Design of A Robotic Accessory for Abdominal Surgery

[1]Dr. Bhavani Rao Reddi, [2]Uttam Grandhi

[1]Associate professor of Surgery, Rangaraya Medical college, Kakinada, INDIA

[2] Mechanical Engineering Group, Birla Institute of Technology and Science , Pilani, INDIA

[1]rbhavanirao@gmail.com, [2]uttam.grandhi@gmail.com

INTRODUCTION

Though advances in Laparoscopy have emerged as instruments like In Vivo Laparoscopes and Articulating Laparoscopes [1]-[4] and Flexible Endoscopes [5], fully capable devices have not yet arrived. The research has led to reducing the number of ports and their sizes, but major part of the instruments are rigid. The long instruments and lack of 3D visual feedback becomes an inherent limitation of the devices used till date. A flexible Robotic accessory that can reach every crevice of abdominal cavity greatly increases the maneuverability. In this paper, we propose a novel design of a robotic accessory controlled by a gloved hand or a set of actuators for performing abdominal surgeries. Recent trend in human-robot interaction [6] has motivated us to implement effective interactivity in the model. Our ultimate aim is to reach a state of unsupervised robotic surgeries with little or no intervention. Also, in the paper we have proposed a novel concept of “Camera Pillar” to give 3D visual information onto the screen of surgeon’s goggles. Additional advantages and other challenges are also discussed.

MATERIALS AND METHODS

The string controlled instrument Fig 1. is made using stainless steel considering the issues of sterility and strength. A flexible rubber sheath which can reach the inside of abdominal cavity either through mouth or laparoscopic port transmits required cables and strings. It also transmits data cables for image transmission and power cable for diathermy and light source. The metallic tips of the device eliminate the need of an additional diathermy tip. The tips can be controlled by a glove like structure from outside the abdominal cavity, Fig 1(a). The device in relaxed mode opens up the instrument as shown Fig 1(b). The instrument can be modified so as to be controlled with actuators that are interfaced to a computer. Different programs can be written for a wide variety of surgeries. Images transmitted through data cables attached to the camera pillars Fig 2(a) and computer onto screens worn by surgeon like goggles gives him 3D view of interior of abdominal cavity.

FINER DETAILS

Considering current challenges and requirements of a surgeon in performing Laparoscopic surgeries, a robotic accessory with a 2-DOF wrist, three 5-DOF fingers with a scissors, a grasper and a forceps as an end effector is proposed.

- **Length:** 7 cm & **Diameter:** 10mm (Standard Laparoscopic Port)

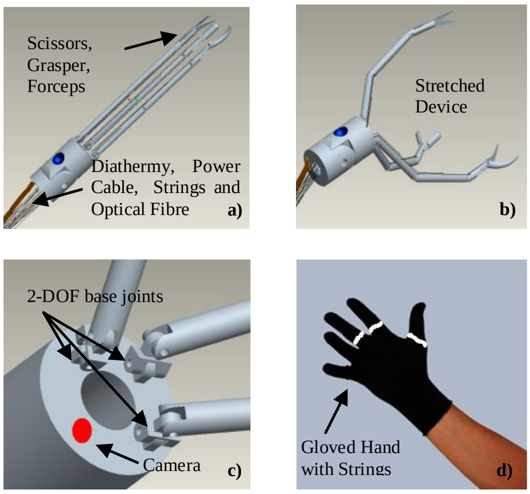

Fig 1. a) Collapsed Device b) Stretched Device c) Base Joints of Fingers and Camera d) Gloved Hand with Strings

- **Tendons:** Each finger joint is loaded with a spring and in default position is in flexed position. 5 tendons control each finger including the end-effectors (Scissors/ Grasper/ Forceps). Therefore, a total of 15 strings (tendons) for 3 fingers . Additional 2 tendons are required for wrist. The entire gadget needs a total of 17 tendons, one diathermy cable, one camera cable and an optical fibre .Steel Wires with sufficient strength and diameters 0.2mm-0.6mm are readily available [8]. The sheath of the device hosting the cables can be accommodated in a diamter of 9mm.
- **Actuation:** The aim is to replicate precise and smooth moments of each finger joint individually and in a well coordinated combined activity either by a Gloved Hand or with the help of a series of Actuators. The actuators are attached to a computer and are programmable to do different and complex surgeries.
- **Image Acquisition:** Image acquisition is done with the help of a, *Camera Pillar*. It is initially dropped into gas inflated abdominal cavity through the 10mm port made for inserting the robotic accessory. A Camera Pillar is a co-axial structure which houses light sources and cameras with inbuilt powerup the equipment. It has a diameter of 9 mm and length of 7.5 cm (in buckled up state). The inner shaft which slides on outer sheath can reach any length up to 14 cms in unbuckled state. The inner shaft has a core that transmits light vertically and cameras with dedicated light sources on its periphery near the

apex. Once placed vertically in the gas filled abdomen, the light pillar is unbuckled to desired length by pressing a lever close to its apex. Reduction in height can be done by simply pressing on its apex. Each pillar acts as tent support for anterior abdominal wall. Any number of Camera Pillars can be used. However, the use of two pillars is minimum requirement to obtain 3-D images.

