ISSN: 2279 - 0594

Journal of Biomedical and Pharmaceutical Research
Available Online at www.jbpr.in
CODEN: - JBPRAU (Source: - American Chemical Society)
Volume 4, Issue 2, 2015, 71-78

Review Article

ROBOTIC SURGERY: A CRITICAL EVALUATION

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Received 19 March 2015; Accepted 15 April 2015

ABSTRACT

The recent introduction of surgical robotics into the operating room offers a significant break through in the way surgery is conducted. It combines technological and clinical breakthroughs in developing new robotic systems and surgical techniques to improve the quality and outcome of surgery. These breakthroughs are based on more than a decade of innovation in the field of robotics in both academia and industry. The scope of this review covers the fundamental concepts and approaches utilized in surgical robotics. A detailed review of seven FDA approved and commercially available systems is presented in terms of the clinical procedure conducted by each robot along with the associated problems and needs, as well as the system architecture. The capabilities and merits of surgical robots are then contrasted with the related field of computer assisted surgery. The revolutionary process involved with the introduction of surgical robotics system into the operating room is still in its infancy. The review article finishes with a discussion of the main difficulties facing robotic surgery and a prediction of future progress.

Keywords: Surgery, Robotics, technology, surgical robots.

INTRODUCTION:

Robotic surgery, or robot-assisted surgery, allows doctors to perform many types of complex procedures with more precision, flexibility and control than is possible with conventional techniques. Robotic surgery is usually associated with minimally invasive surgery — procedures performed through tiny incisions. It is also sometimes used in certain traditional open surgical procedures.[1]

Robotic Surgery(Figure 1)[1]

The technique has been rapidly adopted by hospitals in the United States and Europe for use in the treatment of a wide range of conditions.

The most widely used clinical robotic surgical system includes a camera arm and mechanical arms with surgical instruments attached to them. The surgeon controls the arms while seated at a computer console near the operating table. The console gives the surgeon a high-definition, magnified, 3-D view of the surgical site. The surgeon leads other team members who assist during the operation.[2]

Origins of Robotic Surgery:

The first documented use of a robot-assisted surgical procedure occurred in 1985 when the PUMA 560 robotic surgical arm was used in a delicate neurosurgical biopsy, a non-laparoscopic surgery. The robotic system allowed for a successful robotic surgery and the potential for greater precision when used in minimally invasive surgeries, such as laparoscopies which typically utilize flexible fiber optic cameras. The 1985 robotic surgery lead to the first laparoscopic procedure involving a robotic system, a cholecystectomy, in 1987. The following year the same PUMA system was used to perform a robotic surgery transurethral resection. In 1990 the AESOP system produced by Computer Motion became the first system approved by the Food and Drug Administration (FDA) for its endoscopic surgical procedure.[3]

In 2000, the da Vinci Surgery System broke new ground by becoming the first robotic surgery system approved by the FDA for general laparoscopic surgery.

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The da Vinci system has been approved by the FDA for use in both adult and pediatric robotic surgery procedures in the following areas:[4]

- Urological surgeries
- General laparoscopic surgeries
- General non-cardiovascular thoracosopic surgeries
- Thoracoscopically-assisted cardiotomy procedures

The da Vinci is intended to assist in the control of several endoscopic instruments, including rigid endoscopes, blunt and sharp dissectors, scissors, scalpels, and forceps. The system is cleared by the FDA to manipulate tissue by grasping, cutting, dissecting and suturing.[5]

DA_VINCI SURGICAL SYSTEM(Figure 2)[5]

The da Vinci system consists of three components: the vision system, the patient-side cart, and the surgeon console.

- The vision system includes the endoscope, the cameras, and other equipment to produce a 3D image of the operating field.
- The patient-side cart has three robotic arms and an optional fourth arm. One arm holds the endoscope, while the other arms hold interchangeable surgical instruments. The da Vinci system uses EndoWrist surgical instruments, which mimic the movements of the human hand and wrist.[6]
- The Surgeon Console In use, a surgeon sits at a console ("Surgeon's Console") several feet away from the operating table and manipulates the robot's surgical instruments. The robot has three hands attached to a free-standing cart. One arm holds a camera (endoscope) that has been passed into the patient through small openings. The surgeon operates the other two hands by inserting fingers into rings.[7]

The history of robotics in surgery:

