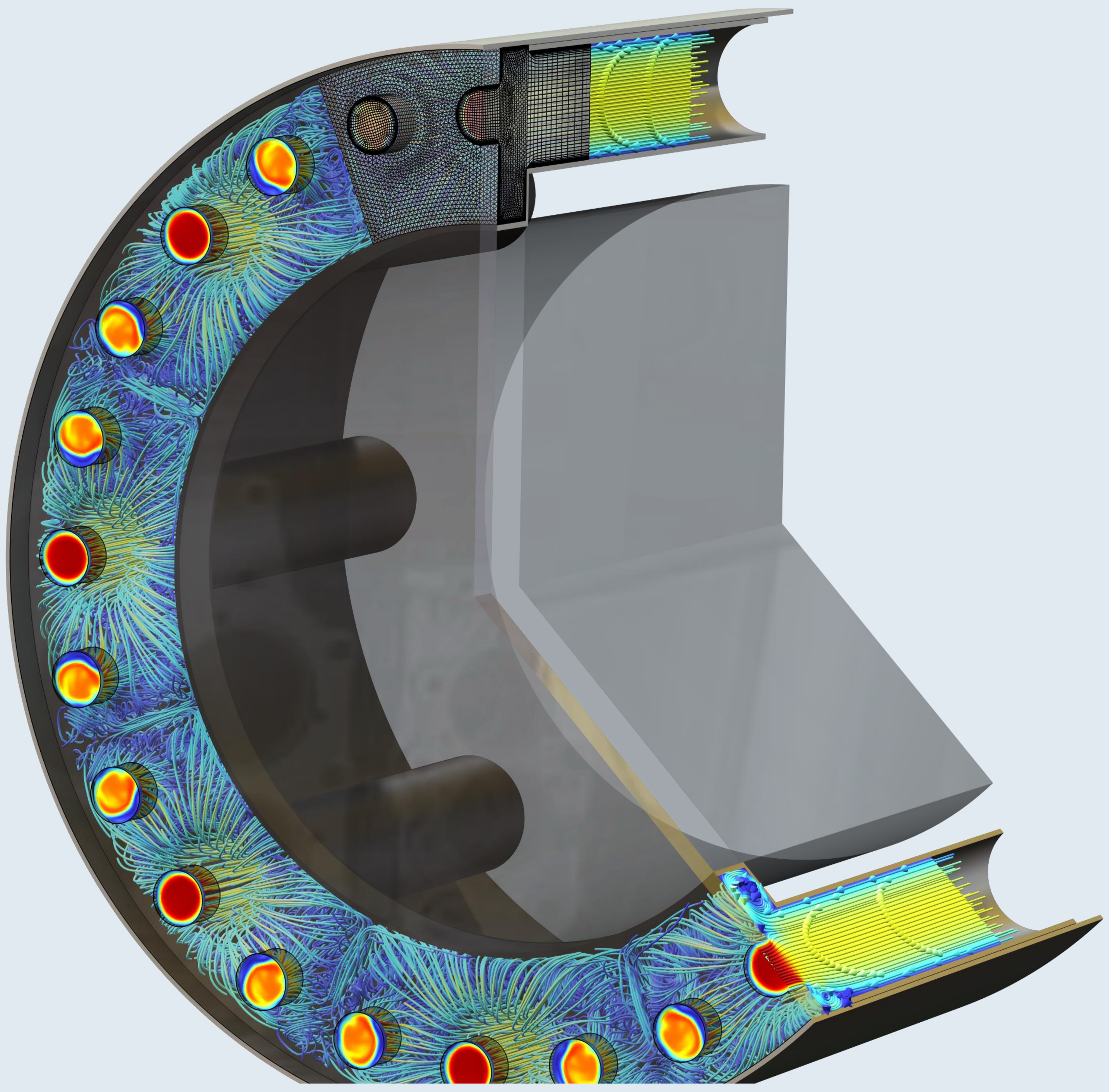

CFD-based Development of a Safety Device for Laparoscopes against Visual Obstructions

Accelerate the prototyping of an innovative medical device by investigating internal flow and resulting outflow for various designs and operating conditions using COMSOL Multiphysics 6.1.

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Abstract

Laparoscopy, which allows for video-assisted surgical interventions in the abdomen through thin-caliber instruments, has established itself as an effective method for minimizing surgical trauma.

However, visibility obstructions, primarily caused by bodily fluids and smoke, remain a major issue that leads to extended operation times, increased blood loss, a higher error rate, and therefore a significantly increased risk for patients[1].

This work presents an innovative laparoscope design where the insufflation gas (used for inflating the abdomen) is directed through the laparoscope itself and expands through a perforated endplate, forming a protective gas curtain in front of the optical lens.

