CAD Modelling of a 3D Printed Solution to CO_2 Leaks in Laparoscopic Surgery

Haley Barnes
School of Mechanical and Materials Engineering
University College Dublin

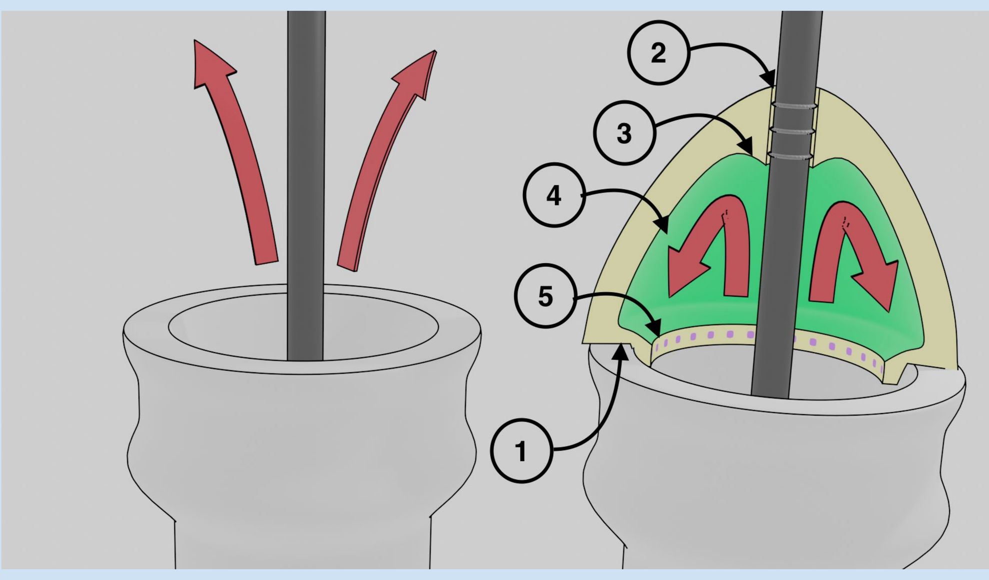
Introduction

In laparoscopic surgery, a patient's abdomen is inflated with CO_2 in order to allow for a greater range of movement of the operating surgeon's instruments within the body. This CO_2, however, can leak from the trocar, the point of insertion for laparoscopic tools into the body. Schlieren imaging has shown that this CO_2 remains in the space between the surgical staff and the patient, thus causing potentially harmful effects to those in the operating room.

The goal of this research is to create a device that redirects the flow of these CO_2 jets away from the staff's faces, allowing the positive pressure in the operating room to send the CO_2 downwards and out of the space.

Previous Work

Prior to my involvement in the project, a similar device had been created with the same goal, shown in the images below. This device, nicknamed "The Egg", was successful in lessening the amount of CO_2 in the central space, but was realized to be a slight burden for the surgeons to work with, as it added an additional barrier that the instruments must be maneuvered through.



Using this work as a building block, the objective is to design a new device that provides the same or better outcomes while lessening the difficulties caused to the surgeons.

Using the Coandă Effect

The Coandă Effect in fluid mechanics describes the tendency of a jet of fluid, in this case CO_2 to attach to and follow the curvature of a convex surface.

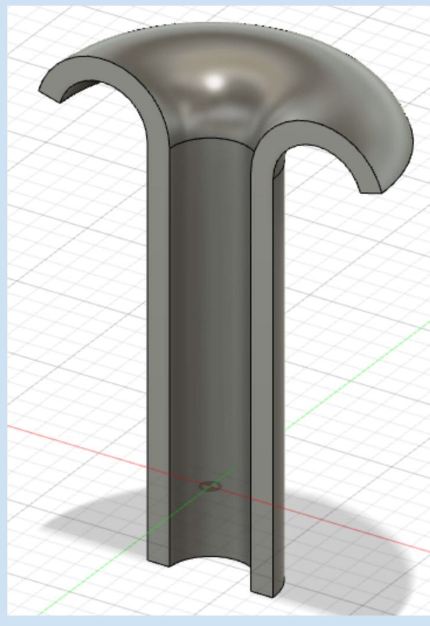
When the ratio of the width of the jet, h, to the radius of the curved surface, r, is less than 0.5, a true Coandă Effect is observed and the jet will remain attached until the surface ends. Thus, as the gap between the surgical instrument and this device is relatively small, measuring only a few millimeters, this phenomenon will take effect as long as the radius of the curvature is at least twice this distance. The CAD model created for the application of the Coandă Effect to the CO_2 jets can be seen at right labelled "Model 1."

