

\*Selected, quality filtered, not subject to external review

**Background:** Robotic surgery refers to the application of computer-assisted "robotic" technologies to enhance the surgeon's ability to carry out various surgical procedures, the most common being endoscopic procedures. Reported benefits of robotic surgery include faster, steadier and easier surgery, greater precision, and visual enhancement, all of which may translate into improved benefits to the patient.

A wide range of robotic devices exists for a variety of surgical tasks. The devices vary in the degree to which the robotic component performs a function independent of surgeon control. Those which are the most functionally independent of the surgeon's control have the greatest safety concerns. Since safety concerns are paramount, this report considers only robotic surgical devices that have received FDA approval. In this case, all devices have received FDA Class II 510(k) pre-market approval intended to be used in an operating room environment during selected minimally invasive endoscopic procedures by surgeons trained in minimally invasive surgery<sup>1,2,3,4,5,6</sup>. This FDA classification means that manufacturers have demonstrated substantial equivalence to devices already on the market, but have not been required to provide clinical trial data demonstrating effectiveness or cost-effectiveness.

Of particular interest to health care providers are telesurgical systems, also called master-slave telemanipulators (MST). In brief, the surgeon (master), situated at a control console, carries out his/her commands by controlling a robotic arm (slave), which is separated from the master by physical distance via a data cable (telemanipulation). Telesurgical systems available in the US are the da Vinci™ Surgical System (Intuitive Surgical, Inc. Mountain View, CA), the Zeus® Robotic Surgical System and the newer Zeus® Microwrist™ Surgical System (Computer Motion, Inc., Goleta, CA). As a note, on June 30, 2003 Intuitive Surgical, Inc. acquired Computer Motion, Inc.; Intuitive Surgical will continue to market Computer Motion's products<sup>7</sup>.

Devices such as endoscope holders, which are used to assist the surgeon in holding the endoscope during minimally invasive surgical procedures, and voice-control systems may serve as components of telesurgical systems. AESOP® Endoscope Positioner (Computer Motion, Inc., Goleta, CA) and EndoAssist (Armstrong Healthcare Ltd., High Wycombe, England) are available in the US. The Hermes® O.R. Control Center (Computer Motion, Inc., Goleta, CA), also available in the US, is a central voice-activated control center designed to work within integrated computer-assisted surgical systems, such as with the AESOP HR® models.

**Issue:** The VHA National Leadership Board Health Systems Committee, which advises the Under Secretary for Health on matters pertaining to VHA policy, planning and performance, requested information on robotic surgery in order to make recommendations on national policy for adopting this technology for use in VHA. Specifically, they asked whether this technology should be adopted on a piecemeal basis or on the basis of a national recommendation for the

<sup>1</sup> Hermes: <http://www.fda.gov/cdrh/pdf3/k031720.pdf>

<sup>2</sup> da Vinci: <http://www.fda.gov/cdrh/pdf2/k022574.pdf>

<sup>3</sup> Zeus: <http://www.fda.gov/cdrh/pdf/k003431.pdf>

<sup>4</sup> Zeus Microwrist: <http://www.fda.gov/cdrh/pdf2/k021152.pdf>

<sup>5</sup> Aesop: <http://www.fda.gov/cdrh/pdf/k960655.pdf>

<sup>6</sup> EndoAssist: <http://www.fda.gov/cdrh/pdf/k973249.pdf>

<sup>7</sup> [http://www.intuitivesurgical.com/news\\_room/press\\_releases/pr\\_063003.html](http://www.intuitivesurgical.com/news_room/press_releases/pr_063003.html)

whole system. VATAP was asked to provide a bibliographic list of completed health technology assessments and relevant literature on the subject.

**Methods:** In December 2003, VATAP queried INAHTA<sup>8</sup> via electronic mail for relevant completed or ongoing health technology assessments (HTA). In addition, VATAP searched the HTA database ([www.inahta.org](http://www.inahta.org)) for HTA reports (completed) and HTA projects (ongoing) using search terms for surgery, computer-assisted, and robotics.

These queries resulted in six completed HTAs and briefings on robotic surgery from INAHTA members and one from the University Healthsystem Consortium (UHC) (see Table 1). The scope of each assessment ranged from a particular telesurgical system e.g. the da Vinci™ system, to all telesurgical systems, to the full range of computer-assisted technologies used in surgery. Some assessments reported on the diffusion of the technology and solicited expert opinion within their healthcare system. Collectively, these reports cover information available on the subject through most of 2001.

VATAP supplemented these reviews with an updated search in December 2003 of studies reporting primary data published since 2001. VATAP searched for articles on robotic surgery in humans and all languages on MEDLINE<sup>®</sup>, Current Contents<sup>®</sup>, EMBASE<sup>®</sup>, BIOSIS<sup>®</sup> and The Cochrane Library<sup>®</sup>, databases for the years 2001 through 2003. Multiple strategies were employed to retrieve as broad a range of citations as possible given the variety of terms and indexing possibilities. Descriptors for robotics, telerobotics, telemanipulation, telepresence, remote control, and video assisted plus the various trade names for current products were combined with surgery and surgeon terms. VATAP employed various strategies using MeSH on MEDLINE<sup>®</sup> such as the subheading for surgery combined with the subheading for methods and then combined with the free text robotics words from above. Because the literature is sparse on this topic and had been lacking in randomized controlled trials or controlled studies, VATAP did not use a filter for study quality in order to retrieve all available literature. The search retrieved 465 unique references.

For the final bibliographic list, VATAP included only studies that met the following criteria:

- Studies reporting primary data and outcomes using FDA-approved robotic surgery technology;
- Published with abstract or full text in English;
- N ≥ 12 consecutive live, human subjects;
- High quality systematic reviews;
- The most recent or largest version of a study by the same investigators for the same purpose (to eliminate redundancy).

Meeting abstracts, studies of only visual-assisted devices, studies of cadavers and studies already covered in prior assessments were excluded. Fifty-nine citations met inclusion criteria. Since VATAP was asked to provide only a bibliographic list, no systematic appraisal of these articles was undertaken.

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<sup>8</sup> International Network of Agencies for Health Technology Assessment, [www.inahta.org](http://www.inahta.org)

### **Results:**

- Seven HTAs, including six from INAHTA members and one from UHC, published through early 2002 with full text or summaries in English (summarized in Table 1).
- Updated bibliographic list of 59 citations published since 2001, which includes 54 studies reporting primary data from case series, one systematic review of telemedicine systems applied to the surgical field, and four descriptive articles about subjects related to robotic surgery (eg. clinical privileging).

**Conclusions/Discussion:** Interest in robotic surgery, and in particular telesurgical robotics, is growing due to its potential to generate profit, to improve access to care, surgical procedures and patient outcomes, and to reduce the cost of care. These technologies are marketed with FDA 510(K) premarket approval for a fairly restricted array of indications.

Evidence from health technology assessments to date confirms that robotic surgery technologies are emerging technologies for which limited data from heterogeneous case series show them to be safe and feasible for a range of minimally invasive procedures. However, their clinical use is limited by: high initial investment and operating costs; substantial training requirements; and lack of strong evidence from well-designed clinical trials from which to determine effectiveness and cost-effectiveness relative to current practices.

It is also unclear how the introduction of these technologies will impact the overall design and work processes in the operating theater, or how the corporate merger of the two major telesurgical producers in the US will affect the cost and availability of their devices. Diffusion of the technologies is taking place primarily to fulfill research and education missions or to enhance prestige and profit, and likely will continue to increase as the technology evolves and both effectiveness and cost-effectiveness are demonstrated.

**Recommendations:** Available HTAs of surgical robotics uniformly agree that controlled diffusion of surgical robotics is warranted at this time to ensure patient safety. The reports recommend:

- Concentrating the use of this technology in specialized surgical centers with access to conventional surgical techniques, when needed. This would facilitate clinical research that requires both pre-approved methods and outcomes for outcome assessment, data collection and exchange, and training.
- Conducting clinical research to define appropriate indications for use and patient selection criteria, and to compare clinical risks and benefits of robotic surgery to current surgical practices.
- Monitoring the literature for evidence of effectiveness and cost-effectiveness as it becomes available.

### Completed Health Technology Assessments

Corbillon E, Poullié A, et al. Computer Assisted Surgery – Progress Report. Agence Nationale d'Accréditation et d'Évaluation en Santé (ANAES). May 2002. Full text in French. English summary.

Cummings JP. Technology Report: Surgical Robotics. University Healthsystem Consortium (UHC). February 2002

Da Vinci Surgical System. Alberta Heritage Foundation for Medical Research (AHFMR). Health Technology Assessment Publication. July 2000.

Heffner T, Hailey D. Computer-enhanced surgical systems ('robotic surgery'). Canadian Coordinating Office for Health Technology Assessment (CCOHTA) 2002 (Issues in Emerging Health Technologies Issue 29): 4.

Robotic Surgery Using Telemanipulators. Comité d'Évaluation et de Diffusion des Innovations Technologiques (CEDIT). CEDIT Recommendations. Reference 02.01/Re1/02. Date: 10/10/2002. Full text in French. English summary.

Robots for Use in Cardiac Surgery. Comité d'Évaluation et de Diffusion des Innovations Technologiques (CEDIT). CEDIT Recommendations. Reference 99.05. Date: 07/07/1999. Full text in French. English summary.

Surgical robots: Update. New and Emerging Technology Briefing. National Horizon Scanning Centre (NHSC). January 2002. (New and Emerging Technology Briefing): 11.

**Table 1. Completed Health Technology Assessments from INAHTA members and the University Healthsystem Consortium on Robotics Surgery**

(listed in descending order of publication date)

Organization	Topic/Citation	Scope of review	Results
UHC (USA) <a href="http://www.uhc.edu">www.uhc.edu</a>	Cummings JP. Technology Report: Surgical Robotics. University Healthsystem Consortium (UHC). February 2002	Surgical robotics	Proprietary.  Contact Joe Cummings ( <a href="mailto:cummings@uhc.edu">cummings@uhc.edu</a> ) or website for more information.
CCOHTA (Canada) <a href="http://www.ccohta.ca">www.ccohta.ca</a>	Computer-enhanced surgical systems ('robotic surgery'). Heffner T, Hailey D. Canadian Coordinating Office for Health Technology Assessment (CCOHTA) 2002 (Issues in Emerging Health Technologies) Issue 29):4.	Telesurgical systems	<ul style="list-style-type: none"> <li>• Computer-linked surgical systems allow surgeons to perform procedures without coming into contact with the patient. Indications for these robotic surgery systems are expanding.</li> <li>• This technology offers potential advantages through enabling more precise surgery, which may lead to shorter patient recovery times, fewer complications and improved patient outcomes.</li> <li>• Limited studies indicate the promise of these systems, which appear to be safe, but their efficacy is not fully established. In some procedures, the advantages they offer may also be achieved by newer non-computer assisted techniques.</li> <li>• Capital costs are high and cost-effectiveness has not been demonstrated.</li> <li>• Diffusion of these systems can be expected to continue, but their place in surgical practice is not yet clear. They are most likely to be of value for centres undertaking specialized surgical services.</li> </ul>
CEDIT (France)	Robotic Surgery Using Telemanipulators. CEDIT Recommendations. Reference 02.01/Re1/02. Date: 10/10/2002. Full text in French. English summary.  Robots for Use in Cardiac Surgery. CEDIT Recommendations. Reference 99.05. Date: 07/07/1999. Full text in French. English summary.	Telesurgical systems	<ul style="list-style-type: none"> <li>• Evidence shows techniques' feasibility for performing various cardiac and laparoscopic surgical procedures, but initial investment and operating costs are high.</li> <li>• Clinical utility is still unknown. Benefits of the procedure in terms of length of hospital stays, post-operative morbidity and economics, and the role of robotic surgery systems in health care, are undefined.</li> <li>• Expert opinion confirms that robotic systems are not yet appropriate for routine use. A phased-in introduction of the technology must be adopted that accounts for training of specialized surgical teams.</li> <li>• Randomized multicenter studies including hundreds of patients are needed to gauge the benefit of robotic surgery compared to conventional minimally invasive surgery; CEDIT recommends multisite evaluation of robotic surgery in AP-HP.</li> </ul>

Organization	Topic/Citation	Scope of review	Results
ANAES (France)	Corbillon E, Poullié A, et al. Computer Assisted Surgery – Progress Report. ANAES. May 2002.	Computer-assisted surgery	<ul style="list-style-type: none"> <li>• Clinical experience of robot-assisted surgery is too limited to judge its performance and patient safety.</li> <li>• Indications for use relative to length of hospital stay, post-operative morbidity, and proportion of patients likely to benefit are still unknown.</li> <li>• Clinical research should be encouraged.</li> <li>• ANAES will need to monitor scientific advances in relation to the technology so that a clinical and economic assessment can be made when the quality and quantity of data allow it</li> <li>• Centralizing the technology in specific centers of excellence was recommended to provide appropriate training, to encourage data exchange within the context of telesurgery, and to carry out clinical research.</li> </ul>
NHSC (United Kingdom)	Surgical robots: Update. New and Emerging Technology Briefing. NHSC. January 2002.	Surgical robots	<ul style="list-style-type: none"> <li>• Horizon scanning review included several robotic systems, including telesurgical systems.</li> <li>• Review briefly summarized the technology, regulatory status, indications for use, stage of diffusion, and state of research.</li> <li>• Published data for da Vinci consist of case series; no data reported for Zeus system</li> </ul>
AHFMR (Canada) <a href="http://www.ahfmr.ab.ca">www.ahfmr.ab.ca</a>	Da Vinci Surgical System. Health Technology Assessment Publication. AHFMR. July 2000.	Telesurgical system: da Vinci system	<ul style="list-style-type: none"> <li>• Horizon scanning review briefly describes the system, regulatory status, stage of diffusion and state of research</li> <li>• Preliminary feasibility data are available.</li> <li>• Introduction of the technology will need to consider capital and recurrent costs of the system, theater time, selection of patients and effects on health outcomes.</li> </ul>
AHFMR <a href="http://www.ahfmr.ab.ca">www.ahfmr.ab.ca</a>	Technology assessment of robotic surgery (presentation given by David Hailey)	Computer assisted surgery	Provides an overview of HTA in robotic surgery, including above assessments Contact David Hailey for more information <a href="mailto:dhailey@ozemail.com.au">dhailey@ozemail.com.au</a>

