Tracking Surgical Port Leaks with Particle Image Velocimetry

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Introduction

Laparoscopic Surgery is a minimally invasive procedure commonly used in hospitals around the world. The procedure involves making a few small incisions in the patients abdomen and preforming the surgery through ports. While designed to seal around the instruments inserted when under pressure, these ports often leak gasses and particles into the surgeons field.

This research sought to experimentally validate velocity and path projections by utilizing particle image velocimetry software.

Methodology

Filming in 8k at a frame rate of 128 fps we captured video of the leaking ports under pressures ranging from 5-20 mmHg with the following procedure.

1. Darken room and turn on laser
2. Bring rig up to desired pressure and close pressure valve
3. Fill rig with 5 μm particles of saline via nebulizer
4. Start recording and open pressure valve
5. Slowly inset instrument into port and remove
6. Run video through PIVlab and process

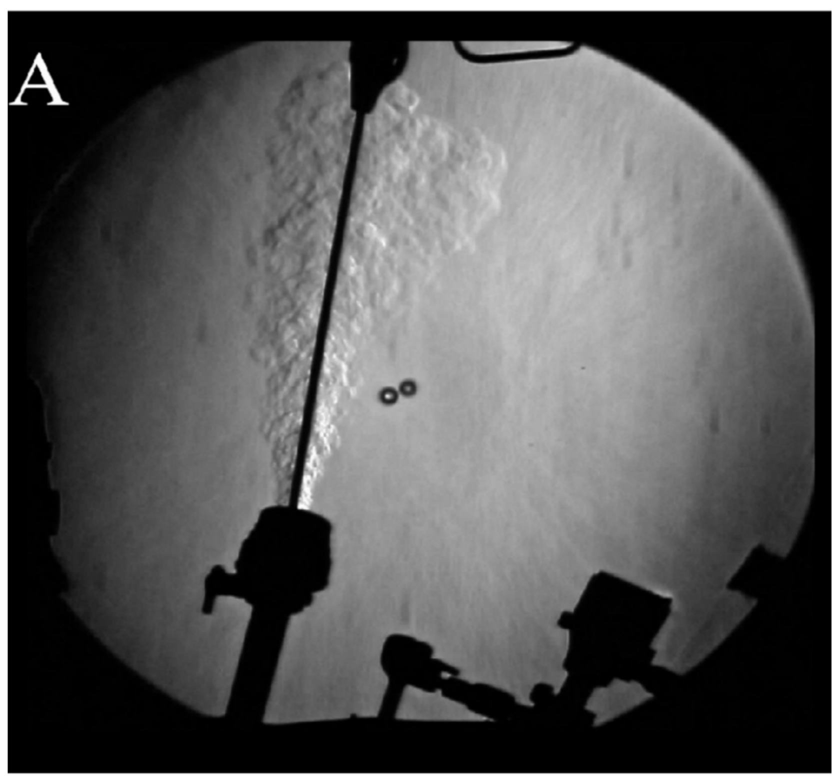
Particle Image Velocimetry

First done with any accuracy in 1977, measuring flow through a combination of particles and photography has propelled the field of fluid mechanics (Adrian, 2005, pp. 3-6).

Similar to the double exposure method used at its invention, PIV today uses the overlay of two images to track particles in a fluid to map its flow.