The Addition Internal Rifling

A second version of this device was created using the addition of internal rifling to redirect the flow. In this design, shown below labelled "Model 2," there is no longer a gap between the device and the surgical instrument, but rather two continuous spirals to direct the flow upwards and sideways.

CAD Models and Prototypes

The two designs were modelled using Fusion 360, and can be seen below. Model 1 shows a sectional view of the design relying on the application of the Coandă Effect and Model 2 shows a sectional view of the spiral design.



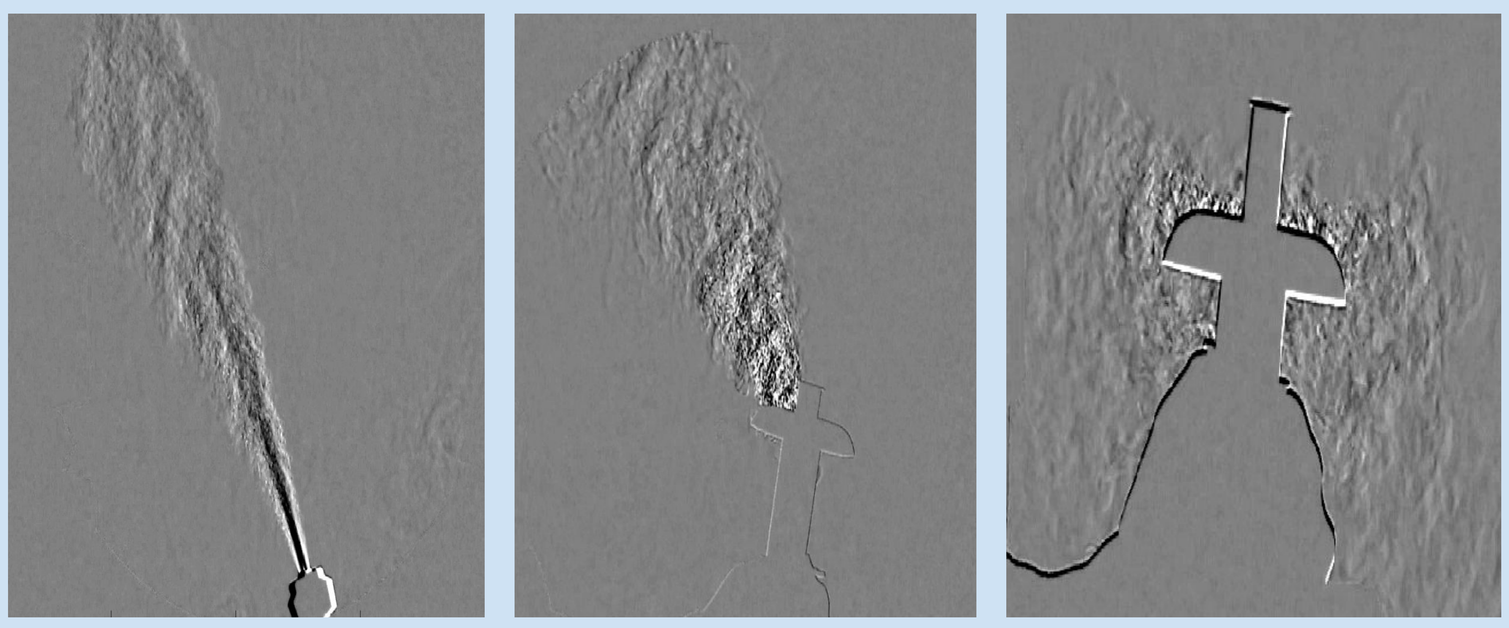
Model 1

Model 2

Upon completion of these models, the two prototypes were 3D printed using TPU on a Ultimaker S3 printer.

Conclusions

Once the models had been designed and printed, they were tested at the Mater Misericordiae Hospital and videoed using Schlieren imaging technology. They were then compared with each others well as with the trocar with no device in order to determine their effectiveness. This testing showed that though Model 1 had little to no effect, the addition of internal rifling in Model 2 was successful in diverted the flow of CO2, allowing for the Coandă Effect to take hold.



The above images, created through a MATLAB video analysis of the Schlieren results show the CO2 jet with no device, with Model 1, and with Model 2, in that order.

Future Work

In future work these models will need to be decreased in size and a means of attachment to the trocar will need to be added.