AP-HP, Assistance Publique-Hôpitaux de Paris



### Studies with primary data that met inclusion criteria

1. **Surgical robotics . Evaluation of the Computer Motion AESOP 3000 robotic endoscope holder.** *Health devices* 2002;31(7):256-68. *The use of robots to manipulate surgical instruments inside the patient has already moved from the world of fiction to fact. While the widespread use of full-function surgical robots is still many years away, less sophisticated robots that perform very specific surgical functions are already at a stage where the typical hospital can consider their use. Currently, the most affordable and commonly used type of " surgical -assist" robot is the robotic endoscope holder, which is used to hold and position rigid endoscopes during minimally invasive surgery . In this study, we introduce readers to the topic of surgical robotics , focusing specifically on robotic endoscope holders. The study includes a Technology Management Guide, in which we discuss who should and who shouldn't consider implementing such robots, and it includes our evaluation protocol and findings for one such robot, the Computer Motion AESOP 3000. We judged the evaluated system based on its performance relative to the human scope holders it is designed to replace, as well as its safety and ease of use. While we found the AESOP 3000 to be an acceptable, and sometimes preferred, alternative to the use of a human scope holder, we caution that many healthcare facilities won't see sufficient clinical benefit to warrant its purchase at this time.*

2. Ahlering Thomas, E, Skarecky, D, Lee, D, Clayman Ralph, V. **Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy.** *Journal of urology* 2003;170(5):1738-41. **PURPOSE:** For a skilled laparoscopic surgeon the learning curve for achieving proficiency with laparoscopic radical prostatectomy (LRP) is estimated at 40 to 60 cases. For the laparoscopically naive surgeon the curve is estimated at 80 to 100 cases. The development of a robotic interface might significantly shorten the LRP learning curve for an experienced open yet naive laparoscopic surgeon . To our knowledge we report the initial experience with robot assisted LRP of a surgeon without laparoscopic experience. **MATERIALS AND METHODS:** Following a 1-day da Vinci (Intuitive Surgical , Mountain View, California) robotic laparoscopic training course and 2 cadaveric robotic LRPs an experienced oncologist (TEA) without laparoscopic experience performed 45 robotic LRPs. **RESULTS:** All procedures were successfully completed laparoscopically with no rectal injuries or transfusions. The learning curve to 4-hour proficiency was 12 patients and mean operating time subsequently was 3.45 hours (range 2.5 to 5.1). Mean blood loss was 145 cc (range 25 to 350), the mean postoperative day 1 decrease in hemoglobin was 2.6 mg/dl (range 1.9% to 5.1) and mean hospital stay was 36 hours (range 18 to 168). Mean Gleason score was 6.8, mean prostate volume was 50.5 gm (range 12.5 to 163) and the margin positive rate was 35.5%. Four patients (8.8%) had a total of 6 complications, which were managed conservatively. Catheterization time was 7 days (range 7 to 42). Continence (0 pads) was 33% at 1 week, 63% at 1 month and 81% at 3 months. **CONCLUSIONS:** A laparoscopically naive yet experienced open surgeon

successfully transferred open surgical skills to a laparoscopic environment in 8 to 12 cases using a robotic interface. This outcome is comparable to the reported experience of skilled laparoscopic surgeons after more than 100 LRPs.

3. Aiono, S, Gilbert, JM, Soin, B, Finlay, PA, Gordan, A. **Controlled trial of the introduction of a robotic camera assistant (EndoAssist) for laparoscopic cholecystectomy.** *Surgical Endoscopy and Other Interventional Techniques* 2002;16:1267-1270. **Background:** The role of the human camera holder during laparoscopic surgery keeps valuable personnel from other duties. EndoAssist is a robotic camera-holding device controlled by the operator's head movements. This study assesses its introduction into clinical practice. **Method:** Ninety-three patients undergoing laparoscopic cholecystectomy were randomized to have either the robotic (40) or a human (46) assistant. Seven patients converted to open operation were excluded. Six surgeons were evaluated. Operating time and subjective assessments were recorded. Learning curves were constructed. **Results:** The mean operating time was less using the robotic assistant (66 min) than with human assistance (74 min) ( $p < 0.05$ , two-tailed t-test). The learning curves for operating time showed that within three operations surgeons were trained in using, the robot. The device was safe in use. **Conclusion:** The EndoAssist operating device is a significant asset in laparoscopic surgery and a suitable substitute for a human assistant. Surgeons became competent in the use of the robot within three operations. The robot offers stability and good control of the television image in laparoscopic surgery.

4. Antiphon, P, Hoznek, A, Benyoussef, A, de laille, A, et al. **Complete solo laparoscopic radical prostatectomy: initial experience.** *Urology* 2003;61(4):724-8; discussion 728-9. **OBJECTIVES:** To demonstrate the feasibility of "complete solo" (CS) laparoscopic radical prostatectomy (LRP) performed solely with robotic manipulation of the laparoscope and without any human assistant at all. A comparison was made between CS LRP and the standard technique to identify the advantages and drawbacks. **METHODS:** Sixteen consecutive patients undergoing CS LRP were compared with the last 16 patients undergoing standard LRP. The standard procedure was performed with five trocars and one human assistant. Therefore, the surgeon had three instruments immediately available and could switch quickly from one to another, while the assistant held the laparoscope and a retractor. The CS method used a voice-controlled robotic arm to manipulate the laparoscope and a mechanical arm for the assisting instrument. **RESULTS:** The mean operative time in the CS and standard groups was 324 and 347 minutes, respectively ( $P > 0.5$ ). An additional human assistant was required, for 1 hour, in 3 patients of each group. No significant difference was noted between the two groups in terms of catheterization time, hospital stay, positive margin rate, complications, short-term cancer control, or functional results. The CS method has been demonstrated to be highly cost-effective compared with the standard technique. **CONCLUSIONS:** The CS LRP is feasible and compares favorably with the standard technique. It offers unique advantages in terms of direct control of the operative view, standardization of the assistance, and higher stability of

the laparoscope, thus greatly enhancing the surgeon's comfort. The diminished need for human operative assistance provides significant economic and organizational benefits.

5. Argenziano, M. **Totally endoscopic, robotic cardiac surgery.** heart surgery forum **2003**;6(2):104. Columbia-Presbyterian is participating in all four FDA-sanctioned clinical trials of robotic cardiac surgery, and serves as the principal investigative site for two of the trials-robotic ASD repair and totally endoscopic CABG (TECAB). ATRIAL SEPTAL DEFECT (ASD) REPAIR: On July 24, 2001, the Columbia Presbyterian Robotic Cardiac Surgery team performed the first U.S. robotically-assisted atrial septal defect repair. This represented the first totally closed-chest open-heart operation in U.S. history. The patient was discharged home on the third postoperative day. For the 17 patients who have had robotic ASD repair so far at Columbia, the median postoperative stay has been three days, and all have experienced a rapid return to their normal lives. TECAB (TOTALLY ENDOSCOPIC CORONARY ARTERY BYPASS GRAFTING): The nation's first robotically-assisted, totally endoscopic coronary artery bypass surgery (TECAB) was performed at New York-Presbyterian's Columbia Presbyterian Medical Center on January 15, 2002. The patient experienced virtually no post-operative pain and returned to normal activities a week after surgery. During this historic operation, three tiny holes between the ribs permitted two robotic arms and an endoscope to access the heart. The procedure was performed as part of a multicenter clinical trial sanctioned by the Food and Drug Administration. This 10-center trial is the first in the nation of totally closed chest coronary bypass surgery. Dr. Argenziano is principal investigator of this national trial. Eligible patients include those requiring single vessel surgical revascularization, either with to single vessel coronary disease, or multivessel disease approachable by hybrid (stenting + CABG) techniques. To date, over 20 TECAB procedures have been completed in the trial. TOTALLY ENDOSCOPIC ATRIAL FIBRILLATION SURGERY: The Columbia team has performed over 150 operations for atrial fibrillation, with a success rate approaching 85% at one-year follow-up. The majority of these operations have been performed in conjunction with other cardiac operations (such as valve repair or coronary bypass), but the procedure has been used for atrial fibrillation as the sole indication. The Columbia team has performed several beating heart epicardial atrial fibrillation operations, and has also developed a totally endoscopic, beating heart version of this procedure. Within a few months, this minimally invasive operation will be available in the U.S. for atrial fibrillation as the sole indication.

6. Ballantyne Garth, H. **The pitfalls of laparoscopic surgery : challenges for robotics and telerobotic surgery.** Surgical laparoscopy, endoscopy & percutaneous techniques **2002**;12(1):1-5. After its debut in 1988, laparoscopic cholecystectomy rapidly became the standard of care for cholelithiasis, yet very few surgeons use minimally invasive techniques for other abdominal operations. Why do most surgeons continue to perform traditional open gastrointestinal operations? We believe that the answer to this question lies in the fact that advanced laparoscopic operations are difficult to learn, perform, and master. A number of inherent pitfalls of laparoscopy hinder the performance of these operations even after the surgeon has accumulated years of experience. These pitfalls include an unstable video camera

platform, limited motion (degrees of freedom) of straight laparoscopic instruments, two-dimensional imaging, and poor ergonomics for the surgeon. Inexperienced or bored laparoscopic camera-holders move the camera frequently and rotate it away from the horizon. The long, straight laparoscopic instruments are limited in their motion by the fixation enforced by the abdominal wall trocars. Similarly, the standard two-dimensional video imaging used in most laparoscopic operations impedes the surgeon's depth perception, compounding the limitations of laparoscopic instruments. In addition, surgeons are forced to assume ergonomically awkward stances in performing many laparoscopic operations. These four factors hinder a surgeon's efforts to learn and to perform advanced laparoscopic operations, significantly lengthening the learning curve. The articles presented in this issue suggest that robotics and telerobotics offer solutions to these nagging pitfalls of laparoscopic surgery.

7. Ballantyne Garth, H, Kelley William, E. **Granting clinical privileges for telerobotic surgery.** Surgical laparoscopy, endoscopy & percutaneous techniques **2002**;12(1):17-25. Surgeons can now perform operations on their patients while sitting at a remote site. During telerobotic operations, the surgeon sits at a computer console. The computer translates the motions of the surgeon's hands into motions of the robotic instruments. Introduction of telerobotics into clinical practice raises issues comparable to those generated by the rapid introduction of laparoscopic cholecystectomy in the late 1980s. As a result, we have instituted processes in our hospitals for the granting of clinical privileges for telerobotic surgery. These processes are derived from the guidelines of the Society of American Gastrointestinal Endoscopic Surgeons for granting clinical privileges for laparoscopic general surgery. Our hospitals require the following: (1) board certification or board eligibility for the appropriate surgical board; (2) clinical privileges for the open and laparoscopic operations that will be performed telerobotically; (3) satisfactory completion of the Food and Drug Administration-mandated training course in the safe use of the robotic surgical system; (4) performance of telerobotic operations in animate models; (5) observation of clinical cases of telerobotic surgery by an expert surgeon; (6) acting as bedside assistant surgeon in telerobotic operations or supervision by a preceptor during the surgeon's initial operations; (7) observation by a proctor of the surgeon's initial clinical telerobotic operations; and (8) ongoing monitoring of surgical outcomes of telerobotic operations. This process has facilitated the safe and orderly introduction of telerobotics operations into clinical practice in our hospitals.

8. Beninca, G, Garrone, C, Rebecchi, F, Giaccone, C, Morino, M. **[In Process Citation] Chirurgia laparoscopica robot-assistita. Risultati preliminari del nostro Centro.** Chirurgia italiana **2003**;55(3):321-31. The aim of our study was to evaluate the advantages and disadvantages of robot-assisted laparoscopic surgery, in terms of operative times, complications and length of hospital stay, using the Da Vinci Robotic Surgical System (Intuitive Surgical, Inc.). Twenty-five patients underwent robotic procedures. The indications were gastro-oesophageal reflux disease in 13 cases, achalasia in 2, cholelithiasis in 2, adrenal adenoma in Cushing syndrome in 6, pheochromocytoma in 2, and incidentaloma in 1. Robotic surgery was compared with the traditional laparoscopic approach. From January to September 2002 13 Nissen-



Rossetti funduplications, 2 Heller myotomies with Dor fundoplication, 2 cholecystectomies and 9 adrenalectomies (6 left adrenalectomies, 3 right adrenalectomies) were performed. There were no significant differences in age, preoperative body mass index (mean 28; range: 18-32) or sex between patients treated by robotic surgery and those treated by traditional laparoscopy. Operative times were significantly longer in the robotic surgery group (97.1 minutes, range: 77-126 minutes, versus 82.5 minutes, range: 65-100 minutes, for Nissen-Rossetti fundoplication; 132.8 minutes, range 104-181 minutes, versus 82.1 minutes, range 55-120 minutes, for adrenalectomy). There were no intraoperative complications. Conversion to traditional laparoscopy was necessary owing to technical difficulties in 4/9 adrenalectomies (44.4%; 3 left, 1 right). There was no significant difference in length of hospital stay (3.2 days, range 2-7 days, for Nissen-Rossetti fundoplication; 5.7 days, range 4-9 days, for adrenalectomy). Our study confirms the safety and feasibility of robot-assisted laparoscopic surgery. However, operative times were longer and costs higher, with no difference in outcomes. Given the current level of technology and experience, robotic surgery would not appear to afford any advantage over standard laparoscopic approaches.