PROBOT- a robot developed at Imperial College London was designed specifically to aid in the resection of prostatic tissue. The system is image guided, model based, with simulation and online video monitoring. The development and trial of the system have not only demonstrated the successful robotic imaging and resection of the prostate, but have also shown that soft tissue robotic surgery in general, can be successful.[8]

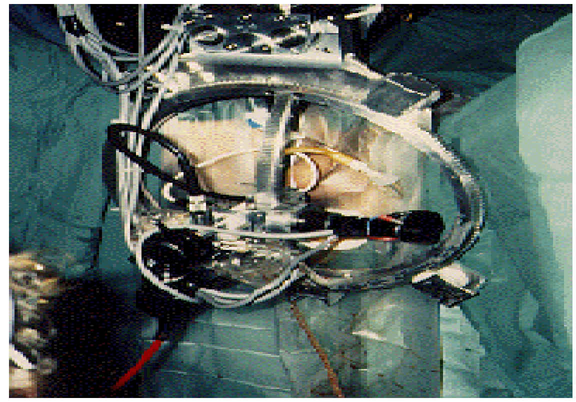

Figure 3:

In 1988, the PROBOT, developed at Imperial College London, was used to perform prostatic surgery.(Figure 3)[8]

THE ROBODOC- a robotic system, previously marketed by Integrated Surgical Systems (ISS), made medical history in 1992 as the first robot assisting in a human Total Hip Arthroplasty (THA). Since then, it has been used in over 24,000 surgical procedures around the world.
Designed to machine the femur with greater precision in hip replacement surgeries,[9] The ROBODOC® Surgical System has been cleared by the U.S. Food and Drug Administration (FDA) for Total Hip Arthroplasty proceudres; making it the only active robotic system cleared by the FDA for orthopaedic surgery.

Figure 4:

The ROBODOC from Integrated Surgical Systems was introduced in 1992 to mill out precise fittings in the femur for hip replacement.(Figure 4)[9]

The ORTHODOC® Preoperative Planning Workstation (ORTHODOC)- The ORTHODOC converts the CT scan of the patient's joint into a 3-dimensional bone image, which can be manipulated by the surgeon to view bone and joint characteristics. This enables the surgeon to use the ORTHODOC tool in a simulated surgery using CT scanned images of the patient's anatomy.[10]

A prosthetic image is selected from the ORTHODOC's extensive digital library. The surgeon is able to manipulate the three-dimensional model against the CT bone image, allowing for optimal prosthetic selection and accurate alignment.

This virtual surgery creates a precise preoperative plan customized for each patient.

In the case of a primary Total Hip Arthroplasty (THA) procedure, the surgeon plans the femoral cavity preparation on the ORTHODOC. The surgeon can determine the specific brand, size, type (anatomical or straight stem) of the femoral stem prosthesis and can precisely define the optimal fit and alignment of the femoral stem.[11] This precision is used in determining optimal anteversion,leg length, etc.

Orthopilot- The Orthopilot system is used to provide doctors with a way to accurately execute large joint replacement/corrective surgeries. The procedures vary depending on the type of surgery; however the general methodology of the surgery is as follows:

The surgeon fixes sensors to the part of the patient being operated on, and then moves the patient in specific natural motions so that the camera receives the data and uses it to form a model on the screen.[12] The representations on the monitor allow the surgeon to perform the surgery with greater accuracy, as the Orthopilot system will be able judge when the joint is properly aligned.

Orthopilot(Figure 5)[12]

Acrobot Precision Surgical Systems- Improving the speed, accuracy and reproducibility of joint replacement, ensuring maximum benefit for the surgeon and the patient Acrobot provides precision surgical systems for computer-assisted 3D planning, surgical navigation and surgeon-controlled robotic surgery.[13]

The overall goal of Acrobot's technologies is to provide:

- •Speed
- •Accuracy
- •Reproducibility

In order to enhance clinical outcomes, augment (but not replacing) surgeon skills, facilitate bone conservation and increase productivity.

When joint replacement components are implanted accurately and successfully, the patient's post-operative recovery time can be reduced and discomfort and complications can be minimised, which should then lead to improved quality of life for the patient.[14]

MAKO Surgical Corp- it is a medical device company based out of Fort Lauderdale, Florida that markets its advanced robotic solution and implants for minimally invasive orthopedic knee procedures.