The CFD development-based device has been proven to effectively enhance visibility, thereby reducing cleaning breaks and improving the safety and precision of laparoscopic procedures.

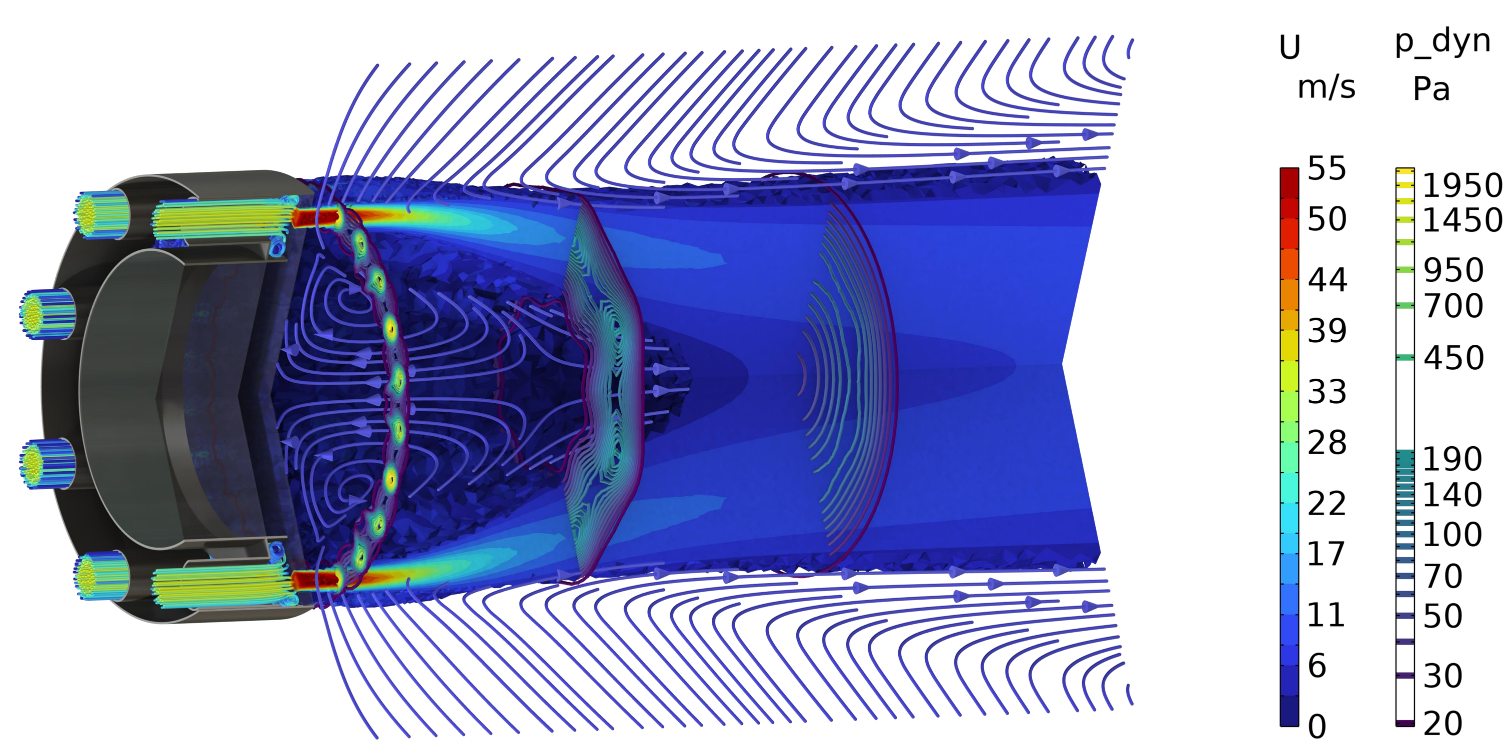

FIGURE 1: Protective gas curtain in front of the optical lens of a laparoscope with internal gas supply (volume plot for U > 5 m/s)

Methodology

A non-isothermal, compressible, turbulent (SST) flow model was chosen due to high volume flow rates (≤ 50 l/min) through small cross-sections (≤ Ø 1 mm). The flow domain was reduced to a 3D sector (symmetry BC) to minimize computational effort.

Based on a large parametric study involving several geometric parameters and volume flow rates, the internal gas flow was designed to properly account for flow distribution, pressure loss and temperature stability of the expanding gas (preventing patient hypothermia).

The formation of the protective gas curtain was then evaluated using a second model with spatially resolved flow distribution as the inlet BC.