9. Bantas, W, Wolfram, M, Jones, J, Brautigam, R, Kramer, W, Binder, J. **Robotic technology and the translation of open radical prostatectomy to laparoscopy: the early Frankfurt experience with robotic radical prostatectomy and one year follow-up.** *European urology* 2003;44(2):175-81. **OBJECTIVE:** Laparoscopic radical prostatectomy is a complex procedure and has been standardized only during the last years. The remote controlled da Vinci Surgical System has opened up a new era in minimally invasive surgery. We here present our initial experience with the translation of open retropubic radical prostatectomy to laparoscopic technique using da Vinci and a one year follow-up. **METHODS:** After a period of technical development and training on cadavers, 40 consecutive patients eligible for radical prostatectomy were treated. After port placement, the urologist took control of the 3D 30 degrees laparoscope and the two instrument arms at the da Vinci remote console to perform bilateral pelvic lymph node dissection, radical prostatovesiculectomy and urethrovesical anastomosis. **RESULTS:** The procedure was completed laparoscopically in all but two patients. Mean procedure time was 8.3 hours and mean intra-operative blood loss 570 ml. Learning curves associated with the use of the da Vinci Surgical System show that there is a 22-minute decrease in time required to perform the radical prostatectomy and lymphadenectomy for each case ( $p < 0.0001$ ). Patients recovered rapidly after surgery with early oncological and functional results that were similar to those obtained with our standard radical prostatectomy technique. **CONCLUSIONS:** Remote controlled robotic surgical systems are useful to translate open retropubic radical prostatectomy to laparoscopy. This new technology has the potential to equip the urologist with the microsurgical precision needed to preserve the delicate structural integrity of the pelvic floor in order to improve functional results without compromising the oncological outcome.

10. Bochenek, A, Cisowski, M. **Computer motion's AESOP(R) 3000 with voice control. An initial step in the evolution to closed-chest, beating heart bypass surgery?** *Kardiologia Polska* 2001;54(SUPPL. 1):181-183. *Computer Motion,*

*Inc., today announced the successful completion of more than 500 endoscopic internal mammary artery harvest procedures with robotic assistance. From April 1998 to September 2000, 140 patients have undergone a minimally invasive direct coronary artery bypass procedure in our institution. All patients underwent a video-assisted minimally invasive operation. In 50 patients AESOP(R) system was used. We performed these operations utilizing the Computer Motion AESOP(R) 3000 with Voice Control through a 5-mm surgical port in the patient's chest as part of a minimally invasive heart bypass surgery. The AESOP system is a surgeon voice-controlled robotic arm which actively positions an endoscope (a slender optical tube which is passed into the patient's body allowing the surgeon to view the operation on a video monitor) in minimally invasive heart surgeries. The AESOP robotic arm is the first United States Food and Drug Administration approved surgical robot. In a heart bypass surgery, the surgeon must harvest a conduit from the patient's body that can be used to redirect the blood flow around the blocked portion of the coronary artery. When the left anterior descending (LAD) artery, which is the principal artery for patient survival, is blocked, the internal mammary artery (IMA) is the preferred conduit for the bypass graft to ensure long-term survival. Surgeons are now routinely performing a minimal access coronary artery bypass through a 4 to 6 cm minithoracotomy incision. With this reduced surgical incision, there is minimized patient trauma but not necessarily reduced patient pain, due to rib spreading still required to harvest the IMA for this procedure. By using the AESOP robotic arm in a minimal access approach, the surgeon can reduce the pain of harvesting the IMA by working endoscopically with robotic assistance. Robotic assisted instruments make endoscopic coronary bypass possible and open a new era in minimally invasive surgery.*

11. Bodner, J, Schmid, T, Wykypiel, H, Bodner, E. **First experiences with robotic-assisted laparoscopic cholecystectomies.** *European Surgery - Acta Chirurgica Austriaca* 2002;34(3):166-169. **Background:** The recent introduction of surgical robotic systems marks a new milestone in surgical medicine comparable to the laparoscopic approach in the late 1980s. At Innsbruck University Hospital we have been using the da Vinci(TM) robotic system (Intuitive Surgical, Mountain View, CA, USA) since June 2001. Our first general surgical experiences with this device and laparoscopic cholecystectomies are reported here. **Methods:** The da Vinci(TM) robot is a supervised on-line system in which the surgeon at a remote console controls the endoscopic instruments and a binocular 3-D videoscope via three robotic arms. A scrubbed 'conventional' team consisting of at least one surgeon and a nurse assists the procedure to change the robotic surgical instruments as well as to allow immediate conversion to a conventional laparoscopic or open procedure, if necessary. During the first 6 months, 25 cholecystectomies were performed using the da Vinci(TM) surgical robot. **Results:** Two out of 25 cholecystectomies had to be converted to conventional laparoscopy due to system break-down. Two intraoperative complications were managed successfully, and one redo-operation was necessary because of postoperative bleeding at a port site. Operating time was 100 (60-171) min with a duration of 52 (35-99) min for the robot-assisted act itself. **Postoperative results and hospitalization times did not differ from conventional laparoscopic procedures. Conclusions:** Laparoscopic cholecystectomy can be performed with the surgical robotic da Vinci(TM) system as safely as with the conventional laparoscopic

approach. The longer operating time is mainly due to the learning curve and the time-consuming installation of the robot itself. Laparoscopic cholecystectomy is the ideal procedure for learning and teaching robot-assisted operations in general surgery. Although the present limitations of the system are evident (cumbersome equipment, lack of special instruments, only two working arms) we feel ready to perform more complex procedures in the near future.

12. Boyd, WD, Kiaii, B, Kodera, K, Rayman, R, et al. **Early experience with robotically assisted internal thoracic artery harvest.** Surgical Laparoscopy, Endoscopy and Percutaneous Techniques 2002;12(1):52-57. We sought to determine the efficacy of using robotic assistance to facilitate endoscopic harvesting of internal thoracic arteries (ITAs). A total of 104 patients had ITAs harvested endoscopically with use of both the AESOP 3000 system (Computer Motion, Goleta, CA, U.S.A.) and Zeus robotic telesurgical system (Computer Motion). All ITAs were harvested with a harmonic scalpel (Ethicon Endosurgery, Cincinnati, OH, U.S.A.). With the left lung collapsed, ITAs were harvested with COSUB2 insufflation through three 5-mm ports in the left chest. All patients tolerated insufflation without hemodynamic compromise. Average ITA harvest time was 61.3 +/- 20.9 minutes. Intraoperative graft flows averaged 36.3 +/- 22.4 mL/min. There were three distal ITA injuries; all other vessels were patent after harvesting and demonstrated no angiographic evidence of injury. This article demonstrates a technique by which ITA can be safely harvested totally endoscopically with use of computer-enhanced robotic systems and a harmonic scalpel, allowing complete pedicle dissection through 5-mm ports with minimal ITA manipulation.

13. Brunaud, L, Bresler, L, Ayav, A, Tretou, S, et al. **Advantages of using robotic Da Vinci system for unilateral adrenalectomy: early results.** Annales de chirurgie 2003;128(8):530-5. **STUDY AIM:** The goal of this study was to report the early results of unilateral transperitoneal adrenalectomy using robotic Da Vinci system, and to compare them to the results of the laparoscopic standard adrenalectomy. **METHODS:** Prospective study included all patients operated on for unilateral laparoscopic or robotic adrenalectomy from November 2000 to November 2002. **RESULTS:** Twenty-eight patients underwent unilateral adrenalectomy using either standard laparoscopy (14 patients) or robotic Da Vinci system (14 patients). Mean duration of robotic adrenalectomy seemed to be longer than standard laparoscopy (111 vs. 83 min;  $P = 0.057$ ). This tendency decreased while surgeons' experience was increasing. Mean duration of operating room activity was similar for both types of surgery. Perioperative events without conversion, conversion rate (7%), drainage, morbidity (21%), duration of hospitalisation were similar for both types of surgery. Duration of standard laparoscopic adrenalectomy was positively correlated to patients body mass index. This correlation was absent in patients operated on by robotic Da Vinci system. **CONCLUSION:** This preliminary study found no objective data demonstrating that robotic Da Vinci system was superior to standard laparoscopic approach for unilateral adrenalectomy. However, we think that it is necessary to continue further evaluation of this system to demonstrate its possible superiority.

14. Bucerius, J, Metz, S, Walther, T, Falk, V, et al. **Endoscopic internal thoracic artery dissection leads to significant reduction of pain after minimally invasive direct coronary artery bypass graft surgery.** Annals of thoracic surgery 2002;73(4):1180-4. **BACKGROUND:** The aim of this study was to evaluate postoperative pain levels after endoscopic versus conventional internal thoracic artery (ITA) dissection for minimally invasive direct coronary artery bypass graft surgery (MIDCABG) surgery. Results were compared with pain levels associated with conventional cardiac bypass operations through a median sternotomy. **METHODS:** Of 190 patients included in this prospective study, 24 patients had endoscopic ITA takedown (MIDCABG-endo) using the da Vinci telemanipulator followed by a manual coronary anastomosis through a left minithoracotomy. A conventional MIDCABG operation (MIDCABG-conv) was performed in 73 patients with ITA preparation under direct vision. Postoperative pain levels after conventional CABG through a median sternotomy (CABG-conv,  $n = 93$ ) served as controls. A standardized questionnaire including visual analog scale (VAS) was used for prospective pain assessment from POD 1 to 7. **RESULTS:** Pain levels (VAS) declined in all groups from POD 1 to 7. Overall pain levels were significantly lower in the MIDCABG-endo group as compared with MIDCABG-conv and CABG-conv groups, respectively ( $p < 0.001$ , general linear model). There was no significant difference between the MIDCABG-conv and CABG-conv ( $p =$  not significant, general linear model) groups. Furthermore, patients after MIDCABG-endo required fewer nonsteroidal anti-inflammatory drugs and opioid medications, postoperatively. **CONCLUSIONS:** An endoscopic ITA takedown in MIDCABG surgery leads to significantly reduced postoperative pain levels possibly because of less rib retraction.

15. Burkart, A, Debski, RE, McMahon, PJ, Rudy, T, et al. **Precision of ACL tunnel placement using traditional and robotic techniques.** Computer aided surgery - official journal of the International Society for Computer Aided Surgery 2001;6(5):270-8. The objective of this study was to examine the precision of ACL tunnel placement using: (1) CASPAR (orto MAQUET GmbH Co. KG)--an active robotic system, and (2) four orthopedic surgeons with various levels of experience (between 100 and 3,500 ACL reconstructions). The robotic system and each surgeon drilled tunnels for ACL reconstruction in 10 plastic knees (total  $n = 50$ ) that included a reference cube in the medial aspect of the proximal tibia and distal femur. For the robotic system, the placement of each tunnel was planned preoperatively using custom software and CT data for each femur and tibia. The robotic system then drilled the tunnels in the femur and tibia based on the preoperative plan. For the surgeons, tunnel placement was accomplished using their preferred technique, which was based on the one-incision arthroscopic technique. The distribution of intra-articular points on the tibia was contained within a sphere of radius 2.0 mm (robot system), 2.1 mm (Fellow 1), 2.4 mm (Fellow 2), 3.4 mm (Experienced Surgeon 1), or 2.0 mm (Experienced Surgeon 2). On the femur, no significant differences in the distribution of intra-articular points could be demonstrated between the robotic system (2.1 mm), Fellow 1 (4.5 mm), Fellow 2 (4.1 mm), Experienced Surgeon 1 (2.3 mm), and Experienced Surgeon 2 (3.0 mm). The direction of the tunnels drilled in the femur and tibia was different with the robotic and traditional techniques. However, the robotic system had the most consistent tunnel directions, while the surgeons' tunnels were

more dispersed. Variation in surgeon precision of tunnel placement for ACL reconstruction is greater on the femur than the tibia, and this can be correlated with experience. Our data also suggest that the robotic system has the same precision as the most experienced surgeons.

16. Cadiere, GB, Himpens, J, Vertruyen, M, Bruyns, J, et al. **Evaluation of telesurgical (robotic) NISSEN fundoplication.** *Surgical endoscopy* **2001**;15(9):918-23. **BACKGROUND:** The laparoscopic surgical approach has proven its benefit for the patient. There are however several shortcomings, which have triggered considerable research for improvement. One improvement may be the introduction of telesurgery by the interposition of a computer interface between surgeon and patient. **MATERIAL AND METHODS:** A prospective randomized study was conducted in an advanced laparoscopic procedure, Nissen fundoplication. The control group underwent the conventional laparoscopic approach, while the investigational group underwent the telesurgical approach. **RESULTS:** Feasibility was 100%. The procedure was more time consuming in the Telesurgical group, at all stages of the operation. Mortality was nil and morbidity was comparable in both groups. **CONCLUSION:** The telesurgical approach is feasible in advanced laparoscopic procedures like Nissen fundoplication. At the present time there is however no obvious added benefit from this new technique.