MAKO's Tactile Guidance System ™ includes an interactive robotic arm platform that utilizes tactile-resistance and patient-specific visualization to prepare the knee joint for the insertion and alignment of resurfacing implants through a keyhole incision.[15] MAKO has an intellectual property portfolio of more than two hundred licensed or owned patent applications relating to the areas of computer assisted surgery, haptics, robotics, and implants.

CAE Endoscopy VR Surgical Simulator- Most accurate physiology, better haptics, most advanced bronchoscopy content.

Leading and up-and-coming medical brands use haptics to great advantage. Their products are winning awards, receiving acclaim, and delighting customers with extraordinary user experiences.[16]

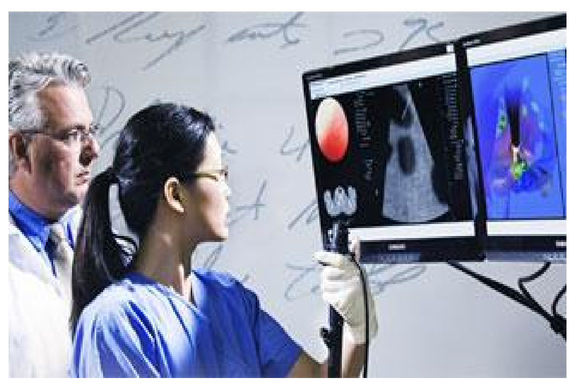

Figure 6:

The EndoscopyVR simulator is a surgical platform that supplies a realistic training environment for both gastrointestinal and bronchoscopy procedures.(Figure 6)[16]

The Endoscopy VR simulator is a surgical platform that supplies a realistic training environment for both gastrointestinal and bronchoscopy procedures. A modular approach to learning allows students to practice skills and gain confidence in a safe environment prior to advancing to more difficult procedures. The Endoscopy VR simulator offers superior force feedback sensation, physiological and anatomically correct simulation, extensive didactic aids, thorough metrics reports, vital signs and ability to administer drugs.[17]

Why the Procedure is Performed:

Robotic surgery is similar to laparoscopic surgery. It can be performed through smaller cuts than open surgery. The small, precise movements that are possible with this type of surgery give it some advantages over standard endoscopic techniques.

The surgeon can make small, precise movements using this method. [18] This can allow the surgeon to do a procedure through a small cut that once could be done only with open surgery.

Once the robotic arm is placed in the abdomen, it is easier for the surgeon to use the surgical tools than with laparoscopic surgery through an endoscope.

The surgeon can also see the area where the surgery is performed more easily. This method lets the surgeon move in a more comfortable way, as well.

Robotic surgery can take longer to perform.[19] This is due to the amount of time needed to set up the robot. Also, many hospitals may not have access to this method.

Robotic surgery may be used for a number of different procedures, including:

- Coronary artery bypass
- Cutting away cancer tissue from sensitive parts of the body such as blood vessels, nerves, or important body organs
- Gallbladder removal
- Hip replacement
- Hysterectomy
- Kidney removal
- Kidney transplant
- Mitral valve repair
- Pyeloplasty (surgery to correct ureteropelvic junction obstruction)
- Pyloroplasty
- Radical prostatectomy
- Tubal ligation[20]

Benefits:

The goal of using robots in medicine is to provide improved diagnostic abilities, a less invasive and more comfortable experience for the patient, and the ability to do smaller and more precise interventions. Robots are currently used not just for prostate surgery, but for hysterectomies, the removal of fibroids, joint replacements, open-heart surgery and kidney surgeries. They can be used along with MRIs to provide organ biopsies.[21] Since the physician can see images of the patient and control the robot through a computer, he/she does not need to be in the room, or even at the same location as the patient.

This means that a specialist can operate on a patient who is very far away without either of them having to travel. It can also provide a better work environment for the physician by reducing strain and fatigue.[22] Surgeries that last for hours can cause even the best surgeons to experience hand fatigue and tremors, whereas robots are much steadier and smoother.

