SMGroup

SM Journal of Minimally Invasive Surgery

Short Communication

A New Era of Minimally Invasive Surgery: A Review of Progress and Development of Major Technical Innovations in the Last Decade

Manjunath Siddaiah-Subramanya[1,2,3]*, Kor Woi Tiang[1,2,3] and Masimba Nyandowe[4]

[1]*Department of Surgery, Logan Hospital, Australia*
[2]*Department of medicine, Griffith University, Australia*
[3]*Department of medicine, University of Queensland, Australia*
[4]*Department of Surgery, Townsville Hospital, Australia*

Article Information

Received date: Jul 26, 2017
Accepted date: Jul 27, 2017
Published date: Jul 31, 2017

***Corresponding author**

Manjunath Siddaiah-Subramanya, Department of Surgery, Armstrong Road, Meadowbrook, Brisbane, Queensland 4131, Australia, Tel: +61 447719975; Email: manjunathbss9@yahoo.com

Keywords Laparoscopy Innovation; Minimally Invasive Surgery; Key hole Surgery; Natural Orifice transluminal endoscopic surgery (NOTES); Single-incision Laparoscopic surgery (SILS)

Abstract

Minimally Invasive Surgery (MIS) continues to play an important role in surgery as an alternative to traditional open surgery as well as traditional laparoscopic techniques. Since the 1980s, technological advancement and innovation has seen surgical techniques in MIS rapidly grow as it is viewed as more desirable. MIS, which includes Natural Orifice Transluminal Endoscopic Surgery (NOTES) and Single Incision Laparoscopic Surgery (SILS), is less invasive and has better cosmetic results. The technological growth and adoption of NOTES and SILS by clinicians in the last decade has however not been uniform. We review the differences in new developments and advancement in the different techniques in the last ten years. We also aim to explain these differences as well as the implications for the future.

Introduction

Healthcare innovation, including ones in the field of Minimally Invasive Surgery (MIS) can be defined as a dynamic and continuous process involving the introduction of a new technology or technique that initiates a change in practice [1]. There have been constant Innovations to improve MIS since its emergence in the early 80s, although the basic concepts have changed little. They include technological innovations in instruments used, such as laparoscopic instruments and sutures or the clinical approach and MIS-associated technology such as surgical robotics, image guidance systems, Natural Orifice Transluminal Endoscopic Surgery (NOTES) and Single Incision Laparoscopic Surgery (SILS).

Main Article

Generally, there are distinct patterns of growth, development and innovations in MIS since early 80s represented by the number of patent applications and literature publication, with each of these patterns containing technologies with unique characteristics [2]. The latest and the third growth phase were noted in late 2000s in relation to NOTES and SILS with its inception in mid 2000s, peaking soon thereafter. Although the popularity of NOTES plateau in late 2000, SILS has continued to receive interest. The reason for this plateau with NOTES is partly due to dwindling of innovation and interest in the technique, and partly due to profound difference between innovators and adopters. Conversely SILS may likely have a brighter future owing to easier access to technology and instrumentation, specialist to mainstream practice, and possibly with increasing popularity of robotics, which may complement SILS [2].

The second growth phase noted is with regards to surgical robotics and image guidance. Their growth shows gradual and exponential patterns starting in mid-1990s throughout 2000 and beyond [2]. The reason for this growth pattern is probably mutilfactorial. These technologies, in spite of numerous complex engineering challenges, have demonstrated continued development to keep up with the clinical demand. Continued development of robotic technology resulted in third generation surgical robots. These technologies also serve to expand the practice of MIS rather than just providing necessary tools for the MIS. This is evident in increased usage of robotics in various operations, sometimes even acting as a complementary technology for an existing method such as SILS. To complete, the first growth pattern was in relation to novel surgical instruments and sutures to complement MIS. This growth shows a peak in mid 1990s and then again in mid 2000s, the second peak corresponding to rise of robotic surgery, NOTES and SILS.

How to cite this article Siddaiah-Subramanya M, Tiang KW and Nyandowe M. A New Era of Minimally Invasive Surgery: A Review of Progress and Development of Major Technical Innovations in the Last Decade. SM Min Inv Surg. 2017; 1(1): 1002.

One of the biggest advances in MIS in the last decade is in the field of robotic surgery. Robotics was introduced for surgery in civilian hospitals in early 1990s, although it was initially used in the military environment performing surgeries in 1970s [3]. Robotics combined with computer science has been able to augment surgeon's skills to achieve greatly improved accuracy and precision in complex surgery. Ever improving technology in optics and computer science has introduced Virtual Reality (VR) and 3 Dimensional (3D) to operating rooms [4,5]. This allows for development of patient specific models enabling planning and practice of complex surgery on VR platform before performing the actual surgery. 3D virtual model improves mental representation of anatomical details, which could be underestimated with two-dimensional visualization platform that are more commonly used currently in operating suites.