17. Cadiere, GB, Himpens, J, Bruyns, J, Capelluto, E, et al. **Robotic Nissen fundoplication.** *European Surgery - Acta Chirurgica Austriaca* **2002**;34(3):161-165. **Background:** Laparoscopic surgery is beneficial to the patient but challenging for the surgeon. The visual axis is not the same as the operative axis. The surgeon must manipulate long, sharp instruments through a fixed opening under the control of a two-dimensional monitor and without the help of any tactile sensation. The body cavity is penetrated by cannulas, which cannot be interchanged, so that the surgeon is obliged to move around the patient in order to reach the best position for every step of the procedure. **Methods:** A computer interface in command of a mechanical system (robot) makes it possible: 1) To regain several lost degrees of freedom through intra-abdominal articulations; 2) to obtain better visual control of instrument manipulation thanks to three-dimensional vision; 3) to modulate amplitude of surgical motions by downscaling and stabilization; 4) to operate at distance from the patient. These possibilities lead to improved surgical performance. In addition, the surgeon operates in an ergonomically correct position. The robot (da Vinci(TM) System, Intuitive Surgical, Mountain View, CA, USA) consists of a console and a surgical cart, which supports three articulated robotic arms. The surgeon sits at the console where he or she manipulates joystick-like handles while observing the operating field through binoculars that provide a three-dimensional image. This computer is capable of modulating data by eliminating physiologic tremor and by downscaling the amplitude of motions by a factor of 5 or 3 to 1. **Results:** The first robot-assisted procedure in a human was performed in March 1997 by our team. Since then, we have used robot-assisted laparoscopic surgery for 147 procedures, including 39 anti-reflux operations. Our study demonstrates the feasibility of telesurgery on humans in a variety of procedures including robotic Nissen fundoplication, with no morbidity specifically related to the use of robotics, and with acceptable operative times. **Conclusions:** In its

present embodiment, the system seems most efficient when involved in microsuturing within the abdomen or in very confined spaces. Improved ergonomic conditions and improved instrument mobility at the level of distal articulation seem beneficial in routine abdominal procedures. More research is necessary for further improvement in tool configuration and visualization. The robotic approach implies new operative strategies, including specific trocar placement.

18. Chitwood Jr, WR. **Robotic mitral valve surgery.** *heart surgery forum* **2003**;6(2):106-7. **ROBOT-ASSISTED CARDIAC SURGERY (AESOP(trademark;)):** In 1997 Mohr first used the Aesop 3000(trademark;) voice-activated camera robot in minimally invasive videoscopic mitral valve surgery. Six months later we began using the Aesop 3000(trademark;) robotic arm to perform both video-assisted and video-directed minimally invasive mitral valve repairs. We have continued to use this device during most isolated mitral valve surgery. This instrument provides surgeon camera site voice activation, precluding translation errors, inherent with verbal transmission to an assistant. Camera motion has been shown to be much smoother, more predictable, and requires less lens cleaning than during manual direction. Currently, if necessary we are able to do over 90% of a mitral repair under video-direction with the Aesop 3000(trademark;). Mohr first termed this method "solo mitral surgery" and reported 8 patients undergoing successful mitral repairs using this robotic technique. Since these early procedures, over 1500 videoscopic and robot-assisted mitral valve repairs have been done worldwide with excellent results. In early 2001 the East Carolina University (ECU) group reported their 128 successful video-assisted mitral valve operations. At first patients with anterior leaflet pathology and annular calcification were avoided. However, now we consider these patients within the realm of video-assisted surgery. The majority of patients had myxomatous disease and 61% of the total group underwent a repair. When the early series is combined with the subsequent 100 video-assisted mitral operations, repairs have been done in 81% of patients at ECU. The operative and 30-day mortalities for our entire series have been 0.4% and 1.7% respectively. After implementing the Aesop 3000(trademark;) robot to voice-direct the endoscopic camera, cross clamp, and perfusion times fell secondary to improved visualization and reduced lens cleaning. However, in the latter half of the early series cross clamp (90 minutes) and perfusion times (143 minutes) still remained longer than conventional operations. Currently, cardiac arrest and perfusion times have fallen to 70 and 100 minutes, respectively. Interestingly, we have seen no difference in bleeding and transfusion requirements between our conventional and minimally invasive patients. However, the hospital lengths of stays have averaged 4.9 days compared to 8 days for conventional operations. Of these 228 patients there have been two conversions to a sternotomy, two strokes, and no aortic dissections. We have had one vena caval injury during cannulation. Included in this series are 28 patients having had either prior coronary or mitral surgery. These patients underwent video-assisted re-operations with a 3.5% mortality and markedly less blood loss than conventional re-operations. Mohr and associates reported 154 video-assisted mitral valve operations using Aesop(trademark;) 3000 robotic camera control. In these patients the aortic cross clamp and perfusion times were similar to his conventional operations, and the operative mortality was 1.2%. He considered three-dimensional visualization to be the key to excellent results during videoscopic valve



reconstructions. In a study comparing the Port-access(trademark;) technique to trans-thoracic clamping, Wimmer-Greinecker obtained similar repair results but with faster operations, less technical difficulties, and lower cost using the clamping method. In early 2002 Vanermen reported success in 187 patients undergoing totally endoscopic repairs using the Port-access(trademark;) method and no rib spreading. He used a holder-mounted, two-dimensional endoscopic camera and performed complex repairs with excellent results at follow-up 19 months later. The hospital mortality was 0.5%, and there were two conversions to a sternotomy for bleeding. Freedom from re-operation was 95% at four years. Over 90% of patients had minimal postoperative pain. Although, this and other series have not been randomized, there are strong suggestions that mitral valve surgery has entered a new era and tur years. Over 90% of patients had minimal postoperative pain. Although, this and other series have not been randomized, there are strong suggestions that mitral valve surgery has entered a new era and that video techniques can facilitate these operations.

19. Cisowski, M, Drzewiecki, J, Samra Rafik, A, Morawski, W, Szczesniak, S, Bochenek, A. **Integrated endoscopic robotic assisted atraumatic coronary artery bypass grafting and angioplasty: a clinical and angiographic long term follow-up.** *heart surgery forum* **2003**;6(Supp 1):S16. **OBJECTIVE:** Atraumatic coronary artery bypass (ACAB) has become a promising therapeutical option in patients with lesion in LAD artery-especially with type C or B lesions. To expand the benefits of ACAB concept to patients with multivessel disease, a hybrid myocardial revascularization procedure (HMR) combining endo-ACAB surgery of the LAD with PCI procedures for additional coronary lesions has recently been introduced. **METHODS:** Between January 1999 and February 2002, 62 pts (46 male, 16 female, mean age 54.8 +/- 20, 1 years) underwent a HMR procedure. Robotic assisted endo-ACAB followed by PCI for additional coronary lesions-PTCA was performed in 16 pts (26%) and stenting in 46 pts (74%). Clinical follow-up period was 10 to 46 months. **RESULTS:** There were no early and late deaths. Baseline Canadian Cardiology Society (CCS) class was 2.8 +/- 0.7 versus 1.1 +/- 0.9 ( $p < 0.001$ ) 30 days after HMR procedure. Angiographic studies showed patent LIMA-LAD graft in 62 pts (100%). We showed good quality of anastomosis in 61 pts (98.3%) and moderate graft stenosis in one patient (1.7%). At long term follow-up the rate of MACE was 11.3%. Six pts (9.7%) developed restenosis after PCI, and one patient (1.6%) developed significant stenosis in site of LITA-LAD anastomosis. **CONCLUSIONS:** The hybrid procedure is a safe and effective method for complete revascularization in selected pts with multi-vessel coronary artery disease. This method allows to perform complete revascularization with minimization of surgical trauma. So far, long-term results of HMR are limited by the results of PCI.

20. D'Attellis, N, Loulmet, D, Carpentier, A, Berrebi, A, et al. **Robotic -assisted cardiac surgery : Anesthetic and postoperative considerations.** *Journal of Cardiothoracic and Vascular Anesthesia* **2002**;16:397-400. **Objective:** To assess the feasibility of endoscopic telemanipulated cardiac surgery and describe the anesthetic, postoperative, and surgical implications of minimally invasive robotic -assisted cardiac surgery. **Design:** Prospective study. **Setting:** Cardiovascular and transplant center, university hospital. **Participants:** Twenty patients (13 men, 7 women) scheduled for either coronary artery bypass graft surgery or valve surgery. Mean age was 53 5 years

(range, 31 to 75 years) and mean New York Heart Association class was 2.4. Three patients (6%) were having redo procedures, and 1 patient had bacterial endocarditis. **Interventions:** Surgery was done with the aid of the daVinci surgical robot (intuitive Surgical, Mountain View, CA). Induction and maintenance of anesthesia consisted of a target-controlled infusion of remifentanyl and propofol. In 11 cases (55%), cardiopulmonary bypass was performed with Port-Access technology (Heartport, Redwood City, CA), and in the remaining 9 cases (45%), conventional femorofemoral bypass was used. **Measurements and Main Results:** Fifteen patients (75%) were extubated within 6 hours and discharged from the cardiac surgery intensive care unit on postoperative day 1. Two patients (10%) were reexplored in the immediate postoperative period. Two conversions to thoracotomy were reported. One reoperation at 6 months and 1 late death occurred. At 1-year follow-up, excellent functional results were observed in 18 cases. **Conclusion:** Caution should be used when assessing innovative medical-surgical techniques. Despite technical difficulties and lengthy procedures, results were satisfactory. The feasibility of robotic -assisted surgery for coronary artery bypass graft and valve procedures is intuitively appealing. Copyright 2002, Elsevier Science (USA). All rights reserved.

21. Davies, B. **Robotic devices in surgery.** *Minimally Invasive Therapy and Allied Technologies* **2003**;12(1-2):5-13. Robotic devices are defined which can be used as an aid to surgery. A classification system is proposed that reflects the manner of use and the safety of the systems. Typical benefits and problems of using robots are discussed, and a number of applications are reviewed. These cover "autonomous" systems, that involve no intervention from the surgeon; "hands-on" systems, that require the direct involvement of the surgeon; and "Master/Slave" (or Telemanipulator) systems, that are somewhere between these two and involve some degree of indirect surgeon activity. A number of predictions for the future of medical robotics are provided.

22. Den Boer, KT, Bruijn, M, Jaspers, JE, Stassen, LPS, et al. **Time-action analysis of instrument positioners in laparoscopic cholecystectomy: A multicenter prospective randomized trial.** *Surgical Endoscopy* **2002**;16(1):142-147. **Background:** Instrument positioners can position and lock a laparoscopic instrument. This study uses time-action analysis to evaluate objectively whether IPs can substitute for a surgical assistant efficiently and safely. **Methods:** In four hospitals, 78 laparoscopic cholecystectomies were randomly assisted by a surgical assistant or an instrument positioner (AESO P and PASSIST). The efficiency and safety of laparoscopic cholecystectomies were analyzed with respect to time, number and type of actions, positioning accuracy, and peroperative complications. A questionnaire evaluated the difficulties for each operation and the comfort of instrument positioner use. **Results:** The PASSIST and AESOP were able to replace the surgical assistant during laparoscopic cholecystectomies without significantly changing either the efficiency or the safety of the operation. The questionnaire showed that the surgeons preferred to operate with an instrument positioner. **Conclusion:** This study assessed objectively that instrument positioners can substitute for a surgical assistant efficiently and safely in elective laparoscopic cholecystectomies.