Applications for Robotic Surgery:

Because robotic surgery is at the cutting edge of precision and miniaturization in the realm of surgery, the possible applications are as extensive as the uses of minimally invasive surgery. Robotic surgery has already become a successful option in neurological, urological, gynecological, cardiothoracic, and numerous general surgical procedures. Intuitive Surgical, makers of the da Vinci robotic surgery system, have released upgrades in the number of operating arms, eliminating the need for one surgical assistant, which may expand its clinical applications.[23]

Robotic surgery procedures performed in Europe, particularly those done by German surgeons, have advanced the field of robotic medicine greatly. Smith & Nephews, in conjunction with URS Orthopedic Systems, have created software to be used with robotic surgical systems such as da Vinci, and is exploring its orthopedic applications in hospital clinical tests throughout Germany.[24-26]

Considerations:

Along with improved patient care, another aim of making medical robotics mainstream is to cut down on medical costs. However, this is not always the case. Some robotic surgery systems cost more than $1 million to purchase and $100,000 a year or more to maintain.

This means that hospitals must evaluate the cost of the machine vs. the cost of traditional care. If robotic surgery cuts down on the trauma and healing time, there is money saved in terms of the number of days the patient stays in the hospital.[27,28] There is also a reduction in the amount of personnel needed in the operating room during surgery.

In contrast, extensive training time is required for physicians to learn to program and operate the machines. Another concern is that there are very few manufacturers of medical robotics. With very little competition, the few manufacturers that exist can set their own prices.[29]

Advantages:
Surgeons who use the robotic system find that for many procedures it enhances precision, flexibility and control during the operation and allows them to better see the site, compared with traditional techniques. Using robotic surgery, surgeons can perform delicate and complex procedures that may have been difficult or impossible with other methods.

Often, robotic surgery makes minimally invasive surgery possible. The benefits of minimally invasive surgery include:[30,31,32]

- Fewer complications, such as surgical site infection
- Less pain and blood loss
- Quicker recovery
- Smaller, less noticeable scars

Risks:
Robotic surgery involves risk, some of which may be similar to those of conventional open surgery, such as a small risk of infection and other complications.[31]

The Future of Robotic Surgery:
The future of robotic surgery is nearly as promising as the human will to invent better ways of accomplishing delicate medical procedures. It is reasonable to assume that the current advantages of robotic surgery systems will be expanded upon in the next generation of medical robotics. Removing human contact during surgery may be taken to the next level with robotic surgery systems capable of functioning at greater distances between surgeons control console and the patient side table robotics. This would allow robotic surgery to be conducted with patients in a nearby "clean room," reducing or eliminating intraoperative infection.[33] It is possible for next generation medical robotics and robotic surgery to conduct surgical prep work remotely as well.

Advancements in making robotic surgery systems more capable of replicating the tactile feel and sensation a surgeon experiences during more invasive traditional procedures would give the surgeon the best of both worlds. The surgeon would gain the precision and advantages of minimally invasive procedures without losing the sensory information helpful in making judgment calls during robotic surgery.[34]

Robot Assisted Gastric Surgery:
Intracorporeal techniques for digestive restoration seem to be the preferred solution for RAS, suitable in every type of patient, the technical precision of suturing is comparable to that of open surgery. Several Eastern authors have reported a technical shift from extracorporeal to intracorporeal anastomoses[35,36]. Probably, increased experience and confidence with RP has enabled surgeons to perform high-precision intracorporeal sutures and digestive anastomoses, especially after total gastrectomy.

Technical advantages of RAG (routine reproduction of D2-lymphadenectomy, possibility of enlarged resections and complex reconstructions) could get an important role for RAG, even in therapeutic strategy of AGC, integrating minimally invasive resection with neoadjuvant and adjuvant therapies.[37]

Laparoscopic Cholecystectomy:
A review by the noted Cochrane Group involving five studies and 453 patients showed no differences in any outcome measure when comparing robotic surgery to conventional laparoscopic surgery.[38]

Colorectal Surgery:
A review of 17 studies, one of which was randomized and controlled, showed no difference in the rates of complications and cancer outcomes. Robotic procedures took longer an cost more than conventional laparoscopic colon surgery.[39] Despite the results, the authors felt that "Robotic colorectal surgery is a promising field and may provide a powerful additional tool…"

Gynecologic Surgery:
A review of 22 non-randomized studies found that robotic surgery resulted in less blood loss [statistically significant but not clinically significant differences] and shorter hospital stays but no differences in overall complication rates when compared to conventional laparoscopic or open surgery.[40,41] The authors commented that the methods used in the papers reviewed were poor and better studies are needed before concluding that robotic surgery offered any true advantages.