Robotic surgery has evolved immensely since the initial operating room version Zeus®. Newer models of surgical robots, da Vinci®, feature compact mobile platforms, multiple operating arms, superior surgeon's console equipped with surgeon- piloted stereotactic 3D immersive and ergonomic handles intuitive to human hand movements providing improved dexterity. Other robotic platforms have been approved and are in various stages of development and introduction to surgical market. They claimed to produce small robotic platforms with better maneuverability, more user friendly in constricted spaces such as during thoracic and ENT operations, provide force feedback and eye tracking capabilities. Some of the examples are Amadeus Composer® from Canada and TELELAP Alf-X® from Italy [3].

The application of robotic surgery, potentially are much wider than just restricted to operating theatre where the robot is physically located. The current platform enables remote access enabling tele surgery, without the need for the surgeon to be present physically. One such event was a surgery performed in Strasbourg (France) by surgeons in New York (USA), which became a milestone in global tele surgery [6,7]. Furthermore robotic surgery experiments have been performed in a weightless environment [8-10]. Considering the current quality and speed of web-based transmission of signals, it would make remote surgery on any facility orbiting the earth, such as international space station, possible. Currently, it would require more advanced telecommunication for surgeries at a distance further from moon [11].

The role of robotic surgery compared to laparoscopic surgery is debatable, mainly due to high cost and equivocal surgical outcome. In spite of that robotic surgery remained appealing to healthcare organizations and surgeons with a passion for cutting-edge technology. Astronomical cost whilst a disadvantage, may change with improved platforms that are easier and quicker to set up, which improves further with experience, and lower cost with vanishing monopoly in production of surgical robots.

Robotic surgery in the in the peritoneal cavity has been investigated fairly extensively and the technology has proven to be of certain benefit in selected operations. Robots have been used in colorectal surgery for over 10 years [12]. A systematic review concluded reduced conversion rate to open in rectal surgery, but no difference was found in duration of surgery, morbidity and oncological outcomes in either rectal or colonic surgeries [13]. When it comes to upper gastrointestinal surgery, especially oncological surgeries, such as gastrectomy and esophagectomy, there is very little benefit in the usage of robots over laparoscopic surgery [14-16]. On the other hand some definite benefit has been shown in benign upper gastrointestinal surgeries where precision is of utmost importance, such as Heller Myotomy where it clearly reduces perforation rates [17]. In the field of bariatric surgery, robots aid in reducing the steep learning curve in Roux-En-Y Gastric Bypass (RYGBP) by making intracorporeal suturing easier and eliminates the use of staplers, potentially proving to be cost effective compared to laparoscopic RYGBP [18,19].

In hepatobiliary surgery, robotic surgeries have not demonstrated a clear superiority compared to laparoscopic surgery [20]. However, there is some evidence that it may be useful in achieving higher rates of radical R0 resection in pancreatic cancers [21]. Currently, there is a paucity of experience regarding liver resection to draw any major conclusions [22].

Another significant innovation in the last decade is NOTES, described by some as perhaps the most significant innovation in surgery since Phillipe Mouret of France performed the first laparoscopic cholecystectomy 1987 [23]. Despite so, it was Kalloo in 2004 that brought the technique into the spotlight [24]. It appears to be a stepwise progression from endoscopic mucosal resection before anyone had the courage to breach the muscular layer intentionally. This novel technique was a result of harmonious union between gastroenterologists and surgeons in America in early 2000. Since then a number of NOTES procedures have been performed using mainly stomach, rectum and vagina as the portal of entry to peritoneal cavity. NOTES was also the first 'scarless', surgical technique introduced to the public and their perception, initially at least, was in favour of this technique [25].

There are a number of barriers to NOTES. Some of them include difficulty in closure of enterotomy, anastomotic techniques, spatial orientation, long learning curve, lack of triangulation of instruments, control of haemorrhage and prevention of transluminal spread of infection. At the same time there are advantages associated with NOTES. They include no scars, less external pain, lower cost, an alternative to laparoscopic procedure in patient not suitable for laparoscopy and it even could act as a complementary technology to laparoscopic surgery and avoid major resections.

