

# Laparoscopic Device for Direct and Indirect Suction

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## 1 Background

In current practice, surgeons use suction and irrigation to clear the field of view during procedures. Devices designed for suction often employ a strong negative pressure (vacuum). This negative pressure may result in tissue damage and/or occlusion of the device lumen [1]. This occlusion significantly compromises the ability to suction, creating inefficiencies and delays in the surgical procedure. To prevent this problem, some surgeons will place a sponge on the target area before applying suction, thereby reducing the negative pressure to which tissue is exposed. In laparoscopic surgery, sponges are inserted through laparoscopic-size incisions or ports and then tracked to ensure eventual removal. This process may be time consuming and may make control of hemorrhage more difficult [2]. This paper describes the design and development of a laparoscopic device that combines suction and irrigation with a novel sponge suction technique to provide a surgeon with a safe and efficient means to maintain a clear field of view.

## 2 Methods

Interviews were conducted with surgeons to identify common challenges and design requirements in laparoscopic surgery. The physicians interviewed expressed the importance of maintaining a clear field of view and the inefficiency of removing fluid using sponges and suction devices. As surgeons attempt to minimize incision size in laparoscopic surgery, the segment of the device entering the surgical field was limited to a diameter of 10 mm.

The device described here consists of a 254-mm-long clear cylindrical tube (to allow visibility of suctioned content) connected to a control handle. The tube is divided into two lumens by a stopper. The outer surface of the cylinder is etched with four channels which traverse the stopper section and have a proximal and distal hole entering the lumen at either end. A heat-shrink coating is applied on top to form a four-channel bypass system.

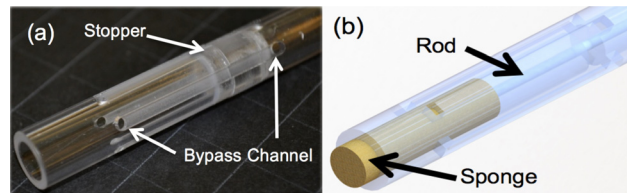


Fig. 1 (a) Distal end showing bypass channels and (b) computer-aided design (CAD) model with sponge

A sponge, attached to the end of a rod and inserted from the distal end of the cylinder to the control handle, is movable between two positions via a trigger mechanism. The stopper is designed with a central hole to allow for movement of this rod. In one position, the rod positions the sponge between the stopper and the distal hole exposing the distal holes of the bypass channels to the atmosphere or the surgical field. This position allows for direct suction into the bypass channel similar to other suction devices without a sponge. In the other position, the distal tip of the sponge is moved toward the distal end of the cylinder and may even overlap the distal end of the cylinder by a few millimeters. In this position, the proximal end of the sponge lies over the distal holes of the bypass channels allowing for suction through the sponge—indirect suction. Fluid removal via indirect suction is achieved by allowing the distal end of the sponge to constantly absorb fluid while suction is applied at the proximal end of the sponge. This method decreases the strength of the negative pressure and thus helps protect tissue from injury.

The cylinder inserts into a screw cap on the control handle and has tubing connecting the cylinder to a Y-valve. The other end of the control handle is designed to receive both a suction tube and an irrigation tube. A centrally located Y-valve is used to connect the three tubes. This allows for multiple settings. In the suction setting, fluid is suctioned into the cylinder and flows through the Y-valve towards the disposal source. In the irrigation setting, fluid flows from a fluid source into the irrigation tube and through the cylinder into the surgical field. The Y-valve has an external valve designed with an arrow to guide the user to the desired setting (Figure 2).

The control handle features an ergonomic trigger along the bottom of the design to allow the user to control the movement of the sponge with a finger. Movement of the sponge is constrained to 20 mm to prevent overextension and potential damage to tissue.

The absorbent material used for the sponge must not only block tissue from occluding the device but must also allow liquid to flow through it at a comparable rate to current suction devices. Darcy's (discharge) velocity dictates that a material with high permeability will increase the speed of fluid flow through the

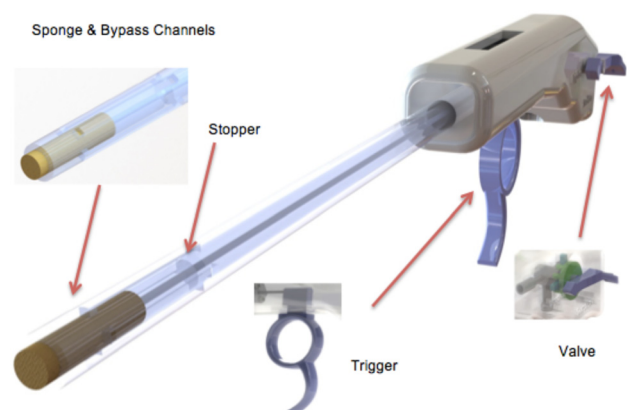


Fig. 2 Prototype CAD model. The trigger on the handle is used to toggle between direct and indirect suction.

