

# Elimination of Laparoscopic Lens Fogging Using Directional Flow of CO<sub>2</sub>

John Teague Calhoun, BS, Jay A. Redan, MD

## ABSTRACT

**Background and Objectives:** Surgeons constantly struggle with the formation of condensation on the lens of a laparoscope, which prolongs procedures and reduces visibility of the abdominal cavity. The goal of this project was to build a device that would direct a flow of carbon dioxide (CO<sub>2</sub>) into an open chamber surrounding the lens of a laparoscope, acting to keep moisture away from the lens and eliminate condensation.

**Methods:** The device isolates the lens of the laparoscope from the humid environment of the intraperitoneal cavity by creating a microenvironment of dry CO<sub>2</sub>. This was accomplished by building a communicating sleeve that created an open chamber around the distal 2 to 3 cm of the scope. Into this cavity, dry cool CO<sub>2</sub> was pumped in from an insufflator so that the path of the gas would surround the lens of the scope and escape through a single outlet location through which the scope views the intraperitoneal cavity. This chamber is proposed to isolate the lens with a high percentage of dry CO<sub>2</sub> and low humidity. The device was tested in 7 different adverse conditions that were meant to challenge the ability of the device to maintain the viewing field with no perceptible obstruction.

**Results:** In all of the conditions tested, 25 trials total, the

device successfully prevented and/or eliminated laparoscopic lens fogging.

**Conclusions:** The device designed for this project points to the potential of a simple and effective mechanical method for eliminating laparoscopic lens fogging.

**Key Words:** Condensation, Fogging, Humidity, Laparoscope, Water vapor.

## INTRODUCTION

Laparoscopic surgery relies on the use of a high-definition camera to provide a surgeon with a clear and precise viewing field while performing minimally invasive procedures and re-creates the view that would normally be available with an open surgery. One of the longest-standing challenges associated with laparoscopic visualization is that of lens fogging. Surgical rooms, generally kept at a dry temperature between 20°C to 24°C, are a stark contrast to temperatures of the human intraperitoneal cavity that are above 37°C (and more than 85% relative humidity).<sup>1</sup> The temperature fluctuation of the scope, as it is placed inside the intraperitoneal cavity, brings the moisture in the pneumoperitoneum surrounding the laparoscope to its dew point (the temperature at which the moisture in air will condense and form a liquid; a temperature that varies with atmospheric pressure and relative humidity) and causes the accumulation of condensation on the lens as well as the shaft of the scope.<sup>1</sup> Furthermore, during a procedure, changes in the intraperitoneal environment, such as cauterization of tissue, produce alterations in heat and moisture that may continue to affect the lens of the scope.

There have been many attempts to circumvent this problem, including the use heat in the form of a warming bath,<sup>2,3</sup> the application of topical solutions or washings,<sup>4-6</sup> and films that counteract the fogging of the lens.<sup>5</sup> Expense, complication due to the need for additional preparation, and a lack of definitive literature have led to underutilization of many of these strategies.<sup>1</sup> Mechanical innovations, in particular, are generally unsuccessful due to their increased cost, enlargement of the laparoscope, and issues with operation and sterilization.<sup>1</sup> Lawrentschuk et al<sup>1</sup> provided a history of cur-

University of Central Florida College of Medicine, Celebration, Florida (Calhoun).

Florida Hospital, Celebration Health Nicholson center, CUCF College of Medicine, Celebration, Florida (Redan).

**Conflict of Interest:** This product was designed to be a solution to a common and pervasive problem. After its development, the authors began the process of patenting the product. Currently, because of the need for revision, there are no plans to further this goal; however, the authors do remain interested in building on the ideas and designs described in this paper with the possibility of arriving at a product that would be worthy of use in hospitals in the United States. To that end, should the device described in this paper be realized as a commercially feasible endeavor, the authors would seek to market it.

**Funding Source:** Financial support for the development of this project was provided by the University of Central Florida.

