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Laparoscopic Simulation Device for Testing and Training

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1 Background

Laparoscopy, a form of minimally invasive surgery focusing on the abdominal area, has become a common choice for surgeons due to its benefits of decreased recovery time and post-operative pain, which results in much lower costs for the patients. Currently, testing new tools in a surgical-like setting requires an animal cadaver, which can be both expensive and difficult to store, or an expensive device.

This paper describes the development of a bench-top laparoscopy simulator that mechanically simulates access ports using outer ‘tissue’ samples for port insertion and an inner cavity region where ex-vivo organs can be placed and operated on using laparoscopic tools.

2 Methods

During the first design iteration, the focus was on geometric accuracy, accuracy of the surgical simulation, and reusability. Geometrical accuracy concerned the layout of the base, and an acrylic rectangular base with a trapezoidal top (to simulate the inflated abdomen) was deemed the best compromise between realism and ease of manufacture. Accurate surgical simulation encompassed three main functional requirements: realistic port placement, realistic tissue samples, and a realistic viewing field.

For the first, as a general rule in laparoscopy, there are three to four trocars: one in the middle, where the camera is inserted, and the others in an arc about a hands-width apart, all three generally 18cm from the object of interest [1]. As only the upper half of the abdomen is most often used, five holes for potential trocar placement were placed around the top edge of the base.

The ‘tissue’ samples used for the first design iteration were ¼” silicone rubber, due to its elasticity and basic similarity to the peritonium, though even in this first design meat samples could also be substituted. When trying to simulate the viewing field, various kinds of cameras were tested as a basic prototype including an adjustable waterproof USB camera.

Reusability consisted of two functional requirements: being able to keep the equipment and the environment clean, and being able to replaced used tissue samples.

Given the potential for animal products to be tested inside of it, the equipment had to be cleanable to prevent bacterial growth. To compensate for this, the device was designed to be machine- or hand-washable, since it is made almost entirely out of acrylic or ABS, with easy access by hand to all areas inside and with a vinyl cover and easily removable ports, so each section could be cleaned individually. The materials, in addition to a rubber seal around the door, also contributed to making the project splatter-proof, to keep workplaces clean while it was in use.

An entirely separate mechanism was designed for holding the tissue samples. It was composed of a base aligned with the surgical holes, and two side pieces with tacks to pierce the tissue and hold it in place, with the two sets of pieces held together with magnets.

3 Results

After successfully testing the device with various laparoscopic tools, it was realized it also has potential as a low-cost, portable supplemental training device. Its ability to hold biological material cleanly would allow surgeons to practice skills on accurate-feeling material, which current simulators do not enable, and the included camera allows a much better feel of the camera-work done during surgeries than the stationary webcams many current models suggest.

The device underwent review by five clinicians at Harvard Medical School. The resulting feedback indicated a desire for a more anatomically accurate base, a specific mechanism for holding the ex-vivo organs in place inside the device, an increase in the realism of the skin samples, and changing from five separate spots for tissue samples to instead having a single sheet that would spread over the entire structure with several holes in structure itself.

4 Interpretation

The device is currently being redesigned; it will consist of a separate top and bottom piece, with flexures holding them together, and three holes in the top piece for trocar placement. The same mechanism of tacks holding the tissue in place will likely be used, but with the attachment piece press-fit to the side, and not using magnets.

Other aspects that are currently in the process of being redesigned include adding a screen to the base itself that more accurately simulates those used during surgery, and designing a camera specifically created for this device.

References