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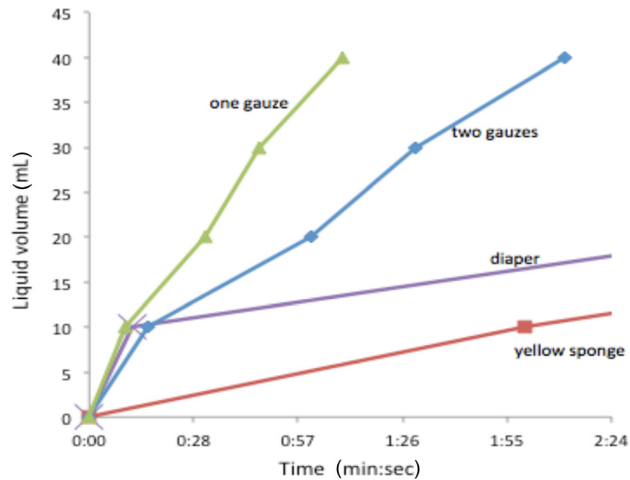


Fig. 3 Comparison of absorbent material flow rate

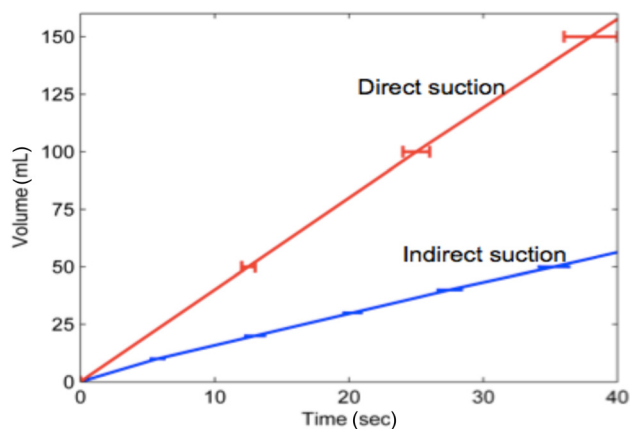


Fig. 4 Flow rate using direct and indirect suction

material, as will a short distance of material for the fluid to pass through [3]. Following this, the design would optimally use a very thin segment of highly permeable material.

To determine the best absorbent material, flow rate was tested using yellow sponge, diaper sponge, and medical-grade gauze. Figure 3 shows the change of volume of the fluid against time.

While diapers and yellow sponges are very absorbent, these materials do not transmit fluid well. Based on experimental data, a single surgical sponge was selected for the final prototype.

### 3 Results

Several tests were conducted to measure the device's performance at different settings. Fluid flow rate tests (Figure 4) showed that the prototype was able to suction effectively using either direct or indirect suction. As expected, the rate of flow was lower for indirect suction. Of note, modifications to the sponge or bypass channel(s) may affect the rates of direct and indirect suction.

Tests were also performed to evaluate the effect of direct and indirect suction on delicate tissues. In this test, gelatinous material

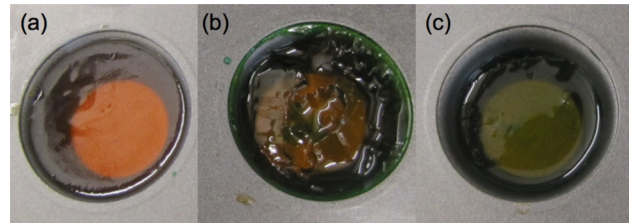


Fig. 5 (a) control, (b) direct suction, and (c) indirect suction

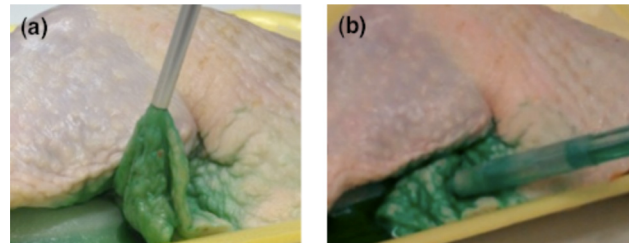


Fig. 6 (a) direct suction and (b) indirect suction

was used as an analog to a delicate tissue and fluid to be suctioned was poured over its surface. When direct suction was applied to the fluid, the gelatinous surface was inadvertently damaged (Figure 5(b)); however, with indirect suction the gelatinous surface maintained its integrity (Figure 5(c)). This experiment highlighted the benefit of indirect suction for removing fluid from delicate tissues.

An experiment on chicken tissue coated with green dye was conducted to evaluate safety and efficiency. Figure 6 shows the tissue adherence and potential tissue damage associated with direct suctioning (a) in comparison to the non-adherent and efficient suctioning with indirect suction (b).

### 4 Interpretation

The present design combines direct and indirect suction with irrigation. The testing conducted demonstrates infrequent lumen occlusion rate and fast removal of blood analogues. Upon further testing, the device may prove to be more efficient and safer to surrounding tissues than current medical devices.

Future development, such as the addition of a cautery tool, may make this device more multi-functional. This could further reduce operation time by preventing the need to remove and re-insert multiple devices through the ports. In addition, adding a safety mechanism may ensure that irrigation does not occur while the sponge is in the indirect suction position.

### References

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