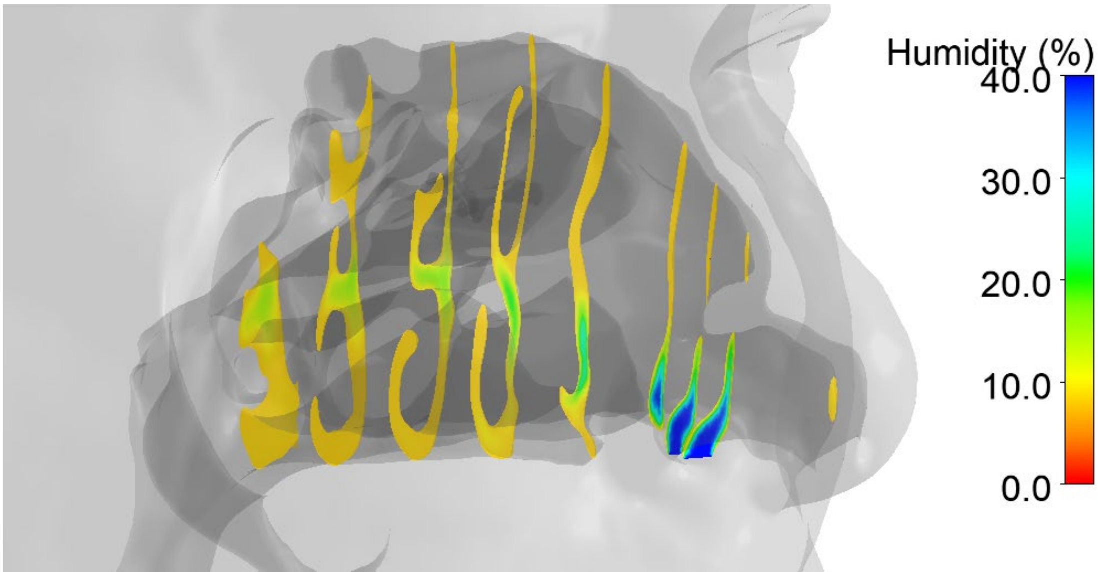


Figure 8.3.3: Humidity field (right airway before simulated surgery)

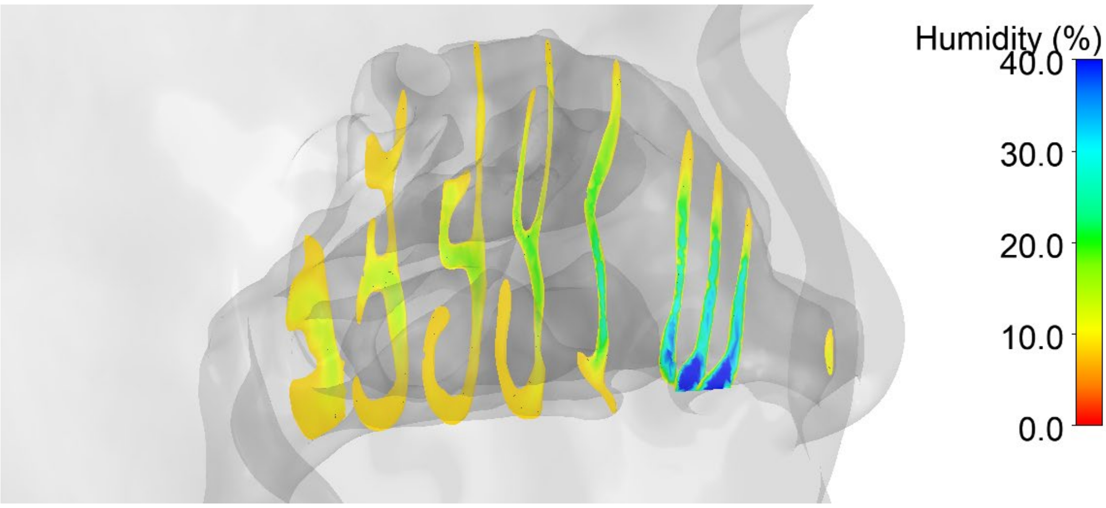


Figure 8.3.4: Humidity field (right airway after simulated surgery)

8.4| Humidity Field Video Before Simulated Surgery

8.5| Humidity Field Video After Simulated Surgery

9.0| Shear Stress

9.1| Shear Stress Distribution

Shear stress is the friction at the nasal wall caused by the air as it flows. Shear stress is important for the perception of airflow. Very low shear stress may cause lack of airflow perception, however very high shear stress may be a sign of obstruction. Physical examination is suggested if values are out of normal range.