Robotic Prostate Surgery:
Robotic prostate cancer surgery using the da Vinci system offers several advantages over the traditional laparoscopic surgical method of treating prostate cancer when objectively compared in the following areas:[42]

- Clinically Superior Results
- Reduced Risk of Complications
- Quicker Recovery Period
- Minimize Scarring

Miniature Robotics:
As scientists seek to improve the versatility and utility of robotics in surgery, some are attempting to miniaturize the robots. For example, the University of Nebraska

Medical Center has led a multi-campus effort to provide collaborative research on mini-robotics among surgeons, engineers and computer scientists.[43]

Warning:

Medical robotics is still a very new idea, and there is much more work to be done. It is still very expensive, which can make it prohibitive for many hospitals and health-care centers.

There are also still issues with latency. This refers to the time lapse between the moments when the physician moves the controls and when the robot responds.[44] Also, there is still a chance for human error if the physician incorrectly programs the robot prior to surgery. Computer programs cannot change course during surgery, whereas a human surgeon can make needed adjustments.

As surgeons become more familiar with using robots for surgery, and as more companies provide medical robots, there will come a day when robots are used in almost every hospital. However, this is still far off in the future.[45]

Is robotic surgery right for patients?

Robotic surgery isn't an option for everyone. Patients may talk with doctor about the benefits and risks of robotic surgery and how it compares with other techniques, such as other types of minimally invasive surgery and conventional open surgery.

Across the United States, the extent to which robotic surgery is used varies widely. Its use depends on a variety of factors.[46-48] These may include physician training, equipment availability and cultural factors, such as what people are most comfortable doing and what other surgeons in the area do. One study of U.S. hospitals showed that some institutions have a culture that prefers traditional open surgery, while others prefer minimally invasive surgery.

CONCLUSION:

Robot-assisted surgery is growing interest in surgical community, and it has been able to achieve satisfactory results in terms of perioperative outcomes and oncological adequacy, even in high technical complexity surgical procedures.

The technical advantages of robotic platform could have an important role to enlarge indications, feasibility, reproducibility and diffusion of complex minimally invasive surgery.

However, more studies will be necessary to evaluate oncological long-term results, and to define the better indications for advanced robot-assisted surgery.

References:

1. Eichel L, McDougall EM, Clayman RV. Fundamentals of laparoscopic and robotic urologic surgery. In: Wein AJ, ed. *Campbell-Walsh Urology*. 10th ed. Philadelphia, Pa: Saunders Elsevier; 2011:chap 9.
2. Fried GM. Emerging technology in surgery: Informatics, electronics, robotics. In: Townsend CM Jr, Beauchamp RD, Evers BM, Mattox KL, eds. *Sabiston Textbook of Surgery*. 19th ed. Philadelphia, Pa: Saunders Elsevier; 2012:chap 17.
3. Oleynikov D. Robotic surgery. *Surg Clin N Am*. 2008;88:1121-1130.
4. Hu JC, Gu X, Lipsitz SR, Barry MJ, D'Amico AV, Weinberg AC, et al. Comparative effectiveness of minimally invasive vs. open radical prostatectomy. *JAMA*. 2009;302(14):1557-1564.
5. Estey, EP (2009). "Robotic prostatectomy: The new standard of care or a marketing success?". *Canadian Urological Association Journal* 3 (6): 488–90.
6. O'Toole, M. D.; Bouazza-Marouf, K.; Kerr, D.; Gooroochurn, M.; Vloeberghs, M. (2009). "A methodology for design and appraisal of surgical robotic systems".*Robotica* 28 (2): 297–310.
7. Weinstein, G. S.; o'Malley, B. W.; Snyder, W.; Sherman, E.; Quon, H. (2007). "Transoral Robotic Surgery: Radical Tonsillectomy". *Archives of Otolaryngology–Head & Neck Surgery* 133 (12): 1220–1226.
8. Kolata, Gina (13 February 2010). "Results Unproven, Robotic Surgery Wins Converts". *The New York Times*. Retrieved 11 March 2010.
9. Finkelstein J; Eckersberger E; Sadri H; Taneja SS; Lepor H; Djavan B (2010). "Open Versus Laparoscopic Versus Robot-Assisted Laparoscopic Prostatectomy: The European and US Experience". *Reviews in Urology* 12 (1): 35–43.
10. Gerhardus, D (July–August 2003). "Robot-assisted surgery: the future is here".*Journal of Healthcare Management* 48 (4): 242–251.
11. Breeden, James T., MD, President of ACOG, [1] Statement on Robotic Surgery, March 14, 2013
12. Melvin, W. S.; Needleman, B. J.; Krause, K. R.; Ellison, E. C. (February 2003). "Robotic Resection of Pancreatic Neuroendocrine Tumor". *Journal of Laparoendoscopic & Advanced Surgical Techniques* 13 (1): 33–36.
13. Talamini, M. A.; Chapman, S.; Horgan, S.; Melvin, W. S. (October 2003). "A prospective analysis of 211 robotic-assisted surgical procedures". *Surgical Endoscopy* 17 (10): 1521–1524.
14. Melvin, W. Scott; Needleman, Bradley J.; Krause, Kevin R.; Schneider, Carol; Ellison, E. Christopher