Address correspondence to: John Teague Calhoun, University of Central Florida College of Medicine, 400 Celebration Place, Suite A-140, Celebration, FL 34747. Telephone: 386-295-8961, E-mail: Calhounj@knights.ucf.edu

DOI:10.4293/108680813X13693422520431

© 2014 by JSLS, *Journal of the Society of Laparoendoscopic Surgeons*. Published by the Society of Laparoendoscopic Surgeons, Inc.

rent methods used to combat lens fogging, and described the use of heat, antifogging solutions and films, and other assorted solutions to this problem, providing a discussion of their usefulness.<sup>1</sup> Notably, a prototype “fogless laparoscope” has been developed that uses the precise temperature modulation of a superficial lens to maintain that lens at a temperature that prevents accumulation of fog; however, this instrument was an expensive solution that required the replacement of current equipment.<sup>1,7</sup> A review of the available literature revealed that the avenue of design not fully explored was that of managing the microenvironment in which the laparoscope lens exists during surgical procedures. The development of this prototype was independent of any prior discoveries; however, during the completion of this project, Minimally Invasive Devices Incorporated (Franklin, Ohio) released a product, FloShield, that utilizes this method to create a vortex of CO<sub>2</sub> flow around the lens of the scope to prevent fogging and accumulation of debris. Currently, the literature regarding this product is limited to that released by the company for marketing purposes.<sup>8</sup>

This project is a discussion of the design, construction, and preliminary testing of a device that was built to determine whether using the flow of CO<sub>2</sub>, similar to the FloShield, could successfully eliminate perceivable laparoscopic lens fogging by isolating the lens in a dry gaseous environment of CO<sub>2</sub> provided by an insufflator. Additionally, this project sought to outline a simple explainable method and design that would not require the replacement of existing equipment such as laparoscopes or insufflators. The prototype built for this purpose functions by channeling CO<sub>2</sub> from an insufflator to the distal end of the scope and using the flow of the gas to eliminate fogging and obstruction of the lens much like the defogger in a car.

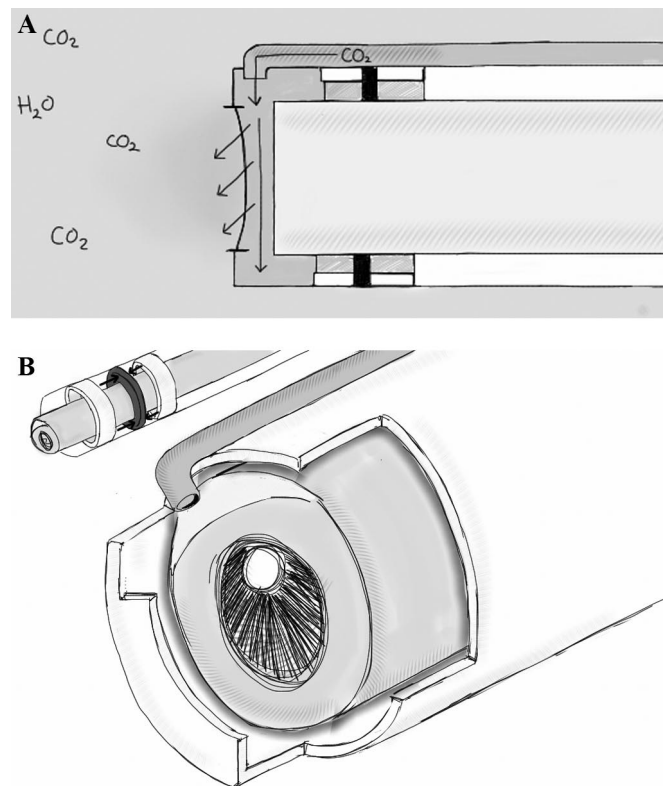
## METHODS AND APPROACH

### Development and Construction of the Device and Testing Materials

The device was built using readily available materials such as chlorinated polyvinyl chloride (CPVC) pipe and silicon rubber. **Figure 1, A and B**, illustrates the construction of the device as it is listed in the following section. The list of materials and procedure is as follows:

#### Materials

1. ½-in CPVC pipe
2. ½-in CPVC pipe cap
3. Aviation-grade silicon rubber (in sheets about 2 mm thick)



**Figure 1.** A, Illustration of a longitudinal cross section of the device. The red color represents the humid environment of the intraperitoneal cavity being forced away from the lens of the laparoscope by the flow of the cool dry CO<sub>2</sub> (blue). B, Depiction of the nature of the sleeve and chamber created by the device as it surrounds the laparoscope. The smaller image illustrates the fittings and washer inside the device. The blue tube represents the channel delivering CO<sub>2</sub>.