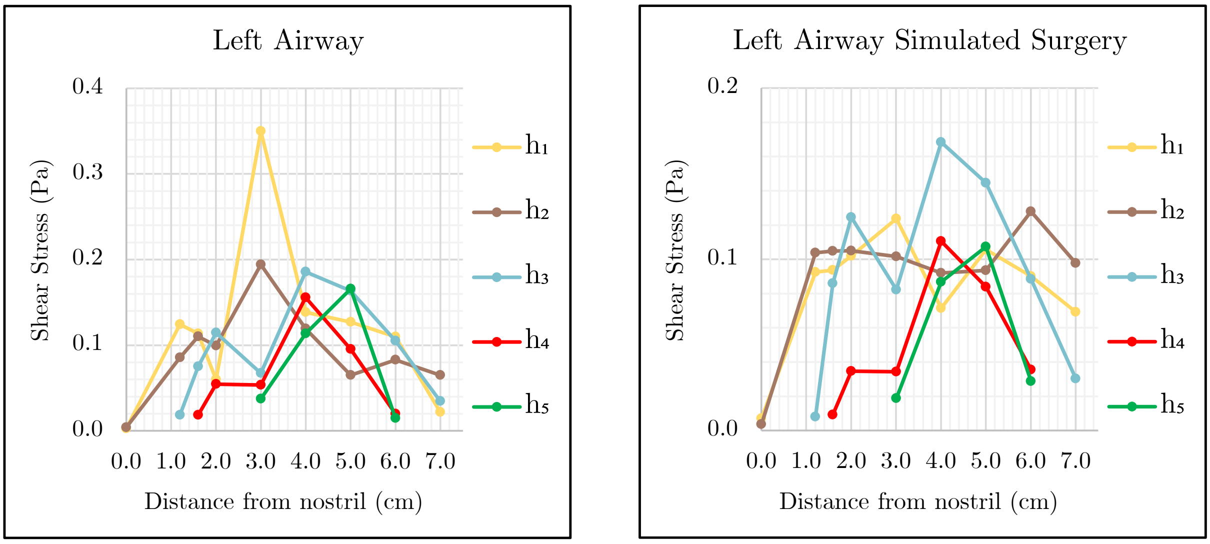


Figure 9.1.1: Shear stress by partition (left airway)

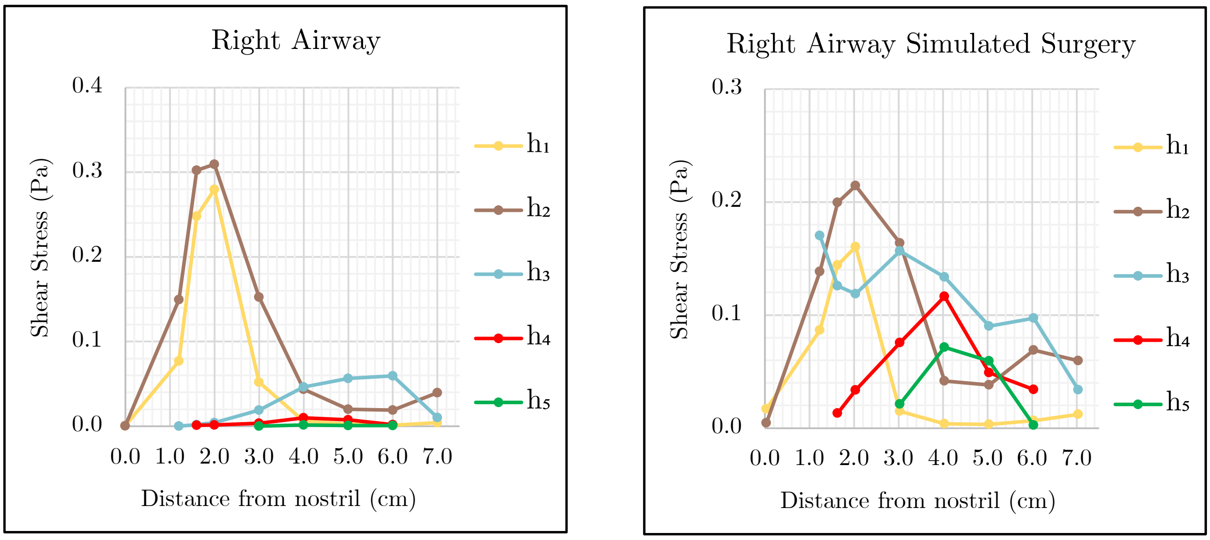


Figure 9.1.1: Shear stress by partition (right airway)

9.2| Shear Stress (Average)