23. Dettler, C, Reichenspurner, H, Boehm, DH, Reichart, B. **Robotic manipulators in cardiac surgery: The computer-assisted surgical system ZEUS. Minimally Invasive Therapy and Allied Technologies** 2001;10(6):275-281. *Minimally invasive strategies continue to evolve in cardiac surgery . Robotic -assisted systems have been introduced recently, to increase the precision of endoscopic coronary surgery. This report describes the experimental and clinical use of the computer-assisted robotic system ZEUS for endoscopic coronary artery bypass anastomoses. The ZEUS system consists of three interactive robotic arms and a control unit, allowing the surgeon to move the instrument arms in a scaled-down mode. The third arms (AESOP) positions the endoscope under voice control. The present study demonstrates the feasibility of endoscopic coronary artery bypass grafting using a computer-assisted surgical robotic system on the arrested heart, as well as on the beating heart in selected patients. However, robotic -assisted cardiac surgery is still developing, and tremendous efforts are still required to establish a routine procedure.*
24. Dettler, C, Boehm Dieter, H, Reichenspurner, H, Deuse, T, Arnold, M, Reichart, B. **Robotically -assisted coronary artery surgery with and without cardiopulmonary bypass - from first clinical use to endoscopic operation. Medical science monitor - international medical journal of experimental and clinical research** 2002;8(7):MT118-23. **BACKGROUND:** Recently, the ZEUS (tm) Robotic Surgical System has been introduced to increase the precision of endoscopic cardiac surgery . This study investigated its clinical use for endoscopic coronary artery bypass grafting. **MATERIAL/METHODS:** Between 1998 and 2001, 41 patients with single and multivessel disease were operated on using the ZEUS (tm) system. The robotic system was introduced step by step into clinical practice. Initially, the system was used only for endoscopic internal mammary artery (IMA) harvest (n=12), later for coronary anastomoses on the arrested (n=13) or beating heart after median sternotomy (n=6), and finally for endoscopic coronary bypass grafting on either the arrested (n=2) or beating heart (n=8). **RESULTS:** Endoscopic IMA harvest ranged from 48 to 110 min and was completed in all cases. In the sternotomy group, the robotic anastomosis time averaged 21 min on the arrested and 25 min on the beating heart, respectively (n.s.). In the endoscopic cases, the average time for endoscopic anastomosis was 41 min on the arrested and 36.5 min on the beating heart (n.s.), with an overall duration of surgery between 4.0 and 8.0 hours. One endoscopic case was intraoperatively converted to a MIDCAB procedure with manual anastomosis. The total patency rate of all graft anastomoses, confirmed by early postoperative angiographic control, was 97%. One patient underwent reoperation with an uneventful postoperative course. **CONCLUSIONS:** The present study demonstrates the feasibility of endoscopic coronary revascularization using a computer-assisted surgical robotic system on the arrested and beating heart in selected patients.
25. Dogan, S, Aybek, T, Khan, MF, Kessler, P, et al. **Computer - enhanced telemanipulation enables a variety of totally endoscopic cardiac procedures. Thoracic and cardiovascular surgeon** 2002;50(5):281-6. **BACKGROUND:** Since its introduction in the field of cardiac surgery in 1997, computer - enhanced telemanipulation has been used in a number of different specialized areas. In cardiac surgery, various procedures have been successfully completed in totally endoscopic fashion ever since. Between June 1999 and January 2002, 75 closed-chest cardiac procedures have been performed at our institution using the da Vinci telemanipulation system. **PATIENTS AND METHODS:** In 42 patients, a single-vessel totally endoscopic coronary artery bypass was performed on the arrested heart (left internal thoracic artery (LITA) to left anterior descending artery (LAD), n = 36; right internal thoracic artery (RITA) to right coronary artery (RCA), n = 6). 12 patients had different types of multivessel revascularization using both internal thoracic arteries. 8 patients underwent LITA-to-LAD grafting on the beating heart. 10 patients underwent closure of an atrial septal defect (9 direct, 1 patch). 3 patients received an epicardial left ventricular pacemaker lead, 2 of which were reoperations. **RESULTS:** Overall conversion rate to any kind of incision was 25 %. The last 26 LITA to LAD patients on the arrested heart had a conversion rate of 4 %. There were no mortalities, 3 patients required reexploration via a median sternotomy, and one patient suffered a hypoxemic brain damage. The first 22 TECAB patients demonstrated excellent graft patency in angiographic control upon discharge. None of the atrial septal defect (ASD) closures showed any residual shunt on the intraoperative transesophageal echocardiogram (TEE). Patients with end-stage heart failure had successful biventricular stimulation. **CONCLUSION:** Our current experience confirms the feasibility of various totally endoscopic cardiac procedures with good clinical outcomes. After a steep learning curve, the conversion rate could be lowered to an acceptable figure. Some of these procedures at our institution became a reasonable treatment alternative in selected patients.
26. Eadie, LH, Seifalian, AM, Davidson, BR. **Telemedicine in surgery. British Journal of Surgery** 2003;90:647-658. **Background:** Telemedicine is influencing surgical training, allows mentoring, proctoring and teleconferencing, and is increasingly being applied to carry out remote surgical procedures. A systematic review of the telemedicine systems available, along with a critical appraisal of their application, potential and limitations in the surgical field, has been undertaken. **Method:** Medline, Ovid and internet searches were carried out using the key words 'telesurgery', 'telepresence surgery' and 'telemedicine and surgery', along with hand searches of the two peer-reviewed telesurgery journals. **Results:** Telementoring and teleconferencing have been used widely for surgical teaching and training. Two clinical telesurgery systems are currently available and have been trialled in patients undergoing a variety of operations including cholecystectomy, coronary artery bypass, prostatectomy and gastroplasty. Most studies have reported successful outcomes but with prolonged operating times. In 2002 the first long-distance telesurgery procedure was successfully performed. **Conclusion:** Telemedicine has huge potential to alter surgical practice but improvements are required in telesurgical technology with respect to tactile feedback, instrumentation, telecommunication speed and availability. Issues of liability, legislation, cost and benefit require clarification. The future of telemedicine in surgery may lie in facilitating complex minimally invasive techniques.
27. Fay, AF, Perrin, JP, Fery-Lemonnier, E. **Classification of the computer assisted surgical system. Itbm Rbm** 2002;23(6):Itbm-Rbm. *In the context of fast technological evolutions and strong demand from the surgeons, it has become necessary to propose to decision makers in terms of investment, a classification of*

computer assisted and robotic surgery systems, taking into account different issues raised by each category of system (medical, organisational, economic, security and legal aspects). This classification also allows to determine the assessment needs specific to each category. It has been derived from the works of the Committee for Evaluation and Diffusion of Innovative Technologies (Cedit, Paris hospitals), that has been asked several times to give an advice on the interest of these technologies. (c) 2002 Editions scientifiques et medicales Elsevier SAS.

28. Felger, JE, Chitwood, WR, Nifong, LW, Holbert, D. **Evolution of mitral valve surgery: toward a totally endoscopic approach.** *Annals of thoracic surgery* 2001;72(4):1203-8; discussion 1208-9. **BACKGROUND:** Our study evaluates a series of video-assisted minimally invasive mitral operations, showing safe progression toward totally endoscopic techniques. **METHODS:** Consecutive patients with isolated mitral valve disease underwent either manually directed (n = 55) or voice-activated robotically directed (n = 72) video-assisted mitral operations. Cold blood cardioplegia, a transthoracic aortic clamp, a 5-mm endoscope, and a 5-cm minithoracotomy were used. This video-assisted minimally invasive mitral operation cohort was compared with a previous sternotomy-based mitral operation cohort (n = 100). **RESULTS:** Group demographics, New York Heart Association classification, and cardiac function were similar. Repairs were performed in 61.8% manually directed (n = 34), 75.0% robotically directed (n = 54), and 54% sternotomy-based (N = 54) mitral operations. The robotically directed technique showed a significant decrease in blood loss, ventilator time, and hospitalization compared with the sternotomy-based technique. Manually directed mitral operations compared with robotically directed mitral operations had decreased arrest times (128.0 +/- 4.5 minutes compared with 90.0 +/- 4.6 minutes; p < 0.001) and decreased perfusion times (173.0 +/- 5.7 minutes compared with 144.0 +/- 4.6 minutes; p < 0.001). In the minimally invasive mitral operation cohort, complications included reexploration for bleeding (2.4%; n = 3) and one stroke (0.8%), whereas the 30-day mortality was 2.3% (n = 3). **CONCLUSIONS:** Video-assisted mitral surgery provides safe and effective results when compared with conventional sternal approaches. These positive results show a safe and stepwise evolution toward a totally endoscopic mitral valve operation.

29. Giulianotti, PC, Coratti, A, Angelini, M, Sbrana, F, et al. **Robotics in general surgery : Personal experience in a large community hospital.** *Archives of Surgery* 2003;138(7):777-784. **Hypothesis:** Robotic technology is the most advanced development of minimally invasive surgery, but there are still some unresolved issues concerning its use in a clinical setting. **Design:** The study describes the clinical experience of the Department of General Surgery, Misericordia Hospital, Grosseto, Italy, in robot-assisted surgery using the da Vinci Surgical System. **Results:** Between October 2000 and November 2002, 193 patients underwent a minimally invasive robotic procedure (74 men and 119 women; mean age, 55.9 years [range, 16-91 years]). A total of 207 robotic surgical operations, including abdominal, thoracic and vascular procedures, were performed; 179 were single procedures, and 14 were double (2 operations on the same patient). There were 4 conversions to open surgery and 3 to conventional laparoscopy (conversion rate, 3.6%; 7 of 193 patients). The perioperative morbidity rate was 9.3% (18 of 193 patients), and 6 patients (3.1%)

required a reoperation. The postoperative mortality rate was 1.5% (3 of 193 patients). **Conclusions:** Our preliminary experience at a large community hospital suggests that robotic surgery is feasible in a clinical setting. Its daily use is safe and easily managed, and it expands the applications of minimally invasive surgery. However, the best indications still have to be defined, and the cost-benefit ratio must be evaluated. This report could serve as a basis for a future prospective, randomized trial.

30. Horgan, S, Vanuno, D. **Robots in laparoscopic surgery.** *Journal of laparoendoscopic & advanced surgical techniques. Part A* 2001;11(6):415-9. **BACKGROUND:** The Da Vinci Robotic System became available at our institution in late August 2000. We decided to utilize this system to perform advanced laparoscopic procedures. **METHODS:** This is a review of the status of robotics and its application in surgery. We report our experience using the Da Vinci system. **RESULTS:** We have used the Da Vinci for 34 advanced laparoscopic cases: 7 gastric bypasses for morbid obesity, 9 Heller myotomies for achalasia, 11 donor nephrectomies, 2 gastrojejunostomies, and single cases of bilateral adrenalectomy, Nissen fundoplication, Toupet fundoplication, and cholecystectomy. No robot-related complications were noted. **CONCLUSIONS:** This early experience suggests that robotic surgery is a safe and effective alternative to conventional laparoscopic surgery. We believe that robotic surgery, with its ability to restore the hand-eye coordination and three-dimensional view lost in laparoscopic surgery, will allow us to perform complex procedures with greater precision and confidence and better results.

31. Isgro, F, Kiessling, AH, Blome, M, Lehmann, A, Kumle, B, Saggau, W. **Robotic surgery using Zeus (TM) MicroWrist(TM) technology: The next generation.** *Journal of Cardiac Surgery* 2003;18(1):1-5 discussion 6-7. **Background:** The use of computer-animated surgical instruments for various cardiac operations has been shown to be feasible, but to date, the available information regarding the operative and technical details of these procedures is still inadequate. **Methods:** We used the Zeus (TM) (Computer Motion Inc., Goleta, Calif, USA) telemanipulation system to perform the internal mammary artery (IMA) takedown in 56 patients, in 12 of whom we used the newest model with MicroWrist(TM) (Computer Motion Inc., Goleta, Calif, USA) technology. Port orientation was based on thoracic anatomy, the decisive landmarks being the mammillary line and the axillary line. The distance between ports was at least 9 cm, and the patient's arm was positioned with the left shoulder raised and angulated by not more than 90 degrees. **Results:** Mean setup time was 44 +/- 18 minutes for the first five patients and 16 +/- 7 minutes for the last five patients, with an overall average of 24 +/- 12 minutes. IMA harvest time at the beginning reached a mean of 95 +/- 23 minutes and decreased to 44 +/- 18 minutes in the last five cases. Average IMA takedown time was 58 +/- 17 minutes. The IMA was patent with a good flow in all 56 patients. **Conclusions:** The introduction of robotic technology into clinical routine has resulted in safe procedures with a short learning curve. However, basic training in the modality is a must in order to achieve technical excellence.

32. Kodera, K, Boyd, WD, Kiaii, B, Novik, RJ, et al. **Clinical experience in thoracoscopic left internal mammary artery harvesting with voice activated robotic assistance.** *Kyobu geka. The Japanese journal of thoracic surgery*



2001;54(12):987-91; discussion 991-4. *Between September 1998 to February 2000, 45 consecutive patients underwent robotic - assisted , video -enhanced coronary artery bypass grafting. All IMA's were harvested using the voice-activated robotic assistant (AESOP 3000, Computer Motion Inc, Santa Barbara, CA) and the Harmonic scalpel (Ethicon Endo- Surgery , Cincinnati, OH). Left IMA's were successfully harvested in all patients. Harvested IMA's were anastomosed to LAD's under direct vision through limited left anterior thoracotomy. The IMA harvest time was 57.8 +/- 23.2 min, intraoperative graft flow was 34.3 +/- 20.5 ml/min, postoperative hospital stay was 3.9 +/- 1.5 days. The early postoperative angiogram showed that all grafts were patent. There was no mortality, no significant morbidity. The robotic assisted , video enhanced CABG provides safe and complete LIMA dissection with minimal manipulation and assures sufficient LITA length for tension free anastomosis.*

33. Loisançe, D, Houel, R, Kirsch, M, Rosanval, O, Thebert, D. **[Computer-assisted coronary surgery]. Bulletin de l'Academie nationale de medecine 2001;185(7):1225-36; discussion 1236-8. Routine totally endoscopic, beating heart, coronary surgery should be made possible by the use of computer enhanced surgical techniques. It includes a totally endoscopic mammary artery harvesting, a correct exposure and an adequate stabilization of the coronary artery at the anastomotic site , a perfect anastomosis of the mammary artery on the left anterior descending coronary artery using a microsurgical suture technique. This complex surgical protocol will be reached by a step by step approach. The first 20 patients who accepted to be operated with tele-manipulated instruments make the substance of this first report. In 19 cases, the dissection of the internal mammary artery could be performed with an optimal result: the lack of bleeding during the dissection emphasizes the excellent visualization of the operative field and the precision of the dissection. The satisfactory blood flow in the mammary artery at the time of the coronary anastomosis suggests the lack of spasm and confirms the atraumatic dissection. The distal anastomosis of the coronary bypass has been performed through a mid line sternotomy to avoid an excessive prolongation of the operative time. The anatomic conditions and the quality of the vessel wall allowed to perform the coronary anastomosis with the tele-manipulated instruments in nine cases only: in six patients, the mammary artery has been implanted on the descending artery, in three, a venous autograft on the diagonal branch. Our initial clinical experience with this new technique suggests that a very precise and fine surgery can be performed with an acceptable prolongation of the operative time. More experience and further developments in the instrumentation are nevertheless required to allow completion of the entire procedure totally closed chest, on a beating heart.**

34. Luketich, JD, Fernando, HC, Buenaventura, PO, Christie, NA, Grondin, SC, Schauer, PR. **Results of a randomized trial of HERMES-assisted vs non-HERMES-assisted laparoscopic antireflux surgery. Surgical Endoscopy and Other Interventional Techniques 2002;16:1264-1266. Background: Speech recognition technology is a recent development in minimally invasive surgery. This study was designed to assess the impact of HERMES on operating room efficiency and user satisfaction. Methods: Patients undergoing laparoscopic antireflux operations by surgeons experienced in minimally invasive surgery were randomized to HERMES-**

*assisted or standard laparoscopic operations. The variables of interest were circulating nurse's time spent adjusting devices that are voice-controlled by HERMES, number of adjustments to devices requested, and surgeon and nurse satisfaction measured on a scale from 1 (dissatisfied) to 10 (satisfied). Results: A total of 30 cases were studied. In the non-HERMES cases, nurses were interrupted to make device adjustments an average of 15.3 times per case versus 0.33 times per case in the with-HERMES cases) < 0.01). The interruptions during the non-HERMES cases averaged 4.35 min per case versus 0.16 min per case in the with-HERMES cases (p = 0.03). Average satisfaction scores for HERMES operations as opposed to non-HERMES operations were 9.2 versus 5.3 for nurses (p < 0.01) and 9.0 versus 5.1 for surgeons (p < 0.01). Conclusions: Physician and nurse acceptance of HERMES was very high because of the smoother interruption-free environment.*