(2002). "Computer-Enhanced vs. Standard Laparoscopic Antireflux Surgery". *Journal of Gastrointestinal Surgery* 6 (1): 11–15; discussion 15–6.
15. Melvin, W. S.; Dundon, J. M.; Talamini, M.; Horgan, S. (October 2005). "Computer-enhanced robotic telesurgery minimizes esophageal perforation during Heller myotomy". *Surgery* 138 (4): 553–558; discussion 558–9.
16. Shaligram A; Unnirevi J; Simorov A; Kothari VM; Oleynikov D (April 2012). "How does the robot affect outcomes? A retrospective review of open, laparoscopic, and robotic Heller myotomy for achalasia". *Surgical Endoscopy* 26 (4): 1047–50.
17. Liu, H; Lawrie, TA; Lu, D; Song, H; Wang, L; Shi, G (10 December 2014). "Robot-assisted surgery in gynaecology". *The Cochrane database of systematic reviews* 12: CD011422.
18. "Committee Opinion: Robotic Surgery in Gynecolgy". *Obstetrics and Gynecolgy*. March 2015.
19. "Robot-Assisted Surgery: Neurosurgery". Biomed. Brown. edu. Retrieved 25 June2013.
20. Giulianotti PC, Coratti A, Angelini M, Sbrana F, Cecconi S, Balestracci T. Robotics in general surgery: personal experience in a large community hospital. Arch Surg 2003 Jul;138(7):777-84.
21. Giulianotti PC, Angelini M, Coratti A. Technique de la gastrectomie subtotale robotique. Journal de Coelio-Chirurgie 2002 Sep;4355-60.
22. Hashizume M, Sugimachi K. Robot-assisted gastric surgery. Surg Clin North Am 2003 Dec;83(6):1429-44.
23. Song J, Oh SJ, Kang WH, Hyung WJ, Choi SH, Noh SH. Robot-assisted gastrectomy with lymph node dissection for gastric cancer: lessons learned from an initial 100 consecutive procedures. Ann Surg 2009 Jun;249(6):927-32.
24. Marano A, Hyung WJ. Robotic gastrectomy: the current state of the art. J Gastric Cancer 2012 Jun;12(2):63-72.
25. Baek SJ, Lee DW, Park SS, Kim SH. Current status of robot-assisted gastric surgery. World J Gastrointest Oncol 2011 Oct;3(10):137-43.
26. Xiong B, Ma L, Zhang C. Robotic versus laparoscopic gastrectomy for gastric cancer: a meta-analysis of short outcomes. Surg Oncol 2012 Dec;21(4):274-80.
27. Pernazza G, Gentile E, Felicioni L, Tumbiolo S, Giulianotti PC. Improved early survival after robotic gastrectomy in advanced gastric cancer. Surg Laparosc Endosc Percutan Tech 2006 Aug;16(4):286.
28. Pugliese R, Maggioni D, Sansonna F, Costanzi A, Ferrari GC, Di Lernia S. Subtotal gastrectomy with D2 dissection by minimally invasive surgery for distal adenocarcinoma of the stomach: results and 5-year survival. Surg Endosc 2010 Oct;24(10):2594-602.
29. Shimizu S, Uchiyama A, Mizumoto K, Morisaki T, Nakamura K, Shimura H. Laparoscopically assisted distal gastrectomy for early gastric cancer: is it superior to open surgery?. Surg Endosc 2000 Jan; 14 (1):27-31.
30. Ganpathi IS, So JB, Ho KY. Endoscopic ultrasonography for gastric cancer: does it influence treatment?. Surg Endosc 2006 Apr;20(4):559-62.
31. Kitano S, Shiraishi N. Minimally invasive surgery for gastric tumors. Surg Clin North Am 2005 Feb;85(1):151-64.
32. Kim MC, Heo GU, Jung GJ. Robotic gastrectomy for gastric cancer: surgical techniques and clinical merits. Surg Endosc 2010 Mar;24(3):610-5.
33. Kang BH, Xuan Y, Hur H, Ahn CW, Cho YK, Han SU. Comparison of surgical outcomes between robotic and laparoscopic gastrectomy for gastric cancer: the learning curve of robotic surgery. J Gastric Cancer 2012 Sep;12(3):156-63.
34. Hur H, Xuan Y, Ahn CW, Cho YK, Han SU. Trends and outcomes of minimally invasive surgery for gastric cancer: 750 consecutive cases in seven years at a single center. Am J Surg 2013 Jan;205(1):45-51.
35. Nguyen KT, Gamblin TC, Geller DA. World review of laparoscopic liver resection-2,804 patients. Ann Surg 2009 Nov;250(5):831-41.
36. Reddy SK, Tsung A, Geller DA. Laparoscopic liver resection. World J Surg 2011 Jul;35(7):1478-86.
37. Ho CM, Wakabayashi G, Nitta H, Ito N, Hasegawa Y. Systematic review of robotic liver resection. Surg Endosc 2013 Mar;27(3):732-9.
38. Ryska M, Fronek J, Rudis J, Jurenka B, Langer D, Pudil J. Manual and robotic laparoscopic liver resection. Two case-reviews. Rozhl Chir 2006 Oct;85(10):511-6.
39. Boggi U, Moretto C, Vistoli F, D'Imporzano S, Mosca F. Robotic suture of a large caval injury caused by endo-GIA stapler malfunction during laparoscopic wedge resection of liver segments VII and VIII en-bloc with the right hepatic vein. Minim Invasive Ther Allied Technol 2009 Jan;18(5):306-10.
40. Idrees K, Bartlett DL. Robotic liver surgery. Surg Clin North Am 2010 Aug;90(4):761-74.
41. Giulianotti PC, Sbrana F, Bianco FM, Elli EF, Shah G, Addeo P. Robot-assisted laparoscopic pancreatic surgery: single-surgeon experience. Surg Endosc 2010 Jul;24(7):1646-57.
42. Zhang J, Wu WM, You L, Zhao YP. Robotic versus open pancreatectomy: a systematic review and meta-analysis. Ann Surg Oncol 2013 Jun;20(6):1774-80.