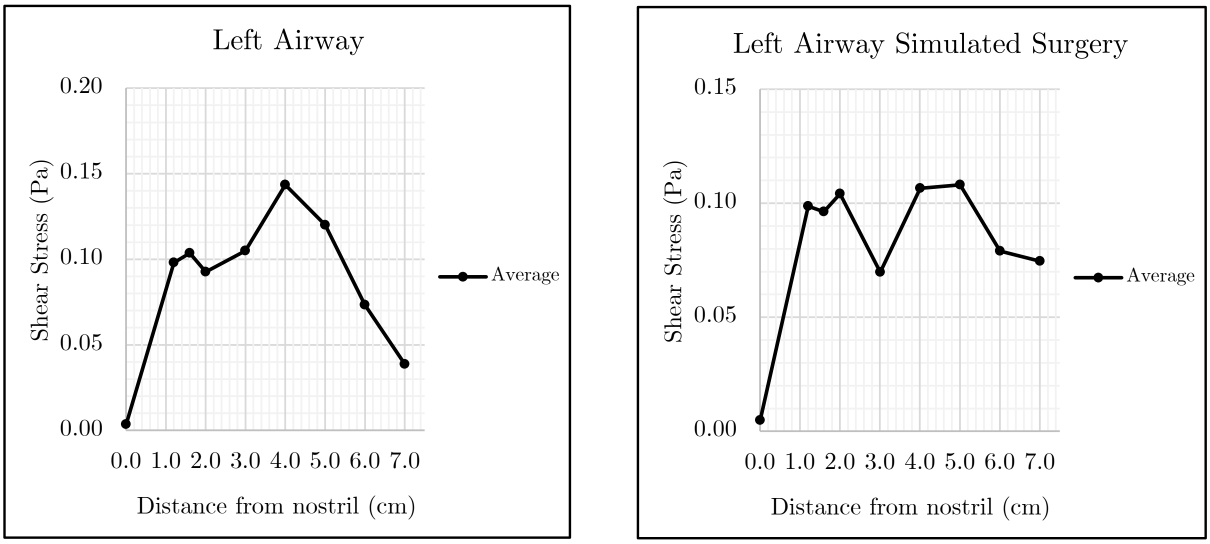


Figure 9.2.1: Average shear stress of all partitions (left airway)

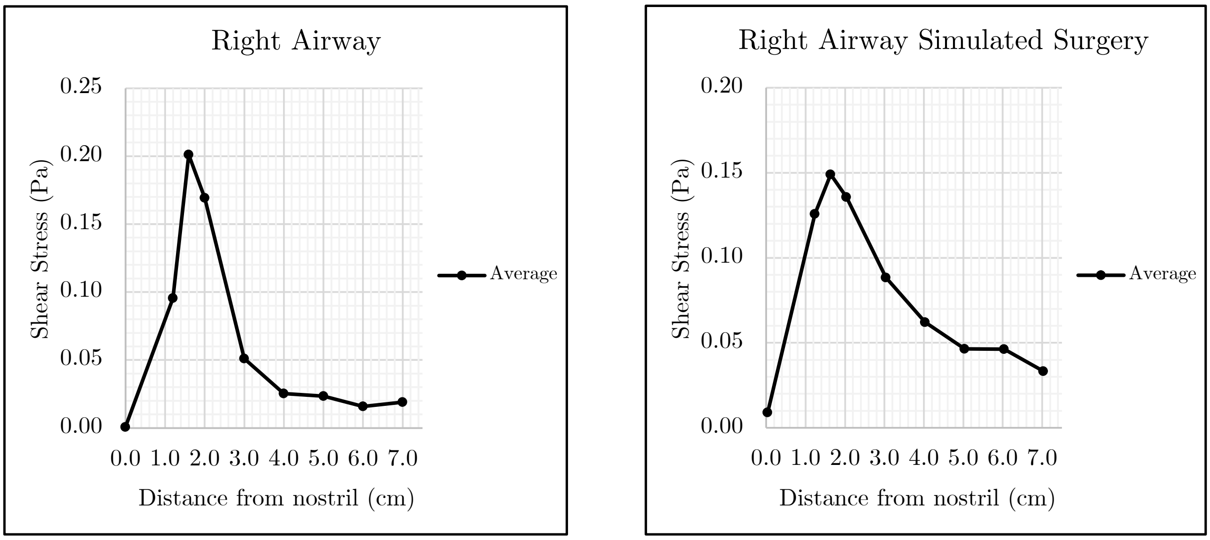


Figure 9.2.2 Average shear stress of all partitions (right airway)