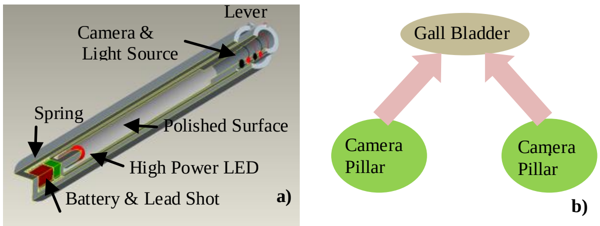

Fig 2. a) Camera Pillar b) Gall Bladder Visualization

Imagine the above scenario. The pillars are placed about 10cms away from point of interest e.g. Gallbladder . Each pillar is placed at a distance of about 7.5 cms (Normal eye position)

- **Data Transfer:** A needle containing data and power cables is punctured through the abdominal cavity into the core of the light pillar. It makes the camera and the light bulbs live. Once, the needle is inserted, it totally illuminates the abdominal cavity and image acquisition starts transmitting to the surgeon's goggles [7] as well as onto the computer monitor.

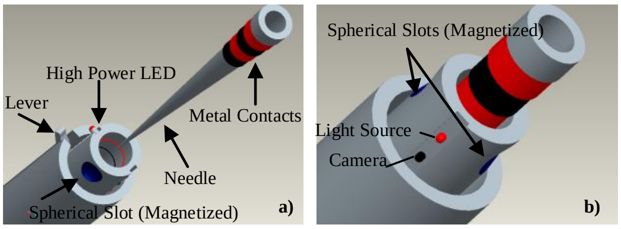

Fig 3. a) Camera Pillar b) Camera Pillar with Needle Inserted

- **Stabilizing the Device:** A uni-polar magnatized pit is provided on the wrist which immediately grasps the stabilizing rod when inserted. The rod is also made hollow (3mm pipe) to suck the secretions and blood that might hinder the operation. After the surgery, it is removed by applying opposite polarity to the rod tip. In the current scenario, of gloved hand model an assistant would be holding the stablizing rod.

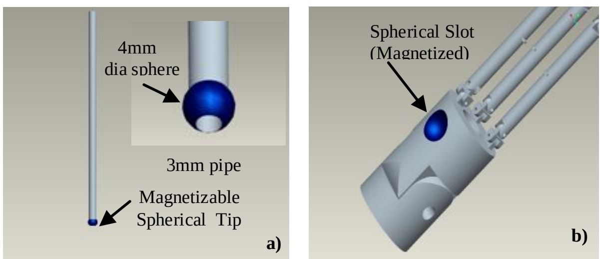

Fig 4. a) Stabilizing Rod (10 cm) b) Slot on device wrist

DISCUSSION

Since the entire program necessary for a given surgery is stored in a computer, the size of the robotic accessory need not be changed. If entire robot has to go to inside the abdomen, the size of the robot has to be bigger depending upon the complexity of the surgery. As the surgeon can manipulate the tip of the instrument through a computer interfaced actuator , he can perform surgery from a distance thus has an application in Tele surgery. With relative ease with which a surgeon can reach smaller anatomical structures, newer surgical modalities can be invented. The tip of the instrument can be modified to incorporate a scanning probe. This is useful for better imaging of liver, pancreas etc. With the possibility of choosing between a manual (Glove System) or an automatic (Actuator Control) , the surgeon can actually choose whether to program his surgery or to do it manually depending on the complexity of the surgery, requirement and interest of the surgeon.

ADVANTAGES

- It reaches remote areas like securing Hepatic vein in liver resection. The conventional lap instruments cannot reach it easily.
- A cholecystectomy or Appendicectomy needs 3 or 4 ports or a single port equivalent to the length of 4 ports in the conventional laparoscopy. With this laparoscopic accessory these surgeries can be performed with single port and two punctures and with ease.
- Surgeries like hemicolectomy can be done with less number of ports, greater ease and with less positional changes of the table.
- One great advantage is its extensibility. The strings can be attached to a pulsed motor which in turn connected to a computer. A real robotic surgery programs can be written and executed.Tele robotic surgery can be performed.
- The working space of the abdominal cavity is maintained without positive intra abdominal pressure. Avoiding positive intra abdominal pressure reduces adverse hemodynamic complications.

REFERENCES

[1] Mark E. Rentschler et al. "In vivo laparoscopic robotics", International Journal of Surgery (2006) 4, 167e171

[2] A. Röse, H.F. Schlaak, "A parallel kinematic mechanism for highly flexible laparoscopic instruments", Technische Universität Darmstadt, Institute of Electromechanical Design, Darmstadt, Germany

[3] Thomas Frede et al. "The Radius Surgical System", European Urology 51 (2007) 1015–1022

[4] Yasumitsu Hirano et al. "Single-incision laparoscopic Cholecystectomy", World J Gastroenterol 2010 January 14; 16(2): 270-274

[5] S. E. Amory, K. A. Forde, and J. L. Tsai, "A new flexible video endoscope for minimal access surgery", Springer Surg Endosc (1993) 7:200-202

[6] http://www.kz.tsukuba.ac.jp/~hoshino/mov/glove-hand.html#

[7] http://computer.howstuffworks.com/3d-pc-glasses1.htm

[8] http://www.alibaba.com/product-gs/277723377/Armouring_cable_wire.html