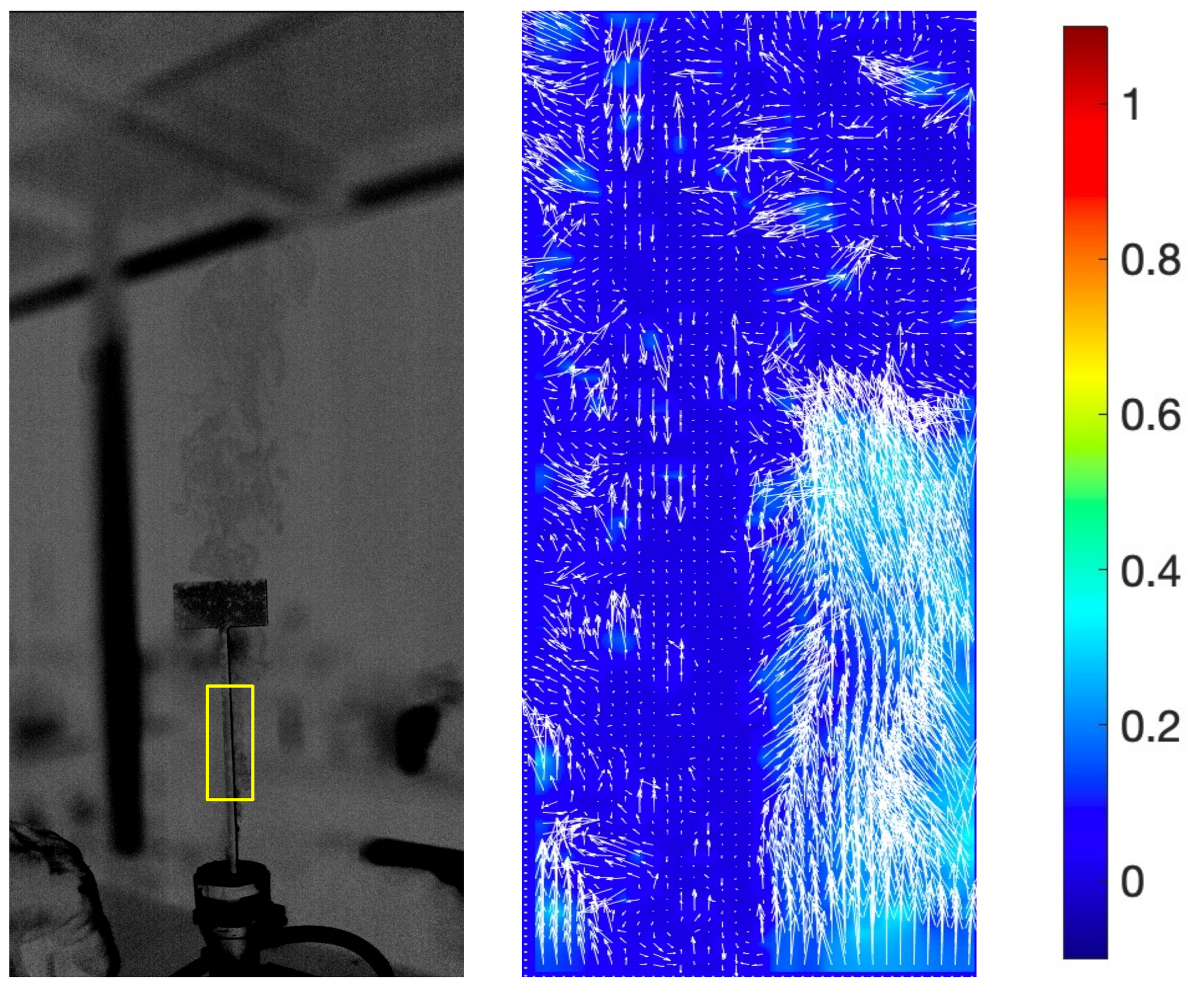
Advanced PIV specific rigs use a pulsating laser to minimize distortion of the seed particles. More general equipment such as a non-pulsating laser however can be used to achieve an adequate result.

A



B

Figure A shows a Schlieren image of gas leaking out of a surgical port. Figure B shows a CFD simulation of the leak (Crowley et al., 2021, p. 5). Schlieren imaging is a useful visual aid that can be used in the surgical theater however, it does not show the individual particles needed to analyze. The laser used in PIV solves this issue.