9.3| Shear Stress Field

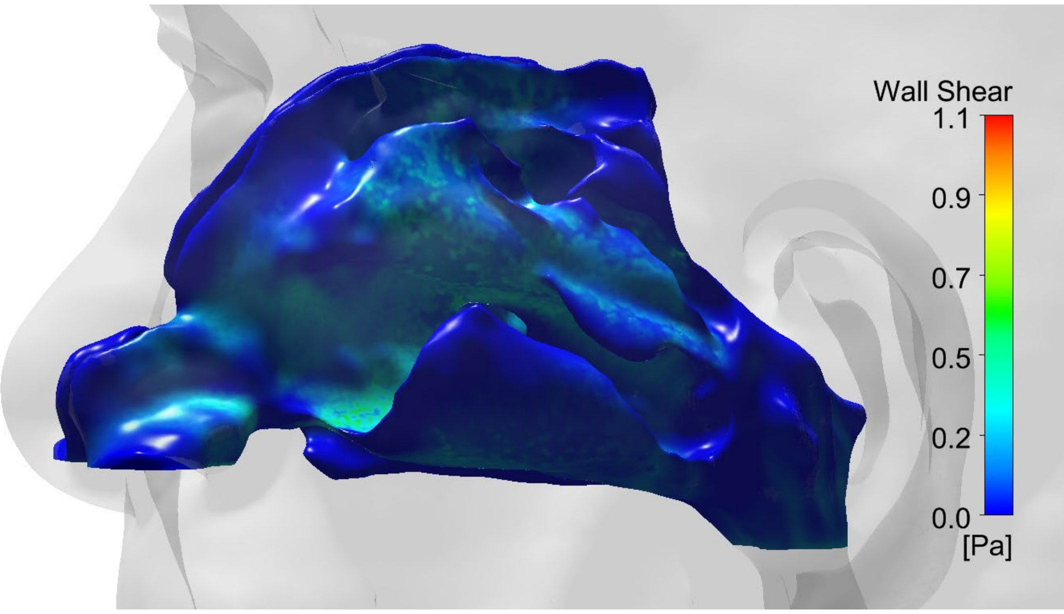


Figure 9.3.1: Shear Stress field (left airway before simulated surgery)

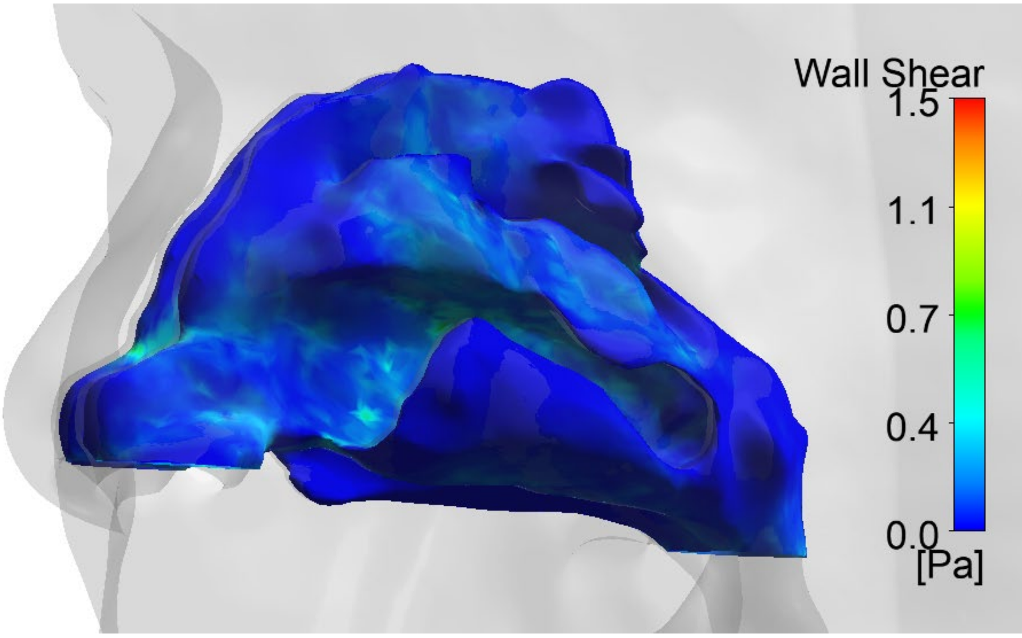


Figure 9.3.2: Shear Stress field (left airway after simulated surgery)