4. Clear polyethylene tubing (5 mm)
5. Amazing GOOP (Eclectic Products, Eugene, Oregon) plumbing sealant and adhesive
6. PVC solvent cement
7. Plastic box
8. Metal screws, washers, and nuts
9. Black paint
10. Thermometer
11. Plastic and metal plugs

A piece of hollow ½-in CPVC pipe was cut to the exact length of a 5-mm laparoscope (30 cm) to create the body of

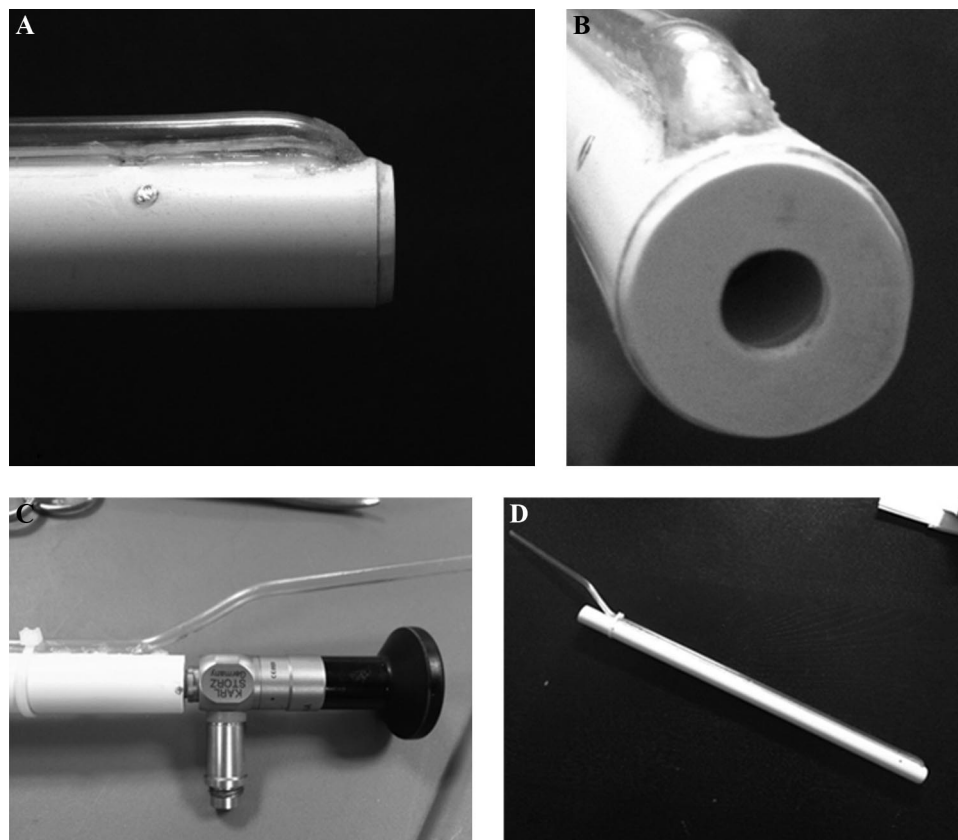
the device. At the distal end, the device was capped with a 1/2-in CPVC pipe cap, which was glued in place with PVC solvent cement, and then ground down to be flush in diameter with the 1/2-in device. In this cap, an ~5-mm hole was cut to allow the laparoscope a field of view. Aviation-grade silicon rubber was cut into “washers” and placed at the proximal and distal sections of the CPVC pipe to stabilize the laparoscope inside the device and, proximally, to contain the flow of the CO<sub>2</sub> such that it would flow specifically over the lens of the scope. Refer to **Figure 1, A and B**, for depictions of the washers. Along the dorsal surface of the laparoscope, 5-mm clear polyethylene tubing traveled the length of the device and terminated inside the distal cavity by curving 90° ventrally. The polyethylene tubing channeled CO<sub>2</sub> from an insufflator (Karl Storz Thermoflator, Tuttlingen, Germany) into the distal chamber created by the device. This created a space that was constantly receiving flow (and outflow) and would act to isolate the lens in an environment of dry CO<sub>2</sub> and maintain visual clarity of the scope. The final product is shown in **Figure 2, A–D**.

