Analysis of Smoke Particles During Laparoscopic Surgery

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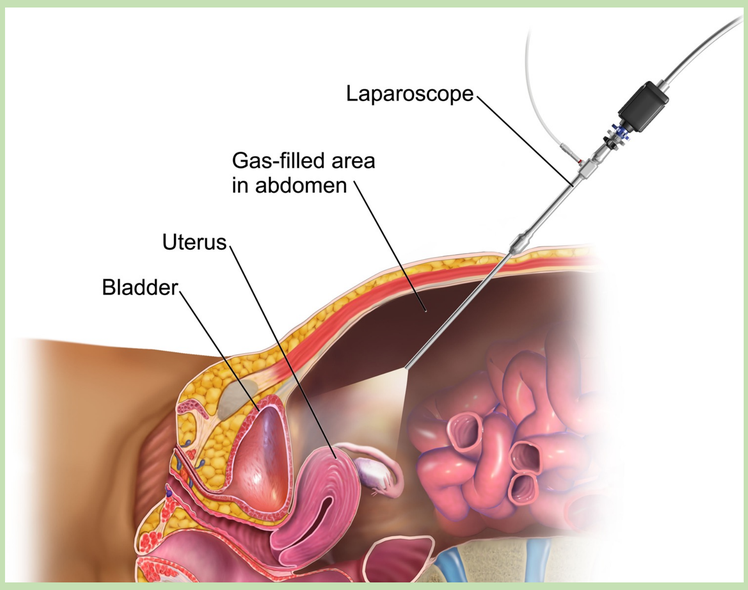
Introduction

Laparoscopic surgery is a minimally invasive abdominal surgery where the patient's abdomen is inflated with CO_2 and specialized instruments are used to perform the surgery through a set of ports. These ports are created by making several 0.5-1 cm incisions in the patient's abdomen and the amount varies per surgery. The inflated abdomen is kept at constant pressure to allow for clear view of the field through a laparoscopic camera. A diagram of this is shown below.

During this procedure, visualization of the field can be severely impaired by electrocautery smoke. Further, there is evidence that the smoke can have a toxic effect on the lungs, affecting both the patient and the operating-room personnel. For these reasons it is important that the smoke is removed from the patient effectively.

This research examined the fluid flow of smoke through a simulated laparoscopic field with the goal of finding the optimal port for smoke extraction.

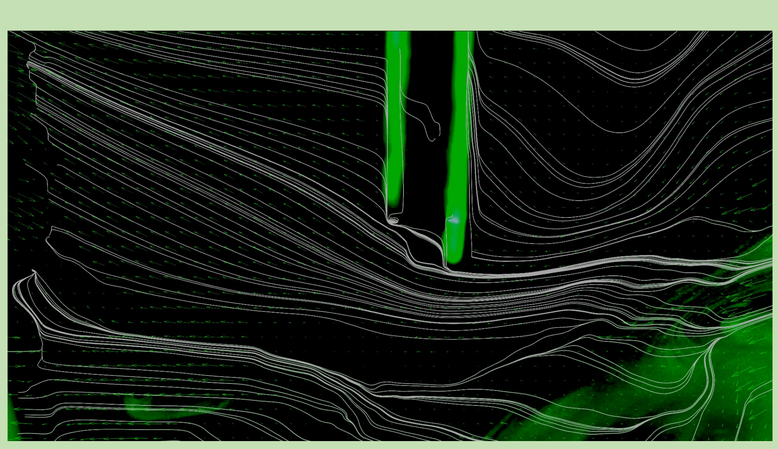


Particle Image Velocimetry

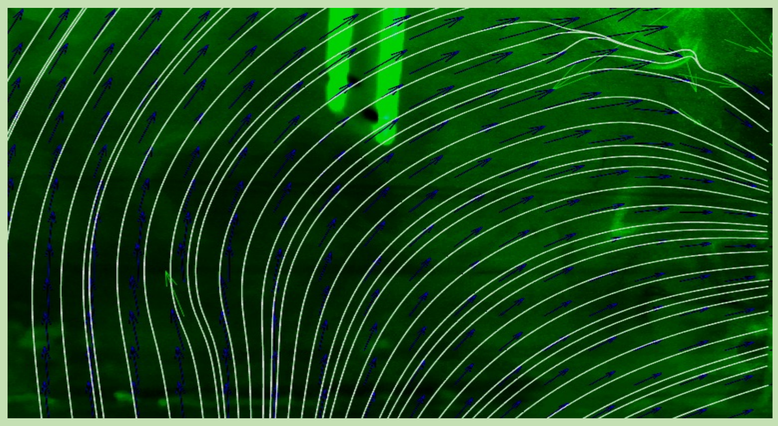
Developed in the late 1900s, Particle Image Velocimetry (PIV) is a methodology used to map quantitative flow and calculate the velocity distribution within a flow field. PIV uses the overlay of individual images to track particles through a given set. Applied in a laparoscopic setting, it allows for the flow of smoke from cauterization to be visualized and for the interactions between the flow and the field boundaries to be examined more rapidly than with individual measurements.

Methodology

In a dark room, a 230mm box was brought to a desired pressure and filled with 5m particles of a saline via a nebulizer. A laser beam is used to form a light sheet, illuminating particles in a 230mm box. Video of the flow field was captured using a high-speed camera at a frame rate of 128 fps under pressure ranging from 5-20 mmHg. PIVlab was then used to analyze the data collected.



Streamlines at 10 mmHg, mean velocity:



Streamlines at 15 mmHg, mean velocity:

Streamlines at 20 mmHg, mean velocity:

Conclusions

The images shown above, created through MATLAB PIVlab tool, show the streamlines of flow through a 230 mm box originating from the upper right corner. The streamlines over all videos display the direction of fluid movement through laparoscopic conditions. The flow patterns demonstrate how the cross flow of smoke will stay in the abdomen, impairing the visual field, until vented. Results demonstrate that PIV is an effective method for modeling in this application.

Future Work

Next steps include additional video processing at each pressure level. Further, future work would include exploring the effects of the origin of the smoke within the box on the flow throughout the field. Upgraded PIV technology would aid in these findings.

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