Minimally invasive surgery: challenges, opportunities and new directions by aniket.kaloti

The appeal of minimally invasive surgery

Minimally invasive surgery creates a small incision or hole to access the body cavity of interest. This approach, most often used in abdominal surgery, translates into minimal scarring as surgeons make several small incisions versus one large cavity opening. Taking the example of a cholecystectomy, an open procedure may use incisions five to eight centimeters in length, while minimally invasive laparoscopic procedures use three to four small incisions, generally no more than five millimeters in length. Benefits include reduced peri-operative pain, anxiety and other morbidities, shorter post-operative recovery time (metabolic recovery time increases with the volume of exposed cavity) and shorter hospital stays (up to 50% reduction in hospital stays for some procedures1). In addition to this quicker path to the ambulatory stage for patients, healthcare providers experience faster patient turn-over and improved efficiency of healthcare delivery leading to more procedures per year and higher revenues. In some cases, the length of surgery is shortened 10 to 20 percent, benefiting surgeons by decreasing the considerable physical stress associated with open surgical procedures. For payers, a shorter hospital stay and reduced post-operative visits yields better compliance with medical instructions and lower costs per patient.

Innovation in technology is at the heart of the new wave of minimally invasive surgery

Minimally invasive surgery is most appealing when it can substitute for open, highly invasive surgeries, e.g. cholecystectomy (removal of the gall bladder). Standard laparoscopic surgery is currently preformed through small incisions that allow camera and surgical instruments to enter the intestinal cavity. Internal organs are visualized using an endoscope equipped with a television camera. This innovation in technology allows the surgeons a detailed view of the internal organs without which it is impossible to perform complex surgical procedures. These techniques are well established for several complex abdominal surgeries.

Another innovative surgical technique is natural orifice surgery. In this technique, surgeries are performed by inserting specialized surgical tools through the mouth or other natural orifices. This technique is particularly suited for luminal procedures. Since this technique is incision-less, all incision-associated problems are averted. Importantly, surgeons observe reduced risk of wound infection and no external scarring. NeoGuide Systems (now part of Intuitive Surgical) and USGI Medical5 are recognized leaders in natural orifice surgical solutions. The USGI Medical platform technologies include a flexible operating platform called TransPort, through which endoscopes and endoscopic instruments can be inserted. TransPort can be shaped to reflect the shape of the intestine, which allows it great flexibility to operate through different natural orifices. Operation is supported with endoscopes, tissue graspers, suturing devices to perform the surgical procedure. Recent FDA clearance of TransPort products (510(k) approval is the typical regulatory path for many of these devices) suggests that the next wave of minimally invasive surgery will likely be in natural orifice surgery.

Robotic-assisted surgery, a cutting-edge surgical technique developed by Intuitive Surgical (da Vinci system3), uses robotic arms to perform laparoscopic procedures. The arms are external to the patient and control specialized surgical instruments inside the patient’s body, inserted through laparoscopic ports (simulating surgeon’s arms). The arms are controlled through a computer console by the surgeon. This is the most advanced operative system available commercially. However, its effectiveness vis-à-vis traditional manual laparoscopic procedures4 has been difficult to prove in randomized controlled trials. The expense of this system has also spurred innovation in presenting similar capabilities at a much-reduced cost.

New Directions

Laparoscopic surgery, natural orifice surgery and robot-assisted-surgery are the principle methods for minimally invasive surgery and numerous companies are working to improve these options through new technology, particularly robotics. An interesting aspect of the development of these techniques is that they are targeted at different procedures. While traditional laparoscopic techniques compete with open surgical procedures, the daVinci system is most often used for prostate surgeries. Natural orifice surgeries are most useful for intra-luminal procedures (colon resection is an example), while miniaturized robotic assisted surgical devices best target the extra-luminal and abdominal cavity procedures (appendectomy, cholecystectomy among other).

One company, Transenterix6, has developed the Spider Surgical System, a remarkably flexible platform that

facilitates laparoscopic surgery. Another company, Virtual Incision (founded partly by Prof. Shane Farritor7, MIT PhD), has been working on developing less expensive solutions for robot-assisted surgery. Both of these systems use robots that operate inside the patient's body. The robots are inserted through laparoscopic ports, as in other forms of robotic-assisted surgery. The surgeon then controls the movements of robots through manual motions that serve as control signals. The chief innovation for both of these companies is in developing precisely-controlled, miniature-sized robots. While the robots used in the well-established daVinci system are the size of a human arm, the robots used by Virtual Incision are the size of a pinky8. If these developments prove effective compared to traditional open field or simpler laparoscopic techniques, then other significant advantages in time, cost and side effects will lead to their rapid adoption across diverse medical practices, meaning that the operating room may look very different in the coming decades.

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1 http://www.innovations-report.com/html/reports/statistics/report-57145.html

2 http://www.springerlink.com/content/t13q1x7381568267/fulltext.html

3 http://www.intuitivesurgical.com/products/davinci_si_surgicalsystem/da-vinci-si-surgical-system-video.aspx

4 http://www.nytimes.com/2010/02/14/health/14robot.html

5 http://www.usgimedical.com/

6 http://www.transenterix.com/

7 http://engineering.unl.edu/academicunits/mechanicalengineering/faculty-staff/ShaneFarritor.shtml

8 Prof. Shane Farritor, personal communication