In addition to the prototype of the device, an ~18.5-L con-

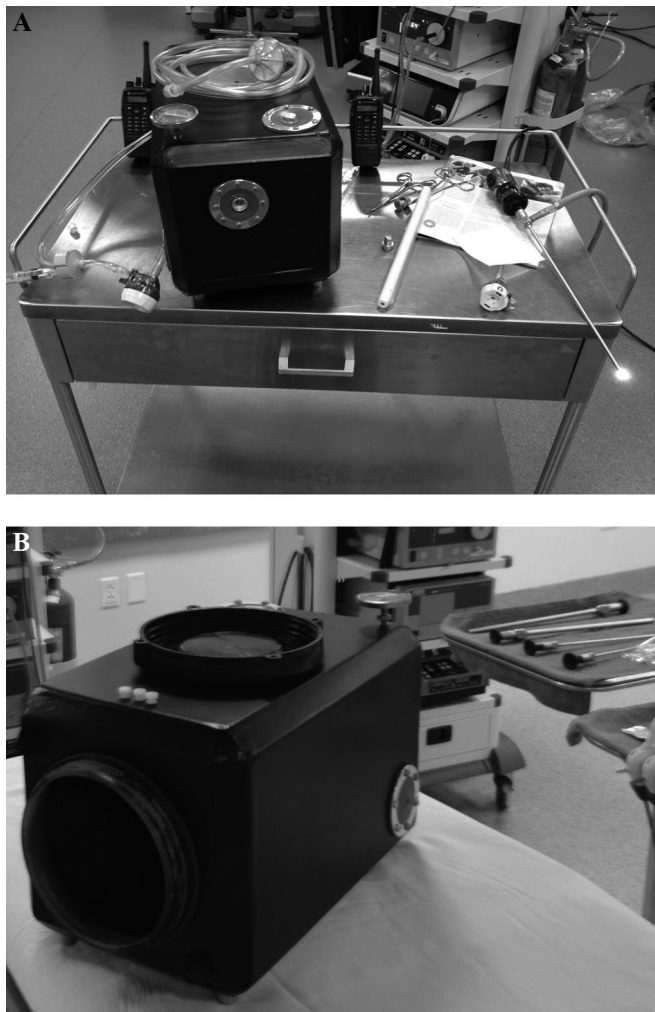
tainer (approximated because of the irregular contour of the container) was used and redesigned to test the device in controlled settings. This container was a modified storage box used for protecting survival gear on a boat and was chosen because it was watertight, had a screw on the lid allowing easy access to the inside, and was large enough to allow easy manipulation during the experiments. Refer to **Figure 3, A and B**, for images of the described humidity box. The box was modified in the following ways: Multiple “ports” were installed using the same silicon rubber used in the prototype, with a small hole punched in it, creating openings that would seal around the laparoscope as it was inserted. A thermometer was installed to monitor the temperature. The box, originally red and translucent, was painted black to prevent a glare from the laparoscope’s light source.

### Methods of Experimentation

A series of experiments was designed to test the device’s ability to prevent lens fogging. In these trials, the outcome was graded on a +/- scale by a comparison of the following



**Figure 2.** Images of the device focused on the distal end (A), focused looking into the distal end (B), focused on the proximal end with the laparoscope in place (C), and of the scope from afar (D).



**Figure 3.** Two views (A, B) of the humidity box showing the “ports” through which the laparoscope, thermometer, and insufflation equipment were inserted.

parameters: the laparoscopic clarity when not exposed to any insulting environment (cold, dry operating room), the laparoscopic clarity of a bare laparoscope in each of the testing conditions, and the laparoscopic clarity when operating with the aforementioned device described in each testing condition. If the lens was perceived to be obstructed in any way in which the visual field was not as clear as the bare scope’s clarity when not exposed to any insulting environment, this was considered a negative result. To act as a control, the bare laparoscope was introduced to each test scenario and allowed to become perceptibly obstructed by fogging, establishing that each scenario was one in which the environment would produce fogging and obstruction. This baseline was imaged for later comparison (see **Figure 4, A–D**). The device was tested in 2 environments with multiple pa-