Unfortunately, over the last decade NOTES encountered more problems than solutions that the industries are still trying to correct. Therefore it has hit a plateau in its popularity and usage [2]. Comparable results were noticed in the first non-randomized trial to be published comparing diagnostic laparoscopy and transgastric peritoneoscopy after careful selection of patients [26]. This study demonstrated that usefulness of NOTES while testing its specific aspects but does not improve the safety of NOTES in general.

While closure of enterotomy remains a huge issue, access and triangulation are fundamental to the success of MIS. Some surgeons have endeavored to address these issues. Combining laparoscopy with NOTES has been suggested and trialed in an effort to improve insufflations, orientation, and retraction, instrument navigation and solid organ manipulation [27]. Another novel technique- dual access NOTES has been proposed and tested to improved handling, orientation and maneuverability (eg: Rectal and gastric) [28,29]. However, dual access doubles the risk of contamination, infection and luminal closure difficulties. Various companies engineered different devices address problems associated with closure of enterostomy. They range from simple endoclips used to close enterotomies as large as 4 cms to purse string applicators used to close gastric incisions and g-prox® tissue grasper [30-32]. Some have only been used in animal models.

Further developments in Virtual reality, stereoscopic 3D cameras and Augmented Reality (AR) camera are some to mention. Conventional cameras are two-dimensional and lack depth perception. Although the present da Vinci robotic camera has 3D visualization, extending that technology to laparoscopic camera could revolutionize laparoscopic surgery. Some research groups have reported developing AR visualization for laparoscopic cameras, fusing pre-operative CT scan images with intraoperative tomographic images [33,34]. These pre-operative images are registered in a rigid manner, which are then superimposed on the available intraoperative images from the laparoscopic camera. However, the surgeon constantly manipulates the tissues and organs in reality, making the above-mentioned model less useful. Upcoming technologies claim that they could reconstruct pre-operative images in real time according to patient's body shape [35].

Another technology worth mentioning is Laparoscopic Ultrasound (LUS), which is two-dimensional with the images displayed along a separate monitor forcing the surgeons to take their eyes off the organ or laparoscopic screen. With the combination of LUS and AR technology in a stereoscopic 3D camera one can view the organ that is subjected to ultrasound and its abnormalities in real time directly on the organ itself and make surgical decisions for accurate dissection with precise movements, so that resection margins are kept to minimum but sufficient and safeguarding the surrounding structures that may not be visible in 2D view [36].

Conclusion

Our future consists of exciting, new emerging technologies, which may make MIS even more efficient, exciting and safe. The possibility is limitless and we await more innovations to enable more sensible applications of different surgical techniques and instruments.