Results

The expansion flow through such a perforation pattern leads to a fully closed gas curtain in front of the optical lens. This occurs due to the mutual influence of the free jets, which incline toward the optical axis of the laparoscope.

It can be observed that this effect is intensified with both an increasing number of perforations and volume flow rate. However, a negative side effect is the formation of internal vortices that occur directly above the optical lens and are also intensified in its direction (see Fig. 2).

The closed gas curtain can be visualized by censoring the velocity-volume plot below a certain threshold value (minimum specific impulse of the expanding gas), as shown in both Fig. 1 and Fig. 2.

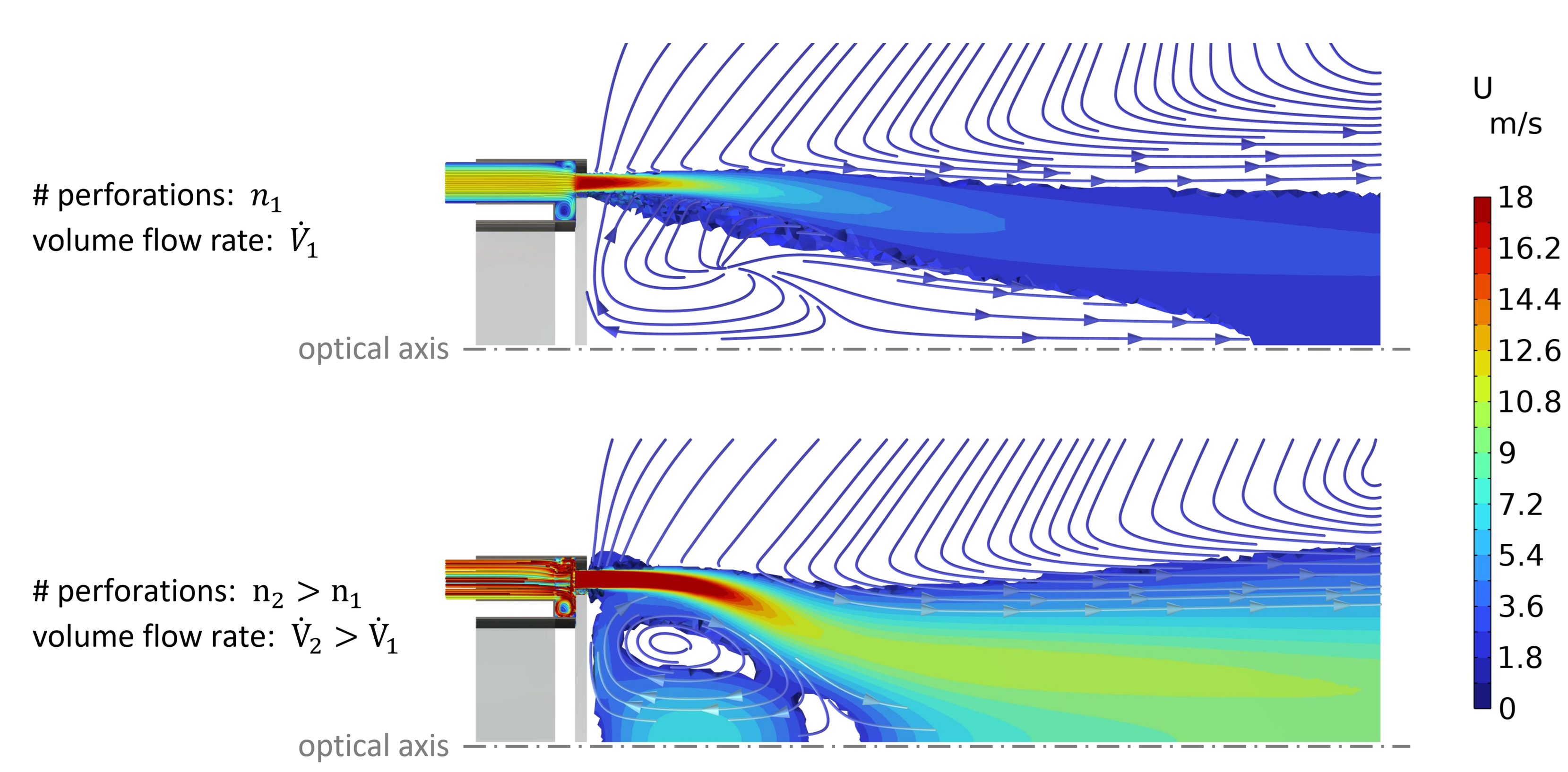

FIGURE 2: Influence of perforation pattern and volume flow rate on the formation of the gas curtain; a higher flow momentum also intensifies the unwanted internal vortices (volume plot for U > 2 m/s)

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