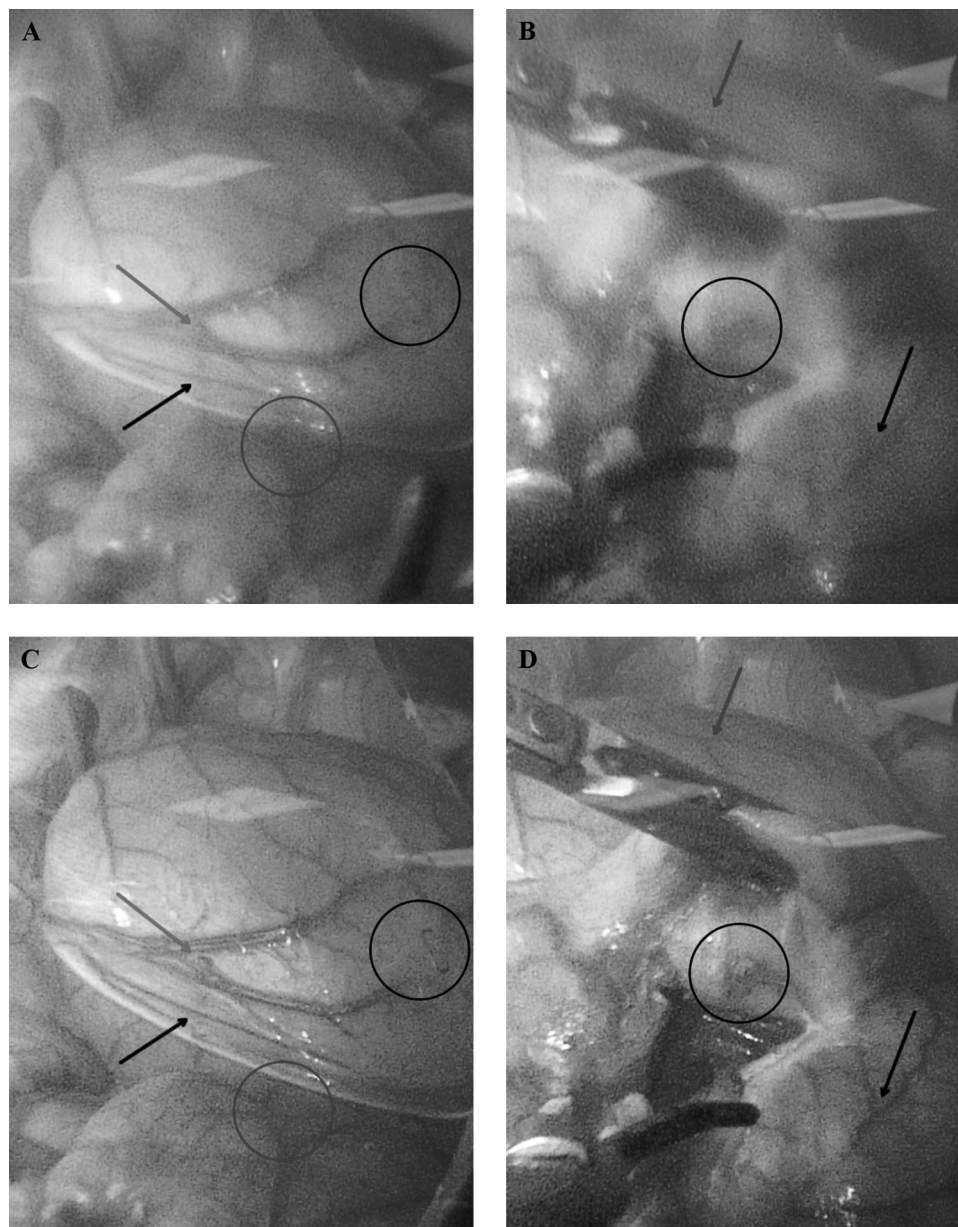
rameters. The first environment was the aforementioned container. The second was the intraperitoneal cavity of a porcine model. The use of the porcine model was approved by the Institutional Animal Care and Use Committee of the University of Central Florida and the Florida Hospital. A summary of the different conditions in which both the bare scope and the scope inside the device were placed follows.