35. Mair, H, Jansens, JL, Lattouf, OM, Reichart, B, Dabritz, S. **Epicardial lead implantation techniques for biventricular pacing via left lateral mini-thoracotomy, video - assisted thoracoscopy, and robotic approach. Heart Surgery Forum 2003;6(5):412-417. Purpose: For optimal biventricular pacing, the left ventricular (LV) lead has been found to be best placed in the area where optimal concordance is achieved between the LV pacing site and the site of the most delayed LV wall. For anatomical or technical reasons, the placement of the LV lead via the coronary sinus at the intended target area of the LV is often not possible. An option for avoiding these drawbacks is the surgical implantation of the LV lead under direct vision. This report describes 3 epicardial lead implantation techniques that are less invasive. Methods: In 80 patients with advanced heart failure and left bundle branch block, epicardial LV leads for biventricular pacing were implanted with 3 different methods: (1) left lateral mini-thoracotomy; (2) a video - assisted thoracoscopy approach using lead implantation tools; and (3) a robotically enhanced telemanipulation system. Video films are provided for all 3 techniques in The Heart Surgery Forum online. Results: Independent of the surgical techniques, the intended lead location on the LV was achieved in all patients. Acute and 3-month LV lead thresholds were satisfactory in 79 patients (99%). Two lead displacements were observed. One thoracotomy was carried out after thoracoscopic lead placement because the patient developed an early exit block. Five patients who underwent an operation with the robot needed a conversion to thoracotomy because of technical failure of the robot (2 patients) or massive pleural adhesions (3 patients). There were no severe adverse events related to any technique. Three patients died in the hospital from the progression of end-stage heart failure. Conclusion: Epicardial lead implantation for biventricular pacing is feasible with all 3 surgical techniques. Each method allows optimal lead implantation under direct vision and therefore reduces the incidence of nonresponders resulting from suboptimal lead placement.**

36. Mehta Vivek, K, Lee, Q-T, Chang Steven, D, Che rney, S, Adler John, R. **Image guided stereotactic radiosurgery for lesions in proximity to the anterior visual pathways: a preliminary report. Technol Cancer Res Treat 2002;1(3):173-80. The incidence of optic neuropathy after stereotactic radiosurgery (SRS) is related to the total dose, fraction size, and treatment volume. Theoretically, fractionated SRS can decrease this risk. In this paper, we report our technique for fractionated SRS and**

assess its potential role in the management of tumors located adjacent to the anterior visual pathways. Since 1997, thirteen patients (median age: 50, range 21-76) with lesions in close proximity to the anterior visual pathways were treated on the CyberKnife image guided SRS system (Accuray, Inc., Sunnyvale, CA). The CyberKnife is a 6MV linear accelerator mounted on a robotic arm which can monitor and adjust to changes in the target position in real time thus eliminating skeletal frame immobilization and allowing for convenient multi-fraction SRS treatments. Magnetic Resonance Imaging (MRI) and computerized tomography (CT) imaging for treatment planning were obtained with the patients head immobilized in an aquaplast mask. After image fusion, the target and critical structures were delineated. Two to five fractions were prescribed with approximately a 24-hour interfraction interval. The patients received 25 Gy in 5 fractions (n=5), 21 Gy in 3 fractions (n=5), or 20 Gy in 2 fractions (n=3) to the 75-95% isodose line. Ten of the thirteen patients had good pretreatment vision. In nearly all instances, the volume of the optic nerve that received 80% of the prescribed dose was < 0.05 cm<sup>3</sup>. In all instances, the volume of the optic nerve that received 50% of the prescribed dose was <= 0.5 cm<sup>3</sup>. Only one patient received more than a 5 Gy daily dose to > 0.03 cm<sup>3</sup> of optic nerve. With median follow up of 18 months (range 12 to 54), four patients have had improvement in their vision. No visual deterioration has been observed in any of the other patients. In addition, there has been no tumor progression within the treated field. Fractionated SRS using the CyberKnife is technically feasible and may decrease the risk of optic neuropathy. Greater patient accrual and longer follow up will be necessary to further determine the clinical benefit of this approach.

37. Melfi Franca, MA, Menconi Gian, F, Mariani, AM, Angeletti Carlo, A. **Early experience with robotic technology for thoracoscopic surgery.** European journal of cardio-thoracic surgery - official journal of the European Association for Cardio-thoracic Surgery 2002;21(5):864-8. **OBJECTIVE:** Recently, robots have been introduced into surgical procedures in an attempt to facilitate surgical performance. The purpose of this study was to develop a technique to perform thoracoscopic lung resection using a telemanipulation system. **METHODS:** We have used a robotic system to perform thoracoscopic surgery in 12 cases: five lobectomies, three tumor enucleations, three excisions and one bulla stitching completed with fibrin glue for spontaneous pneumothorax. The operations were performed using the Intuitive Microsurgical system (Da Vinci System) through three ports and, a fourth space 'service entrance' incision, in the major lung resection. **RESULTS:** Three procedures begun with the robotic technique were completed by a minimal thoracotomy. No technical operative mishaps were associated with the manoeuvres of robotic arms. In all manoeuvres (up, down, insertion, extraction, etc.), the robotic arms moved appropriately in the favorable operative fields. All patients tolerated the procedure well and the post-operative course was satisfactory, requiring few analgesics. **CONCLUSIONS:** Although further studies on robotically assisted procedures are needed to clarify the clinical feasibility of this procedure, the results in our cases are encouraging. We believe that thoracoscopic procedures using a robotic manipulation system may be technically feasible in selected cases and in the hands of experienced thoracic surgeons.

38. Melvin, WS, Needleman, BJ, Krause, KR, Schneider, C, et al. **Computer - enhanced robotic telesurgery. Initial experience in foregut surgery.** Surgical endoscopy 2002;16(12):1790-2. **BACKGROUND:** A new type of computer - enhanced telemanipulator device for "robotic" laparoscopic surgery was recently approved. We prospectively evaluated the initial patients undergoing procedures with this new device at our institution. **METHODS:** Patient demographics, operative indications, port placement, operative time, robot time, complications, and hospital stay were recorded. Follow-up evaluation was appropriate for the individual procedure. **RESULTS:** Initially, 35 cases were managed. There were 22 anti-reflux procedures, 9 Heller myotomies, 1 pyloroplasty, 1 distal pancreatectomy with splenectomy, 1 esophagectomy with intrathoracic anastomosis, and 1 diagnostic laparoscopy. The operative times ranged from 88 to 458 min. The robot use times were between 16 and 185 min. There were no device-related complications. **CONCLUSIONS:** Computer - enhanced robotic telesurgery is a safe and effective treatment method for a variety of diseases of the proximal gastrointestinal tract. Further study is needed to determine the benefits of this approach as compared with current technology.

39. Melvin, WS, Needleman Bradley, J, Krause Kevin, R, Schneider, C, Ellison, EC. **Computer - enhanced vs. standard laparoscopic antireflux surgery.** Journal of gastrointestinal surgery - official journal of the Society for Surgery of the Alimentary Tract 2002;6(1):11-5; discussion 15-6. **Computer-assisted telesurgery devices have recently been approved in the United States for general surgery. To determine the safety and efficacy of these procedures, we performed a prospective trial of computer - enhanced "robotic" fundoplication compared to standard laparoscopic control procedures. Consecutive patients undergoing surgical treatment for gastroesophageal reflux were included. The operating surgeon worked at a console using a three-dimensional image and manipulated hand controls. Operative times, complications, and length of hospital stay were recorded. A standardized questionnaire was administered to evaluate symptoms. Twenty patients were entered into each group. There were no differences in age, preoperative weight, or sex. Operative times were significantly longer in the robot group (97 vs. 141 minutes). There were no complications and most patients went home the first postoperative day. At follow-up, symptoms were similar in both groups; however, there was a significant difference in the number of patients taking antisecretory medication--none in the robotic group but six in the laparoscopic group reported regular use. Computer-assisted laparoscopic antireflux surgery is safe. However, operative times are longer, with little difference in outcomes. At the current level of technology and experience, robotic antireflux surgery appears to offer little advantage over standard laparoscopic approaches.**

40. Merola, S, Weber, P, Wasielewski, A, Ballantyne Garth, H. **Comparison of laparoscopic colectomy with and without the aid of a robotic camera holder.** Surgical laparoscopy, endoscopy & percutaneous techniques 2002;12(1):46-51. **The use of a robotic camera holder (AESOP 3000; Computer Motion, Inc., Santa Barbara, CA, U.S.A.) during laparoscopic surgery is slowly becoming more popular with laparoscopic surgeons. However, few published reports document the effects of the robot on operative outcomes or operative times. In the current study, we compared the use of a voice-controlled robotic camera holder to a human camera holder in a series**

of laparoscopic colectomies. The outcome data measured included the number of patients with postoperative complications, the patients' length of stay at the hospital, and the operative times for the procedures. There were 2 complications among the 11 patients in group 1 (colectomies performed without a robotic camera holder), versus 2 complications among the 15 patients in group 2 (colectomies performed with a robotic camera holder) ( $P = NS$ ). Patients in group 1 had an average length of stay of 4.1 days, versus 4.4 days for those in group 2 ( $P = NS$ ). The operative time for group 1 was 235 minutes, compared with 213 minutes for group 2 ( $P = NS$ ). The use of a voice-controlled robotic camera holder does not alter the length of the operative procedure, the patient's length of stay, or postoperative morbidity. However, surgeons often have a subjective sense that there is less smudging, fogging, and inadvertent movements of the laparoscope when it is controlled by a robotic system. In addition, using a voice-controlled robot as a camera holder does eliminate the need for a surgical assistant.

41. Novick Richard, J, Fox Stephanie, A, Kiaii Bob, B, Stitt Larry, W, et al. **Analysis of the learning curve in telerobotic , beating heart coronary artery bypass grafting: a 90 patient experience.** *Annals of thoracic surgery* 2003;76(3):749-53. **BACKGROUND:** Recent articles have commented on the "learning curve" in robotic -assisted coronary artery bypass grafting. We systematically studied this phenomenon using standard statistical and cumulative sum (CUSUM) failure methods. **METHODS:** Ninety patients underwent internal thoracic artery (ITA) takedown and an attempt at ITA to coronary bypass on the beating heart using the Zeus telerobotic system from September 1999 to December 2001. The rates of mortality and 11 predefined major complications were compared in five quintiles of 18 consecutive patients each and a CUSUM curve was generated for the entire cohort. **RESULTS:** All patients but one underwent successful endoscopic ITA takedown. Thirteen patients had a totally endoscopic anastomosis, whereas in 61 a small mini-thoracotomy or mini-sternotomy was used. Sixteen patients (17.8%) were converted electively to a sternotomy: 11 patients underwent off-pump and 5 patients on-pump surgery. There were no deaths; 13 patients (14.4%) incurred one or more of the 11 major complication(s), including 5, 1, 2, 3, and 2 in each of the five quintiles ( $p = 0.39$ ). Standard statistical analyses identified a significant decrease in operating room time ( $p < 0.0001$ ), as well as a decrease in the incidence of an occluded graft or wrong vessel grafted from quintiles 1 to 5 ( $p = 0.03$ ). On CUSUM analysis, the failure curve was steep for the first 18 to 20 patients, before moderating its slope for the remainder of the experience. **CONCLUSIONS:** Robotic ITA to coronary bypass on the beating heart has a moderately steep learning curve, which is mitigated by further experience. CUSUM analysis complimented standard statistical methods in detecting a cluster of suboptimal results during the early experience with this procedure.

42. Onnasch, J-F, Schneider, F, Falk, V, Mierzwa, M, Bucerus, J, Mohr Friedrich, W. **Five years of less invasive mitral valve surgery: from experimental to routine approach.** *heart surgery forum* 2002;5(2):132-5. **BACKGROUND:** In the last five years, mitral valve surgery has changed fundamentally. This study reviews our experience in less invasive mitral valve surgery (LIMS) during that time. **METHODS:** LIMS was performed in 449 patients (age 59 +/- 14 years, 237 female) via

a right lateral minithoracotomy. The operations included 42 "redo" procedures. After initially experiencing a high number of complications, we have modified and simplified the procedure. After using the Port- Access? Technique (PAT) in the earlier stages of our series, in the last 226 patients the aorta was clamped directly using the transthoracic clamping (Chitwood) technique (TTC). In our most recent cases, PAT was only employed in redo procedures. In 336 patients, the procedure was completed with robotic assistance, and in 23 of these we used the da Vinci telemanipulation system. **RESULTS:** The mitral valve was repaired in 327 patients and replaced in 122 patients. In 100 patients, additional surgical procedures (TVR  $n = 13$ , ASD closure  $n = 16$ , left atrial ablation  $n = 65$ , left atrial reduction plasty  $n = 6$ ) were performed. Bypass and clamp time, including times for both additional and redo procedures, were 124 +/- 44 min. and 65 +/- 29 min. in the overall series. Complications, which were mainly neurological, were fewer in the TTC group than in the PAT group ( $n = 4$  vs.  $n = 17$ ;  $p < 0.04$ ). Hospital mortality was 3.1% and 5.2%, respectively, for the two groups. There were no additional costs associated with using the TTC technique compared to conventional procedures. Mean survival rate was 96.3% at a mean follow-up of 727 +/- 451 days (95% CI, 677 to 779). **CONCLUSIONS:** Less invasive mitral valve surgery enables the patient to avoid the surgical trauma associated with sternotomy. It has developed into a reliable technique with reproducible results for primary, redo, and additional procedures. LIMS has become the standard approach for mitral valve operations at our institution.