5 mmHg m/s

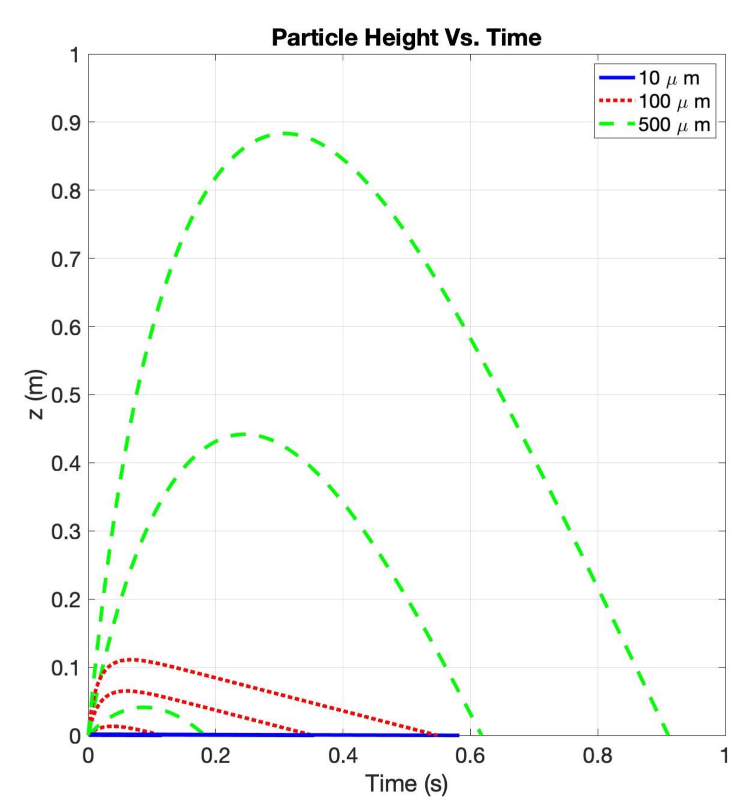
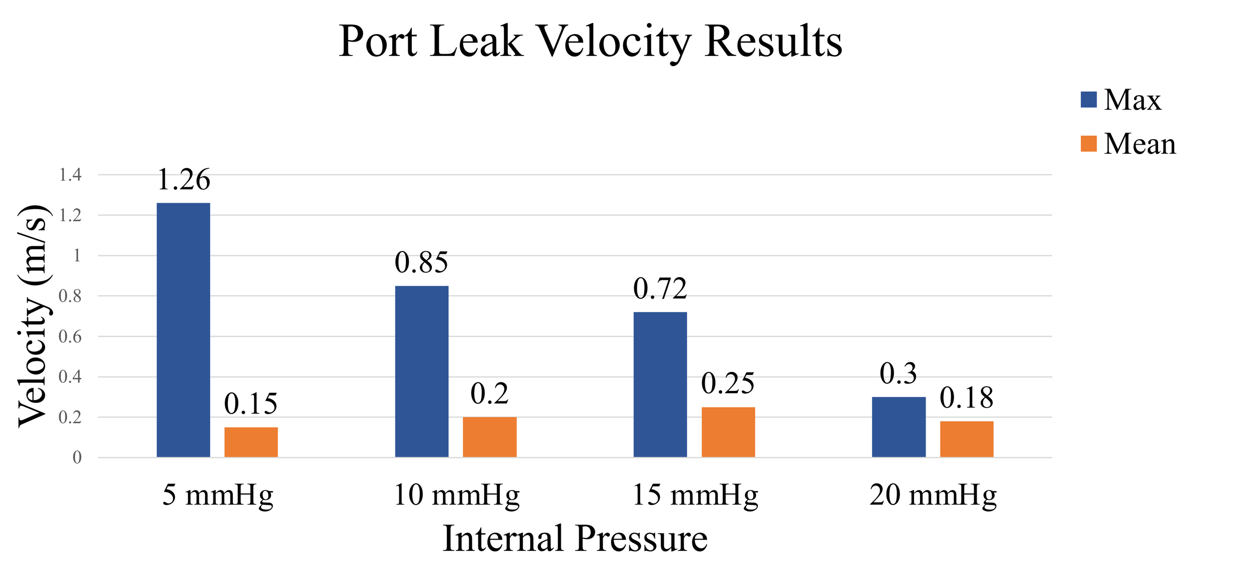


Figure 1

Figure 1 demonstrates how long particles will remain in stationary air after being expelled in a jet. Larger particles reach higher heights but tend to fall more quickly while smaller particles have a much more gradual decent. In laparoscopic surgery particles can very in size and the air is not stationary. Due to these conditions the particles stay in the surgeons field longer than this model predicts. (Code developed as part of PORSAV project)

Conclusions

The velocity of the leaked gas varied according to the internal pressure. This verifies what one would expect to see as the port is meant to be used under pressure. However, each test had an average velocity of at least .15 m/s with maximum values many times that. Taken in combination with visual observation and drag force analysis these results affirm that leaks from ports during surgery have the capability to cloud the surgical field.



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