A trocar attached to an insufflator was inserted into a port on the posterior, lower left side. The insufflation hose was equipped with a filter that was saturated with saline to provide humidification. The insufflator was set to 5 L/min and pumped warmed humidified CO<sub>2</sub> into the container. The internal temperature was at least 80°F at the outset of each experiment and reached as high as 90°F. This temperature was naturally reached as the warmed CO<sub>2</sub> was pumped into the humidity box. Despite the variation between 80°F and 90°F, in each experiment it was established that a bare scope would become fogged before testing the device. In each of the following humidity box conditions, the scope was placed at multiple positions in front of a trocar introducing 100% humid, warmed CO<sub>2</sub>: placed just inside the humidified container; placed flush with the trocar, pointing directly at the trocar (0°); placed within ~7 cm of the trocar (0°); and placed within ~7 cm from the trocar, aimed 45° down from the trocar. In the porcine model at physiologic conditions (>85% humidity, at a temperature ~100°F, or 37.7°C), the scope was placed just inside the intraperitoneal cavity, placed within ~7 cm of the small intestine, and placed within ~7 cm of the small intestine in the context of continued harmonic cauterization. The distance within ~7 cm was chosen to ensure that the scope was close enough to the source of obstruction to ensure reproducible fogging of the lens, while far enough away that the lens would not come into direct contact with the source of the fogging. When testing the device, another variation of this experiment was performed. With the scope and device ~7 cm from the trocar at 0°, the gas flow was turned off, the scope was allowed to fog, and the gas was turned back on. This was performed in both the humidity box and the porcine model. The purpose of this variation was to show that the device was able to clear existing obstruction as well as prevent it.

## RESULTS

In each of the trials conducted, as summarized in **Table 1**, the device prevented the fogging of the laparoscope’s lens. The control trials established that each of the adverse conditions produced fogging on a bare laparoscope. Additionally, in every trial in which the gas flow to the device was removed until the lens fogged and then reinstated,





**Figure 4.** The image obstructed by fogging of the laparoscopic lens (A, B). The corresponding picture using the device (C, D). Arrows and circles point out areas of interest for comparison. Note the staple in C that is not visible in A.

the device produced complete resolution of lens fogging. The device was tested in 7 different adverse conditions, for a total of 25 trials (including the removal and replacement of gas flow). In all 25 trials, the device was able to prevent and/or remove fogging of the lens of a laparoscope. Refer to **Figure 4, A–D**, to compare the effects of the device on fogging and visual clarity, as observed by the experimenters.

## **DISCUSSION**

This project discusses a potential solution to laparoscopic lens fogging and sought to answer the following question: Can a mechanical device using the flow of CO<sub>2</sub> eliminate laparoscopic lens fogging? The preliminary data obtained in this study suggest that the device built for this project would successfully support a clear

**Table 1.**  
Experimental Outcomes: Humidity Box and Porcine Model

Environmental Condition	Trials, n	Fogging of Bare Scope <sup>a</sup>	Obstruction of View (Bare) <sup>a</sup>	Fogging of Scope in Device	Obstruction of View (Device)
Container (80°F–90°F)	13				
Just inside humidified container	5	+	+	–	–
Flush with trocar (100% humidity), 0°	3	+	+	–	–
5–7 cm from trocar (100% humidity), 0°	3	+	+	–	–
5–7 cm from trocar (100% humidity), 45°	2	+	+	–	–
Porcine model (~100°F)	8				
Just inside porcine model	3	+	+	–	–
Within 7 cm of small intestine	2	+	+	–	–
Within 7 cm of intestine (cauterization)	3	+	+	–	–

<sup>a</sup>+ indicates the presence of the described parameter, and–indicates the absence of the described parameter.

viewing field during the entirety of a laparoscopic procedure. It is hypothesized that the device prevented fogging by directing the flow of CO<sub>2</sub> around the lens to isolate the lens from the humid environment, acting much in the way a defogger in a car acts. While Minimally Invasive Devices Incorporated has successfully developed a product using a similar mechanism, the described project serves to strengthen the foundation of the use of CO<sub>2</sub> flow to eliminate laparoscopic lens fogging and further points to a permanent solution to laparoscopic lens fogging.