43. Perez, A, Zinner, MJ, Ashley, SW, Brooks, DC, Whang, EE. **What is the value of telerobotic technology in gastrointestinal surgery ?** *Surgical endoscopy* 2003;17(5):811-3. **BACKGROUND:** Although telerobotic technology has entered clinical application, its value for gastrointestinal surgery is unclear. Our objective was to evaluate the performance characteristics of telerobotically assisted laparoscopic cholecystectomy (TALC). **METHODS:** All TALCs performed using the da Vinci Surgical System between January 2000 and September 2001 at a tertiary academic medical center were analyzed. **RESULTS:** For this study, 20 patients (80% female) with a mean age of 47 +/- 4 years underwent TALC. All had symptomatic cholelithiasis, and all had successful TALC results without complications or need for conversion to conventional laparoscopic cholecystectomy (CLP). The mean procedure time was 152 +/- 8 min. The procedures were performed by one of three staff surgeons experienced in laparoscopic surgery who had training in telerobotic surgery. The perceived advantages of TALC over CLP included easier tissue dissection, enhanced dexterity, and stimulated interest in biliary surgery. The disadvantages included increased operating time and lack of tactile feedback. **CONCLUSIONS:** The TALC procedure is effective and safe when performed by appropriately trained surgeons. Telerobotic technology has the potential to reinvigorate gastrointestinal surgery.

44. Rassweiler, J, Seemann, O, Hatzinger, M, Schulze, M, Frede, T. **Technical evolution of laparoscopic radical prostatectomy after 450 cases.** *Journal of endourology / Endourological Society* 2003;17(3):143-54. **BACKGROUND AND PURPOSE:** In 1998, laparoscopic radical prostatectomy with primary access to the seminal vesicles was introduced. In 1999, we developed a laparoscopic technique



similar to the classic retropubic radical prostatectomy. We focus here on the continuous technical evolution of our technique. **PATIENTS AND METHODS:** From March 1999 to May 2002, we performed 450 laparoscopic radical prostatectomies. All important data of the patients; data concerning the performance of the procedure, including technical modifications, conversion, reintervention, and complication rate; as well as follow-up information were documented contemporaneously. The patients were divided into three groups of 150 individuals each in order to analyze the influence of the technical evolution of the procedure. Additionally, we studied the transferability of our technique, comparing the learning curves of the three surgeons involved in the program. **RESULTS:** The technical modifications included the routine use of a voice-controlled robot (AESOP) for the camera, exposure of the apex with 120 degrees retracting forceps, a free-hand suturing technique instead of the Endostitch device for the dorsal vein complex, 5-mm clipping instead of bipolar coagulation for the nerve-sparing technique, initial 6 o'clock suturing of the urethra before complete division, control of the prostatic pedicles by use of 12-mm Hemo-lok clips instead of the Ultracision or Endo-GIA, the bladder neck-sparing technique in cases of T(1c) and T(2a) tumors, and interrupted instead of continuous sutures for the vesicourethral anastomosis. All these modifications resulted in a significant decrease in operating time and the rates of transfusion, open conversion, and reintervention. The introduction of the nerve-sparing technique increased the number of tumor-positive margins. The mean operating time of the third surgeon was significantly less than that of the first surgeon, but the transfusion, conversion, and reintervention rates did not differ significantly among the surgeons. **CONCLUSIONS:** Laparoscopic radical prostatectomy has undergone continuous technical evolution resulting in a significant improvement of the operative results. Although we were able to demonstrate the transferability of this difficult procedure, we feel that it should be performed only at centers of expertise.

45. Reuthebuch, O, Comber, M, Grunenfelder, J, Zund, G, Turina, M. **Experiences in robotically enhanced IMA-preparation as initial step towards totally endoscopic coronary artery bypass grafting.** Cardiovascular Surgery 2003;11(6):483-487. **Aim:** To evaluate the feasibility of robotically enhanced preparation of internal mammary arteries (IMA). **Method:** Via three trocars in left thoracic wall the left, right or both IMA were skeletonized under COSUB2 insufflation and single lung ventilation using electrocautery. **Results:** In 12 months, 26 LIMA, five BIMA and one RIMA were dissected. In five patients, the procedure had to be determined (IMA injury (two), respiratory insufficiency (two), and heart penetration (one)). Mean intrathoracic pressure was 9.7+/-1.5 mmHg. Mean time for LIMA and RIMA dissection was 66.7+/-21.1 and 99.2+/-8.7 min, respectively. In 10 patients, pericardium was incised and course of LAD assessed. However, in two patients, this coronary did not correlate with LAD. Time for instrument change depended on type of tool (cautery blade: 24.9+/-13.1 s, clip applier 72.8+/-28.4 s). **Conclusion:** Robotic dissection of IMA is reasonable. However, life-threatening complications can barely be managed due to inadequate tools and excessive time for instrument change. Incorrect determination of coronaries can result in misplaced anastomoses. (c) 2003 The International Society for Cardiovascular Surgery. Published by Elsevier Ltd. All rights reserved.

46. Ruurda, JP, Simmermacher, RPM, Borel Rinkes, IHM, Broeders, IAMJ. **Robotic surgery in a routine procedure an evaluation of 40 robot-assisted laparoscopic cholecystectomies.** European Surgery - Acta Chirurgica Austriaca 2002;34(3):170-172. **Background:** Laparoscopic surgery offers distinct benefits to patients but places a burden on surgeons regarding manoeuvrability of instruments and visualization of the operating field. The introduction of robotic telemanipulation systems offers a solution to these problems in videoscopic surgery. **Methods:** In this study, the feasibility of robot-assisted laparoscopic surgery was assessed by performing 40 laparoscopic cholecystectomies with the da Vinci(TM) robotic system. Time necessary for system set-up and operation was recorded, as well as complications, technical problems, postoperative hospital stay, morbidity and mortality. **Results:** 39/40 procedures were completed laparoscopically with the da Vinci(TM) system. There were no intraoperative complications and only minor technical problems. Median hospitalization was 2 days. System set-up time decreased with increasing experience of the operating team. Operating time was at least comparable to times reported for standard laparoscopic cholecystectomy in the literature. There was neither postoperative mortality nor morbidity at the time of discharge and during short-term follow-up. **Conclusions:** Robot-assisted surgery was repeatedly proven as a safe and feasible approach to laparoscopic cholecystectomy.

47. Siebert, W, Mai, S, Kober, R, Heeckt Peter, F, et al. **Technique and first clinical results of robot-assisted total knee replacement.** Knee 2002;9(3):173-80. Total knee replacement (TKR) is a common procedure for treatment of severe gonarthrosis, but the outcome may be unsatisfactory due to primary malalignment of the prosthetic components. In order to improve precision and accuracy of this surgical procedure, a commercial robotic surgical system (CASPAR) has been adapted to assist the surgeon in the preoperative planning and intraoperative execution of TKR. So far, 70 patients with idiopathic gonarthrosis were successfully treated with a robot-assisted technique in our institution. No major adverse events related to the use of the robotic system have been observed. The mean difference between preoperatively planned and postoperatively achieved tibiofemoral alignment was 0.8 degrees (0-4.1 degrees) in the robotic group vs. 2.6 degrees (0-7 degrees) in a manually operated historical control group of 50 patients. A clear advantage of robot-assisted TKR seems to be the ability to execute a highly precise preoperative plan based on computed tomography (CT) scans. Due to better alignment of the prosthetic components and improved bone-implant fit, implant loosening is anticipated to be diminished which may be most evident in non-cemented prostheses. Current disadvantages such as the need for placement of fiducial markers, increased operating times and higher overall costs have to be resolved in the future. Copyright 2002 Elsevier Science B.V.

48. Stahl, KD, Boyd, WD, Vassiliades, TA, Karamanoukian, HL. **Hybrid robotic coronary artery surgery and angioplasty in multivessel coronary artery disease.** Annals of Thoracic Surgery 2002;74(4):S1358-S1362. **Background.** Complete surgical revascularization that includes left internal thoracic artery grafting to the left anterior descending coronary artery remains the gold standard of treatment for coronary artery disease. Not all patients are good candidates for sternotomy. Therefore, we sought to

identify a strategy that would combine the long-term advantages of internal thoracic artery grafting to lessen surgical trauma while still allowing complete revascularization. **Methods.** A total of 54 consecutive patients from four institutions underwent hybrid revascularization combining surgery and angioplasty. All internal thoracic artery grafts were endoscopically harvested with robotic assistance using either the Aesop or Zeus system, and all anastomoses were manually constructed through a 4- to 6-cm anterior thoracotomy incision. Angioplasty was carried out to achieve total revascularization to ungrafted vessels. **Results.** There were no early or late deaths, myocardial infarctions, strokes, or wound infections. Of the patients, 37 (69%) were extubated in the operating room. Length of stay in the intensive care unit averaged 24.4 hours and hospital stay 3.45 days. In all, 16 patients (29.6%) required transfusion of packed red blood cells. Late complications included 1 patient with stent occlusion at 3 months and 2 patients with in-stent restenosis. Three patients were treated for postpericardiotomy syndrome. Mean follow-up was 11.7 months. Event-free survival was 87.1% and freedom from recurrent angina 98.3%. **Conclusions.** Hybrid endoscopic atraumatic internal thoracic artery to anterior descending coronary artery graft surgery combined with angioplasty is a reasonable revascularization strategy in multiple vessel coronary artery disease in selected patients. Longer follow-up and more patient data in a randomized study are needed to determine the patient cohort most likely to benefit from this approach. (c) 2002 by The Society of Thoracic Surgeons.

49. Su, L-M, Stoianovici, D, Jarrett Thomas, W, Patriciu, A, et al. **Robotic percutaneous access to the kidney: comparison with standard manual access.** *Journal of Endourology / Endourological Society* 2002;16(7):471-5. **PURPOSE:** To evaluate the efficiency, accuracy, and safety of robotic percutaneous access to the kidney (PAKY) for percutaneous nephrolithotomy in comparison with conventional manual techniques. **MATERIALS AND METHODS:** We compared the intraoperative access variables (number of access attempts, time to successful access, estimated blood loss, complications) of 23 patients who underwent robotic PAKY with the remote center of motion device (PAKY-RCM) with the same data from a contemporaneous series of 23 patients who underwent conventional manual percutaneous access to the kidney. The PAKY-RCM incorporates a robotic arm and a friction transmission with axial loading system to accurately position and insert a standard 18-gauge needle percutaneously into the kidney. The blood loss during percutaneous access was estimated on a four-point scale (1 = minimal to 4 = large). The color of effluent urine was graded on a four-point scale (1 = clear to 4 = red). **RESULTS:** The mean target calyx width was 13.5 +/- 9.2 mm in the robotic group and 12.2 +/- 4.5 mm in the manual group ( $P = 0.57$ ). When comparing PAKY-RCM with standard manual techniques, the mean number of attempts was 2.2 +/- 1.6 v 3.2 +/- 2.5 ( $P = 0.14$ ), time to access was 10.4 +/- 6.5 minutes v 15.1 +/- 8.8 minutes ( $P = 0.06$ ), estimated blood loss score was 1.3 +/- 0.49 v 1.7 +/- 0.66 ( $P = 0.14$ ), and color of effluent urine following access was 2.0 +/- 0.90 v 2.1 +/- 0.7 ( $P = 0.82$ ). The PAKY-RCM was successful in obtaining access in 87% (20 of 23) of cases. The other three patients (13%) required conversion to manual techniques. There were no major intraoperative complications in either group. **CONCLUSIONS:** Robotic PAKY is a feasible, safe, and efficacious method of obtaining renal access for nephrolithotomy. The number of attempts and time to access were comparable to those of standard manual

percutaneous access techniques. These findings provide the groundwork for the development of a completely automated robot-assisted percutaneous renal access device.

50. Talamini, M, Campbell, K, Stanfield, C. **Robotic gastrointestinal surgery : Early experience and system description.** *Journal of Laparoendoscopic and Advanced Surgical Techniques - Part A* 2002;12(4):225-232. **Background and Purpose:** Robotic technology has recently been introduced to gastrointestinal laparoscopic surgery. Its addition offers the promise of opening more procedures up to minimally invasive surgery. One system is described and illustrated in detail using antireflux surgery as an example. **Patients and Methods:** Seventy patients underwent robotically assisted gastrointestinal surgical procedures. These procedures were antireflux surgery (25), bowel resection (18), cholecystectomy (8), Heller myotomy (5), splenectomy (5), exploratory laparoscopy (4), adrenalectomy (1), pyloroplasty (1), and resection of a gastric mass (1) and duodenal (1) and colonic (1) polyps. **Results and Conclusion:** Seventeen percent of patients required conversion to either an open or a standard laparoscopic procedure. This early experience with the first Food and Drug Administration-approved general surgery robotic surgical system showed that it is safe and effective, the system has significant promise.

51. Talamini, MA, Chapman, S, Horgan, S, Melvin, WS. **A prospective analysis of 211 robotic-assisted surgical procedures.** *Surgical Endoscopy* 2003;17(10):1521-1524. **Background:** The Academic Robotics Group prospectively studied 211 robotically assisted operations to assess the safety and utility of robotically assisted surgery. **Methods:** All operations took place at one of four member institutions between June 2000 and June 2001 using the recently FDA-approved daVinci robotic system. A variety of procedures were undertaken, including antireflux surgery (69), cholecystectomy (36), Heller myotomy (26), bowel resection (17), donor nephrectomy (15), left internal mammary artery mobilization (14), gastric bypass (seven), splenectomy (seven), adrenalectomy (six), exploratory laparoscopy (three), pyloroplasty (four), gastrojejunostomy (two), distal pancreatectomy (one), duodenal polypectomy (one), esophagectomy (one), gastric mass resection (one), and lysis of adhesions (one). **Results:** Average operating room time was 188 min (range 45 to 387, SD = 83), surgical time 143 min (range 35 to 462, SD = 63), and robot time 90 min (range 12 to 235, SD = 47). Median length of stay was 1 day (range 0 to 37). There were 8 (4%) technical complications during procedures, five minor (four hook cautery dislodgement, one slipped robotic trocar) and three major (system malfunctions, two of which required conversion to standard laparoscopy). In all cases, technical problems caused only delay, without apparent altered outcome. There were medical/surgical complications in nine patients (4%). Six (3%) were considered major, including one death unrelated to the robotic procedure. **Conclusions:** The results of robotic-assisted surgery compare favorably with those of conventional laparoscopy with respect to mortality, complications, and length of stay. Robotic-assisted surgery is safe and effective and is a new reality for American surgery. The role of these devices in surgery will expand as the technology evolves.