References

1. Trajtenberg M. A Penny for Your Quotes - Patent Citations and the Value of Innovations. The Rand Journal of Economics. 1990; 21:172-187.
2. Hughes-Hallett A. Quantitative analysis of technological innovation in minimally invasive surgery. British Journal of Surgery. 2015;102:151-157.
3. Diana M, J. Marescaux. Robotic surgery. Br J Surg. 2015;102:15-28.
4. Nicolau S, Augmented reality in laparoscopic surgical oncology. Surgical Oncology-Oxford 2011; 20: 189-201.
5. D'Agostino J. Three-Dimensional Virtual Neck Exploration before Parathyroidectomy. New England Journal of Medicine 2012; 367:1072-1073.
6. Marescaux J.Transatlantic robot-assisted telesurgery (vol 413, pg 379, 2001). Nature. 2001; 414: 710-710.
7. Haidegger T, J. Sandor, Z. Benyo, Surgery in space: the future of robotic telesurgery. Surgical Endoscopy and Other Interventional Techniques. 2011; 25: 681-690.
8. Kirkpatrick A.W. Intraperitoneal Gas Insufflation Will Be Required for Laparoscopic Visualization in Space: A Comparison of Laparoscopic Techniques in Weightlessness. Journal of the American College of Surgeons. 2009; 209: 233-241.
9. Doarn C.R. Evaluation of Teleoperated Surgical Robots in an Enclosed Undersea Environment. Telemedicine Journal and E-Health. 2009;15: 325-335.
10. Lum M.J.H. Telesurgery Via Unmanned Aerial Vehicle (UAV) with a Field Deployable Surgical Robot. Medicine Meets Virtual Reality. 2007;15:313-315.
11. Rayman R. et al. Robotic telesurgery: a real-world comparison of ground- and satellite-based internet performance. International Journal of Medical Robotics and Computer Assisted Surgery. 2007; 3:111-116.
12. Delaney C.P. Comparison of robotically performed and traditional laparoscopic colorectal surgery. Diseases of the Colon & Rectum. 2003; 46:1633-1639.
13. Kanji A. Robotic-assisted colon and rectal surgery: a systematic review. International Journal of Medical Robotics and Computer Assisted Surgery. 2011; 7: 401-407.
14. Woo Y.Robotic Gastrectomy as an Oncologically Sound Alternative to Laparoscopic Resections for the Treatment of Early-Stage Gastric Cancers. Archives of Surgery. 2011;146:1086-1092.
15. Leroy J. Original Technique to Close the Transrectal Viscerotomy Access in a NOTES Transrectal and Transgastric Segmental Colectomy. Surgical Innovation. 2011;18:193-200.
16. Clark J. The role of robotic assisted laparoscopy for oesophagogastric oncological resection; an appraisal of the literature. Dis Esophagus. 2011; 24: 240-50.
17. Melvin WS. Computer-enhanced robotic telesurgery minimizes esophageal perforation during Heller myotomy. Surgery. 2005;138: 553-558.
18. Hagen ME. Reducing Cost of Surgery by Avoiding Complications: the Model of Robotic Roux-en-Y Gastric Bypass. Obesity Surgery. 2012; 22: 52-61.
19. Markar SR. Robotic vs. laparoscopic Roux-en-Y gastric bypass in morbidly obese patients: systematic review and pooled analysis. International Journal of Medical Robotics and Computer Assisted Surgery 2011; 7: 393-400.
20. Breitenstein S. Robotic-assisted versus laparoscopic cholecystectomy: outcome and cost analyses of a case-matched control study. Ann Surg. 2008; 247: 987-93.
21. Chen YG. A meta-analysis of robotic-assisted pancreatectomy versus laparoscopic and open pancreatectomy. Saudi Medical Journal. 2013; 34:1229-1236.
22. Giulianotti PC. Robotic liver surgery: Results for 70 resections. Surgery, 2011; 149: 29-39.
23. Al-Akash M, E. Boyle, WA Tanner. N.O.T.E.S.: the progression of a novel and emerging technique. Surg Oncol. 2009; 18: 95-103.
24. Kalloo AN. Flexible transgastric peritoneoscopy: a novel approach to diagnostic and therapeutic interventions in the peritoneal cavity. Gastrointestinal Endoscopy. 2004; 60: 114-117.
25. Varadarajulu S, A Tamhane, ER Drelichman. Patient perception of natural orifice transluminal endoscopic surgery as a technique for cholecystectomy. Gastrointestinal Endoscopy. 2008; 67: 854-860.
26. Hazey JW. Natural-orifice transgastric endoscopic peritoneoscopy in humans: Initial clinical trial. Surgical Endoscopy and Other Interventional Techniques. 2008; 22:16-20.
27. Shih SP. Hybrid minimally invasive surgery - a bridge between laparoscopic and translumenal surgery. Surgical Endoscopy and Other Interventional Techniques. 2007. 21:1450-1453.
28. Zornig C. Laparoscopic cholecystectomy without visible scar: combined transvaginal and transumbilical approach. Endoscopy. 2007; 39: 913-915.
29. Mintz Y. Dual-lumen natural orifice translumenal endoscopic surgery (NOTES): a new method for performing a safe anastomosis. Surgical Endoscopy and Other Interventional Techniques. 2008; 22: 348-351.
30. Katsarelias D. Endoloop application as an alternative method for gastrotomy closure in experimental transgastric surgery. Surgical Endoscopy and Other Interventional Techniques, 2007; 21: 862-1866.

31. Ryon M. Evaluating an optimal gastric closure method for transgastric surgery. Surgical Endoscopy and Other Interventional Techniques. 2007; 21: 677-680.

32. De la Mora JG. In vivo full-thickness endoluminal gastroplication using tissue anchors in a live pig model. Gastrointestinal Endoscopy. 2005; 61: 223-223.

33. Leven J. DaVinci canvas: A telerobotic surgical system with integrated, robot-assisted, laparoscopic ultrasound capability. Medical Image Computing and Computer-Assisted Intervention - Miccai 2005 Pt 1. 2005; 3749: 811-818.

34. Su LM. Augmented Reality During Robot-assisted Laparoscopic Partial Nephrectomy: Toward Real-Time 3D-CT to Stereoscopic Video Registration. Urology. 2009; 73: 896-900.

35. HostettlerA. Bulk modulus and volume variation measurement of the liver and the kidneys in vivo using abdominal kinetics during free breathing. Computer Methods and Programs in Biomedicine 2010; 100:149-157.

36. Kang X. Stereoscopic augmented reality for laparoscopic surgery. Surgical Endoscopy and Other Interventional Techniques. 2014; 28: 2227-2235.