Weaknesses of this study include a limited number of trials and the lack of a sophisticated measurement of lens clarity beyond images that illustrate the difference. Additionally, the humidity box was not a precise representation of the intraperitoneal cavity. The described humidity box experiments were not meant to perfectly replicate real-life conditions, but were rather designed to show preliminary success using a device such as the one described before testing took place in a live model. The trials conducted showed reproducible results that were present in multiple different adverse conditions; however, a greater number of trials would only strengthen the outcomes described in this project. The next steps in this project would be to conduct a greater number of trials in live models, subject the scope and device to more hostile conditions such as blood splatter, and use a more precise measurement of the actual difference in clarity, possibly an infrared pyrometer in a similar manner to that of Hashimoto and Shouji,<sup>7</sup> or exploring changes in light transmission.

Finally, while this project used cool dry CO<sub>2</sub>, it is important to discuss the effects this would have on tissue. The intraperitoneal environment is characterized by low pressures, warmth, and moisture. Introducing gas that is cooler and dryer than the tissue containing it alters the temperature of the patient and the characteristics of the peritoneum, acting to damage cells through evaporation and desiccation.<sup>9</sup> Following studies that identified and brought this problem to light, efforts have been made to use warm humid gas as an insufflation medium to reduce the damage to tissue during laparoscopic surgery by maintaining insufflation CO<sub>2</sub> optimally at 36°C and 95% humidity.<sup>10</sup> Our study used dry cool CO<sub>2</sub> in an effort to isolate the lens of the laparoscope under the pretense that high humidity and temperature alterations are the root of lens fogging. Because of the adverse nature of dry gas, another avenue of exploration would be to supply our prototype with warm humidified CO<sub>2</sub> to identify whether the simple flow of the gas alone would achieve the same goals, regardless of its relative humidity or temperature.

## CONCLUSIONS

This project successfully demonstrated that a simple mechanical method could prevent laparoscopic lens fogging. This study provides a base for future investigation, development, and use of gas flow to preserve the clarity of a laparoscopic lens. Future experiments of the prevention of laparoscopic lens fogging will address the refinement of this equipment and mechanism.

**References:**

1. Lawrentschuk N, Fleshner NE, Bolton DM. Laparoscopic lens fogging: a review of etiology and methods to maintain a clear visual field. *J Endourol*. 2010;24(6):905–913.
2. Van Deurzen DF, Mannaerts GH, Jakimowicz JJ, Cuschieri A. Prevention of lens condensation in laparoscopic surgery by lens heating with a thermos flask. *Surg Endosc*. 2005;19(2):299–300.
3. Brown JA, Inocencio MD, Sundaram CP. Use of a warming bath to prevent lens fogging during laparoscopy. *J Endourol*. 2008;22(11):2413–2414.
4. Runia AJ, Zengerink JF, Mannaerts GH. Easy cleaning of the scope's lens in a syringe to prevent condensation during laparoscopic surgery. *Surg Endosc*. 2009;23(12):2849–2850.
5. Ohdaira T, Nagai H, Kayano S, Kazuhito H. Antifogging effects of a socket-type device with the superhydrophilic, titanium dioxide-coated glass for the laparoscope. *Surg Endosc*. 2007;21(2):333–338.
6. Mohammadhosseini B. Povidone-iodine surgical scrub solution prevents fogging of the scope's lens during laparoscopic surgery. *Surg Endosc*. 2010;24(6):1498–1499; author reply 1500.
7. Hashimoto D, Shouji M. Development of a fogless scope and its analysis using infrared radiation pyrometer. *Surg Endosc*. 1997;11(8):805–808.
8. Minimally Invasive Devices, LLC. FloShield. <http://www.floshield.com/index.htm>. Accessed February 18, 2012.
9. Ott DE. The pneumoperitoneum. In: Wetter PA, ed. *Prevention and Management of Laparoendoscopic Surgical Complications*. 3rd ed. (PM3) [Medical textbook]. [http://laparoscopy.blogs.com/prevention\\_management\\_3/2010/11/the-pneumoperitoneum.html](http://laparoscopy.blogs.com/prevention_management_3/2010/11/the-pneumoperitoneum.html). Accessed April 25, 2013.
10. Ott DE. Desertification of the peritoneum by thin-film evaporation during laparoscopy. *JLS*. 2003;7(3):189–195.