43. Zeh HJ, Bartlett DL, Moser AJ. Robotic-assisted major pancreatic resection. Adv Surg 2011 Sep;45323-40.
44. Lai EC, Tang CN. Current status of robot-assisted laparoscopic pancreaticoduodenectomy and distal pancreatectomy: a comprehensive review. Asian J Endosc Surg 2013, Aug;6(3):158-64.
45. Hwang HK, Kang CM, Chung YE, Kim KA, Choi SH, Lee WJ. Robot-assisted spleen-preserving distal pancreatectomy: a single surgeon's experiences and proposal of clinical application. Surg Endosc 2013 Mar;27(3):774-81.
46. Jayne DG, Guillou PJ, Thorpe H, Quirke P, Copeland J, Smith AM. Randomized trial of laparoscopic-assisted resection of colorectal carcinoma: 3-year results of the UK MRC CLASICC Trial Group. J Clin Oncol 2007 Jul;25(21):3061-8.
47. Memon S, Heriot AG, Murphy DG, Bressel M, Lynch AC. Robotic versus laparoscopic proctectomy for rectal cancer: a meta-analysis. Ann Surg Oncol 2012 Jul;19(7):2095-101.
48. Yang Y, Wang F, Zhang P, Shi C, Zou Y, Qin H. Robot-assisted versus conventional laparoscopic surgery for colorectal disease, focusing on rectal cancer: a meta-analysis. Ann Surg Oncol 2012 Nov;19(12):3727-36.