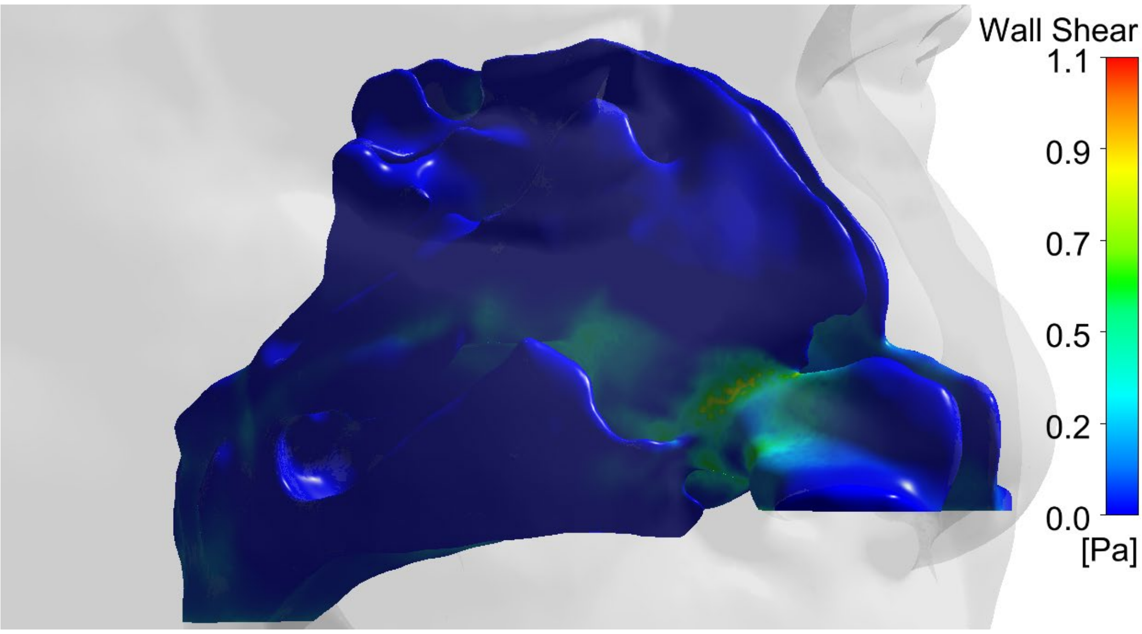


Figure 9.3.3: Shear Stress field (right airway before simulated surgery)

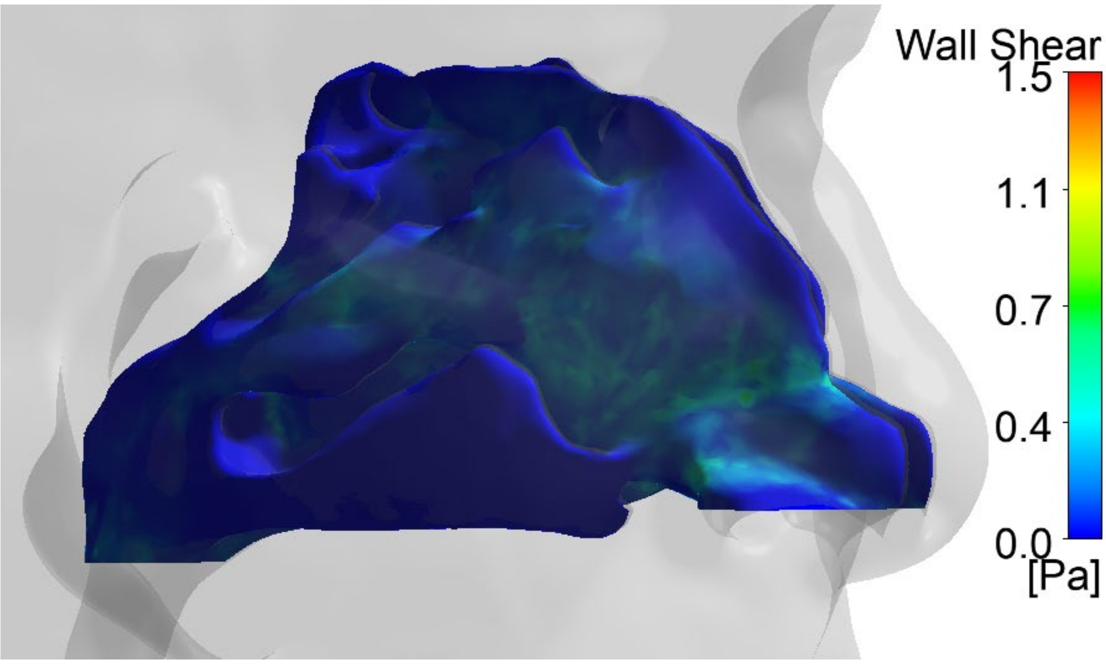


Figure 9.3.4: Shear Stress field (right airway after simulated surgery)