Development Of A Safety Device For Laparoscopes Against Visual Obstruction Using CFD Analysis

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Abstract

In video-assisted minimally invasive surgery, visibility obstruction from contamination of the laparoscope lens is a significant challenge. This work presents an innovative solution where a protective gas curtain is generated around the optical lens by directing the insufflation gas through the laparoscope itself. This approach not only enhances visibility but also improves the safety and precision of laparoscopic procedures, potentially reducing operation times by eliminating the need for cleaning breaks.

Minimizing surgical trauma has been a central concern in surgery for approximately 30 years. Laparoscopy, which allows surgical interventions through thin-caliber instruments, has established itself as an effective method. However, visibility obstructions caused by smoke, bodily fluids, and temperature differences remain a major issue that compromises the quality of surgical procedures. These visibility issues lead to extended operation times, increased blood loss, and a higher error rate, significantly raising the risk for patients. Experts estimate that up to 5 % of operation time is lost to cleaning the optics, which can cost thousands of operating hours annually.

As part of the COMSOL Multiphysics 6.1 CFD studies conducted at Fraunhofer IFAM Dresden, a novel approach to the management of insufflation gas was developed. The simulation work involved the creation of various flow models to represent the internal gas flow within the laparoscope as well as the resulting gas curtain around the optical lens, which were coupled at their interfaces using evaluated turbulent flow variables from the corresponding upstream model. Large-scale parameter studies allowed for the determination of proper component dimensions and gas flow rates regarding pressure loss, flow momentum and flow distribution.

The simulation results indicated that a complete perforation of the optical lens is not necessary for adequate visibility protection. A simple perforation pattern around the optical lens is sufficient to create a fully closed gas curtain. This effect is based on the tendency of the exiting free jets to tilt towards the optical axis of the laparoscope, influenced by the mutual interaction of the shear layers. The number, arrangement and diameter of the exit holes, as well as the volume flow rate, are crucial for the formation of this gas curtain.

Through the simulation-based design of the internal gas flow, the prototype development was significantly accelerated. Additionally, ideas for enhancement of the gas curtain due to passive flow control could be evaluated using COMSOL. In the future, the gas curtain formation is to be validated through experimental flow measurements.

Figures used in the abstract

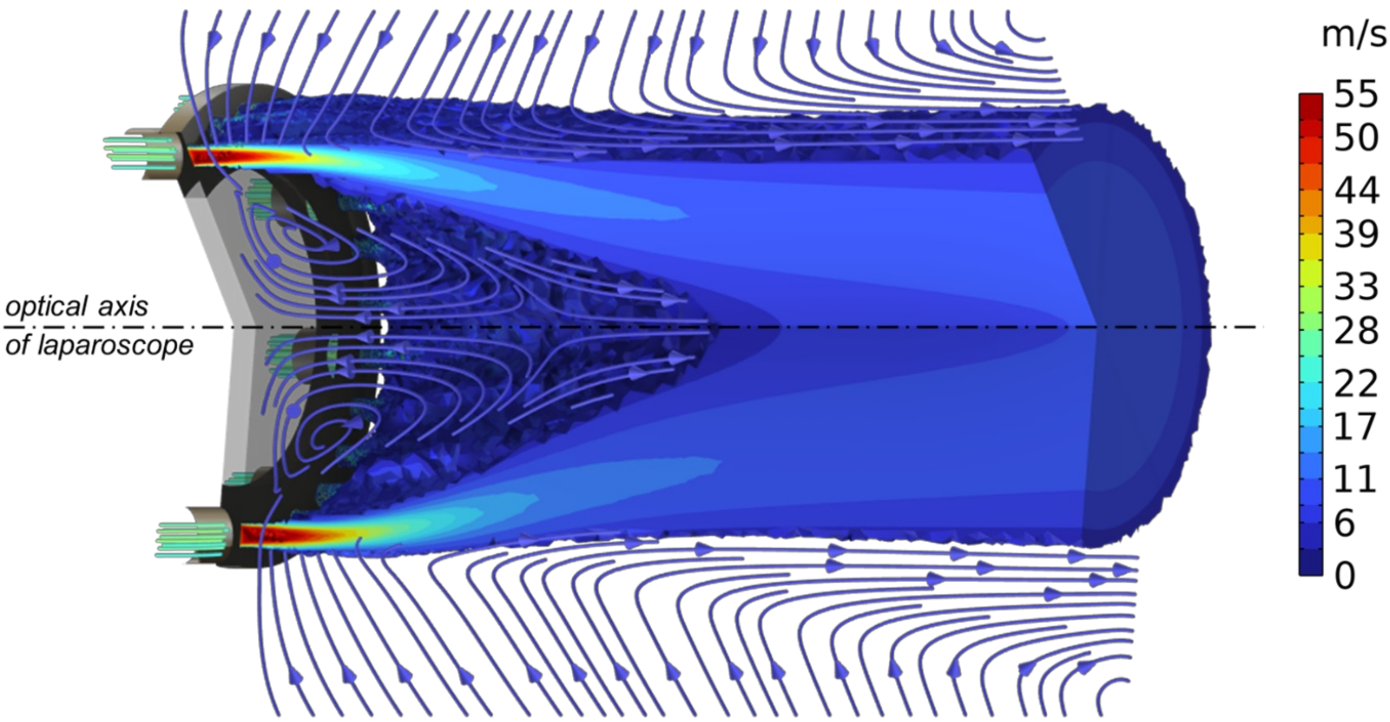

Figure 1 : Gas curtain around the optical lens of a laparoscope with internal insufflation gas supply to prevent the lens from

getting soiled