52. Tewari, A, Srivasatava, A, Menon, M. **A prospective comparison of radical retropubic and robot -assisted prostatectomy: experience in one institution.** BJU international **2003**;92(3):205-10. The authors from the Vattikuti Institute in the USA report a prospective comparison of radical prostatectomy and robot -assisted prostatectomy. They found that the robot -assisted procedure was safer, and yielded favourable oncological and functional results. They also present work in association with the Department of Urology in Mansoura into robot -assisted radical cystoprostatectomy and urinary diversion, and point out the advantages and disadvantages associated with performing the most complex types of urinary diversion. There is also an interesting paper relating to the association between sexual factors and prostate cancer, from authors in institutions in Australia, New Zealand and Italy. They found that in a case-control study of men aged <70 years, ejaculatory frequency was negatively associated with the risk of prostate cancer. Technology has made many contributions to the management of urological patients. The classic example is that of urinary stone management. Authors from the USA evaluated cyroablation of renal carcinoma in patients with solitary kidneys. They are encouraged by their results and suggest that there is merit in this treatment, but indicate the need for a longer follow-up. **OBJECTIVE:** To prospectively compare standard radical retropubic prostatectomy (RRP) and the robotically assisted Vattikuti Institute prostatectomy (VIP) in the management of localized prostate cancer. **PATIENTS AND METHODS:** The study was a single-institution, prospective, unrandomized comparison of histopathological, and functional outcomes, at baseline and during and after surgery, in 100 patients undergoing RRP and 200 undergoing VIP. **RESULTS:** While the variables before surgery, the operative duration (163 vs 160 min) and pathological stages were comparable, there were significant differences in the measured outcomes. The blood loss was 910 and 150 mL for RRP and VIP, respectively, and transfusion was greater after RRP (67% vs none; both  $P < 0.001$ ). There were four times as many complications after RRP (20% vs 5%,  $P < 0.05$ ), the haemoglobin level at discharge was lower (100 vs 130 g/L,  $P < 0.005$ ) and the hospital stay longer (3.5 vs 1.2 days;  $P < 0.05$ ). Most (93%) of VIP and none of the RRP patients were discharged within 24 h ( $P < 0.001$ ); the duration of catheterization was twice as long after RRP (15.8 vs 7 days;  $P < 0.05$ ). Positive margin was more frequent after RRP (23% vs 9%,  $P < 0.05$ ). After VIP, patients achieved continence and return of erections more quickly than after RRP (160 vs 44, and 180 vs 440 days, both  $P < 0.5$ ). The median return to intercourse was 340 days after VIP but after RRP half the patients have as yet not resumed intercourse at 700 days ( $P < 0.05$ ). **CONCLUSIONS:** The VIP procedure appears to be safer, less bloody and requires shorter hospitalization and catheterization. The oncological and functional results were favourable in patients undergoing VIP.
53. Theodossy, T, Bamber, MA. **Model surgery with a passive robot arm for orthognathic surgery planning.** Journal of Oral and Maxillofacial Surgery **2003**;61:1310-1317. Purpose: The aims of the study were to assess the degree of accuracy of model surgery performed manually using the Eastman technique and to compare it with model surgery performed with the aid of a robot arm. Patients and Methods: Twenty-one patients undergoing orthognathic surgery gave consent for this study. They were divided into 2 groups based on the model surgery technique used. Group A (52%) had model surgery performed manually, whereas group B (48%) had their model surgery performed using the robot arm. Patients' maxillary casts were measured before and after model surgery, and results were compared with those for the original treatment plan in horizontal (x-axis), vertical (y-axis), and transverse (z-axis) planes. Results: Statistical analysis using Mann-Whitney U test for x- and y-axis and independent sample t test for z-axis have shown significant differences between both groups in x-axis ( $P = .024$ ) and y-axis ( $P = .01$ ) but not in z-axis ( $P = .776$ ). Conclusions: Model surgery performed with the aid of a robot arm is significantly more accurate in anteroposterior and vertical planes than is manual model surgery. Robot arm has an important role to play in orthognathic surgery planning and in determining the biometrics of orthognathic surgical change at the model surgery stage. (C) 2003 American Association of Oral and Maxillofacial Surgeons.
54. Torracca, L, Ismeno, G, Franze, V, Alfieri, O. **The use of robotic technology in the LAST operation.** Italian heart journal - official journal of the Italian Federation of Cardiology **2001**;2(12):900-3. **BACKGROUND:** The LAST operation represents a good option for single left anterior descending artery (LAD) revascularization. We report our preliminary experience with the LAST operation performed with the aid of the "da Vinci" Intuitive robotic system. **METHODS:** From January 2000 to May 2001, 12 patients (11 males and 1 female, mean age 62 +/- 8 years) underwent the LAST operation. All patients had a proximal LAD lesion either not suitable for coronary angioplasty or unsuccessfully treated at coronary angioplasty previously. The mean preoperative ejection fraction was 55 +/- 5%. In all patients, left internal mammary artery (LIMA) harvesting was carried out endoscopically using robotic technology. After heparin administration the LIMA was distally divided to check the adequacy of the blood flow. An incision of about 6 cm was then made in the appropriate intercostal space and the LAD was exposed using a special costal retractor. Following the insertion of a temporary intracoronary shunt, the LIMA was anastomosed to the LAD. **RESULTS:** No hospital or delayed death occurred. Uneventful conversion to midline sternotomy was necessary in one patient who developed ischemic changes and hemodynamic instability. One patient had a revision for postoperative bleeding. All patients were discharged within the first postoperative week and in 4 of them optimal patency of the LIMA graft was angiographically documented. **CONCLUSIONS:** The use of robotic technology seems to overcome all the drawbacks associated with the LAST operation and enhances the role of minimally invasive surgery in coronary artery revascularization.
55. Trehan, N, Mishra, YK, Sharma, M, Bazaz, S, et al. **Robotically controlled video-assisted port-access mitral valve surgery.** Asian Cardiovascular and Thoracic Annals **2002**;10(2):133-136. From 1997 to 2000, 221 patients underwent mitral valve surgery through a minithoracotomy, using a port-access endovascular cardiopulmonary bypass system in 38 and a transthoracic clamp in 183. In 120 patients, exposure of the mitral valve was facilitated by an endoscope attached to a voice-controlled robotic arm (AESOP 3000). The mitral valve was repaired in 26 patients and replaced in 195; 24 were redo cases. Operating time was 3.5 +/- 1.2 hours, aortic crossclamp time was 58 +/- 16 minutes, intensive care unit stay was 22



+/- 7 hours, and hospital stay was 6.4 +/- 1.2 days. Median postoperative blood loss was 332 +/- 104 mL. There was 1 hospital death. On follow-up at 16.4 +/- 12.2 months, there was no late death or reoperation. New York Heart Association functional class improved from 2.6 +/- 0.5 to 1.4 +/- 0.8. Use of video and robotic assistance minimized incision length and allowed visualization of the whole mitral valve apparatus. The transthoracic clamp facilitated aortic crossclamping and injection of cardioplegia. These findings indicate that the procedure is safe and effective and suggest advantages over conventional surgery in terms of cost, cosmesis, blood loss, postoperative discomfort, intensive care unit and hospital stay.

56. Uranus, S, Machler, H, Bergmann, P, Huber, S, et al. **Early experience with telemanipulative abdominal and cardiac surgery with the Zeus (TM) robotic system.** *European Surgery - Acta Chirurgica Austriaca* 2002;34(3):190-193. *Background:* In the past 15 years, abdominal and thoracic surgery has been greatly changed by the introduction of minimally invasive techniques; these offer great advantages for the patient but pose problems for surgeons. Disadvantages due to the limited movement radius of the endoscopic instruments and the rigidity of the instrument tips can be reduced or eliminated by the use of computer-assisted telemanipulators. *Methods:* We report our experience with eight abdominal and seven heart operations performed between 16 March and 31 July 2001 with a Zeus (TM) surgical robotic system. There were four cholecystectomies, four Nissen funduplications, five atraumatic dissections of the left internal mammary artery (ITA), and two pericardotomies. *Results:* All but one operation were completed successfully with the Zeus (TM) device. No patient suffered any peri- or postoperative complications. Due to an electronic defect in one of the manipulators, the final cholecystectomy had to be completed as a conventional laparoscopic procedure. The duration of surgery was about 40% longer than with conventional laparoscopic technique. The specific costs related to the robotic system were EUR 910 per operation. *Conclusions:* Computer-assisted manipulators are at a developmental stage that allows their successful use in clinical applications. Routine use is, however, at present only possible with a limited number of procedures.

57. Vassiliades Jr, TA. **Technical aids to performing thoracoscopic robotically-assisted internal mammary artery harvesting.** *Heart Surgery Forum* 2002;5(2):119-124. *Objective:* This report outlines the procedures and technical aids used for performing thoracoscopic internal mammary artery (IMA) harvesting in a series of 308 patients. *Methods:* As a part of atraumatic coronary artery bypass (ACAB) operations, thoracoscopic LMA harvests (294 left, 14 right, and 12 bilateral) were performed in 308 consecutive patients. Single-lung ventilation and carbon dioxide insufflation were employed in all cases to facilitate exposure and dissection. A voice-activated robotic arm controlled the camera view, and harvesting was accomplished with the electrocautery on a low setting. *Results:* Harvest time decreased from a mean of 58.4 minutes in the first fifty procedures to 29.4 minutes in the last fifty procedures. There were no significant complications as a result of this technique, and no patients required a conversion to sternotomy as a result of IMA injury. *Conclusions:* Thoracoscopic internal mammary artery harvesting is an essential basic skill for cardiac surgeons interested in performing minimally invasive and

atraumatic coronary bypass procedures. Thoracoscopic IMA harvesting can be successfully performed with the use of the technical aids and procedures outlined in this report.

58. Whyte Richard, I, Crownover, R, Murphy Martin, J, Martin David, P, et al. **Stereotactic radiosurgery for lung tumors: preliminary report of a phase I trial.** *Annals of thoracic surgery* 2003;75(4):1097-101. *BACKGROUND:* Stereotactic radiosurgery is well established for the treatment of intracranial neoplasms but its use for lung tumors is novel. *METHODS:* Twenty-three patients with biopsy-proven lung tumors were recruited into a two-institution, dose-escalation, phase I clinical trial using a frameless stereotactic radiosurgery system (CyberKnife). Fifteen patients had primary lung tumors and 8 had metastatic tumors. The age range was 23 to 87 years (mean, 63 years). After undergoing computed tomography-guided percutaneous placement of two to four small metal fiducials directly into the tumor, patients received 1,500 cGY of radiation in a single fraction using a linear accelerator mounted on a computer-controlled robotic arm. Safety, feasibility, and efficacy were studied. *RESULTS:* Nine patients were treated with a breath-holding technique, and 14 with a respiratory-gating, automated, robotic technique. Tumor size ranged from 1 to 5 cm in maximal diameter. There were four complications related to fiducial placement: three pneumothoraces requiring chest tube insertion and one emphysema exacerbation. There were no grade 3 to 5 radiation-related complications. Follow-up ranged from 1 to 26 months (mean, 7.0 months). Radiographic response was scored as complete in 2 patients, partial in 15, stable in 4, and progressive in 2. Four patients died of non-treatment-related causes at 1, 5, 9, and 11 months after radiation. *CONCLUSIONS:* Single-fraction stereotactic radiosurgery is safe and feasible for the treatment of selected lung tumors. Additional studies are planned to investigate the optimal radiation dose, best motion-suppression technique, and overall treatment efficacy.

59. Wolfram, M, Brautigam, R, Engl, T, Bentas, W, et al. **Robotic-assisted laparoscopic radical prostatectomy: the Frankfurt technique.** *World journal of urology* 2003;21(3):128-32. *The robotic technique, which was first introduced in laparoscopic heart surgery, has revolutionized laparoscopic surgery over the last 5 years. In May 2000, our department accomplished the first robot assisted laparoscopic radical prostatectomy. Since that time we have performed more than 118 such procedures and several other laparoscopic operations using the robotic technique. We here summarize our experience in robot assisted laparoscopic radical prostatectomy as it has been developed over the past 3 years. Between May 2000 and May 2003, 118 patients with clinically localized prostate cancer were operated using the telerobotic da Vinci Surgical System. Operations were performed with a senior surgeon at the console, assisted by an assistant and a nurse at the operating table. Bilateral pelvic lymph node dissection was undertaken as a first step in all patients. In the initial 60 cases, we investigated different laparoscopic approaches. We used transperitoneal as well as extraperitoneal approaches. For dissection of the prostate we used ascending, descending as well as combined techniques. The combined ascending and descending technique via the transperitoneal route was chosen in 30 patients, and via the extraperitoneal route in seven patients. A modification of the descending Montsouris technique was performed in 81 patients. The robot assisted*

## Bibliography\*: Robotic surgery

*laparoscopic radical prostatectomy with the da Vinci system has been well standardized . After performing more than 100 radical prostatectomies with this system, we conclude that in our hands the Montsouris technique with only minor*

*adoptions is the most appropriate technique for performing robot assisted radical prostatectomy.*

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