

# Robot assisted gastro-intestinal surgery. Is it really worth it?

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REVIEW

GENERAL SURGERY



**ABSTRACT:** This paper intends to be a review on the idea and concept of robotic surgery. Also the basic historical background is discussed.

Robotic surgery offers several potential advantages, such as three-dimensional visualization, increased surgical field magnitude and an increased number of degrees of freedom. There are also ergonomic innovations which promise a more favorable handling of the instruments and permit the disappearance of tremor. We should not lose sight of this new technology as an advanced engineering work and without a doubt, that the progress will be made. We analyze the available information about robot surgery with an emphasis on the impact on digestive procedures.

**KEYWORDS:** Robotic surgery, Da Vinci surgical system, general surgery, gastro intestinal surgery.

## Introduction

Surgery has been a constantly and rapidly evolving branch of medicine. The advent of laparoscopy at the end of the last century allowed the concept of minimal invasion. Numerous procedures adapted to technical endoscopic benefit of patients (less pain after surgery, stays shorter, more comfortable postoperative course and better cosmetic results).<sup>1</sup>

Endoscopic surgery revolutionized the world of modern surgery, however in the past decade robot assisted surgery has become the next paradigm of our age.<sup>2</sup> If technological progress continues with the same intensity, possibly laparoscopic surgery will become a technology in the process of transition to robotic surgery. The advantages of the latter are evident:

- Better depth perception (image in three dimensions).
- Correction of postural vices and operative tremor.
- Potentiation of maneuverability.

Surgical specialties such as general surgery, urology, gynecology, neurosurgery, cardiovascular surgery, among others, have dabbled in this technology.<sup>3</sup> Numerous efforts around the world are geared towards perfecting the efficiency of robotic surgery, and we will continually witness dizzying progress. The expansion rate depends only on the affordability, when an equilibrium point is achieved between cost and benefit. In the medium and long term, robotic technology will be a very useful tool for the surgeon's performance, practically of any specialty.

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## Concept

Robotic Surgery is a term widely used by the medical profession and the media. It refers to the technology that places an electromechanical device between the surgeon and the patient. A more scientific concept corresponds to that of "computer assisted surgeon", since explicit and direct control of the human operator is required.<sup>4</sup>

The SAGES (Society of American Gastrointestinal Endoscopic Surgeons) defines robotic surgery as a surgical procedure with technology that facilitates the interaction between the surgeon and the patient, which can assume some degree of control.<sup>5</sup>

In laparoscopic surgery, the surgeon controls and manipulates the tissue directly, in front of the patient and through a support point on the abdominal wall. This differs from the robotic system, where the surgeon enters a virtual environment, away from the patient, outside the sterile field, control over the operation is maintained, but control is indirect and distant.

## History and evolution

The history of robotic surgery begins in the 1940s with the term "telem Manipulation" or "telepresence".<sup>6</sup> A late 1980s in the United States of America through the DARPA (Defense Advanced Research Projects Agency) developed a program of remote surgery for the battlefield. The idea was to replace to the surgeons with robots and minimize human casualties. It turned out unviable due to changes in policy on how and where the wounded soldiers would be treated. However, this program achieved significant advances

in technology robotics. The race for control of the market was fierce. In 1992 “RoboDoc” (Integrated Surgical Systems UK) was presented in England as the first mechanical assistant for hip and knee arthroplasty surgery. The 1994 AESOP project (Automated Endoscopic System for Optical Positioning) with model 1000, was the first robot in the world approved by the FDA. In 1996, the company Computer Motion Inc. developed innovations up to the AESOP 4000 (intelligent robotic arm controlled by means of a digitized card that recognizes the voice of each surgeon).<sup>7</sup> On 3 March 1997 was carried out the first laparoscopic cholecystectomy assisted by robot (Hospital St Blasius in Dendermonde, Belgium). Surgeons were J. Himmens and GB Cadiere, using the robot MONA (Intuitive Surgical, Mountain View, California, United States).<sup>8</sup>

In July 2000, the “Da Vinci”<sup>®</sup> Surgical System presented a remote console (in which the surgeon was positioned), with a three-dimensional optical system and 2 manual controls for instrument manipulation. It has 4 articulating arms, one supports the camera and the remaining 3 are used to position and maneuver the specific surgical instruments of the system. Robotic technology digitizes the surgeon's hand movements on the console, eliminates any tremors, and reproduces the degrees of mobility of the human wrist in real time. These properties exceed the maneuvering and dissecting capabilities of the instruments available in conventional laparoscopic surgery.<sup>9</sup>

Without a doubt, September 2001 can be considered as the true conceptual watershed of Robotics. On this date, a cholecystectomy was performed, with the surgeon in a New York building (Equant Building), and the patient on the other side of the Atlantic.

### Clinical applications

The contrast between the great advantages of robotic technology and its limited advance in expansion and adoption, is mainly explained by the high cost of the system and some practical limitations in the technical and logistical sphere.<sup>10</sup> Despite this, in the last 12 years, various surgical groups around the world have incorporated robotic technology in their daily practice, and report their experience in the scientific literature. Today there are around 2,000 “da Vinci” systems installed in the world and around 350,000 surgeries are performed per year.<sup>11</sup>

### Cholecystectomy

The cholecystectomy is the procedure of choice to start the robotic surgical experience, according to most surgical groups. For this reason, since 2001, numerous publications of cholecystectomies associated with

series of other procedures have been reported.<sup>4</sup> Breitenstein at the University of Zurich (Switzerland) published in 2008 the only comparative case-control study in 100 patients. (50 robotic cholecystectomies versus 50 laparoscopic). The intervention time and results were comparable, but the costs were higher for the robotic group.<sup>12</sup>

### Nissen funduplication

Cadière reports funduplications (CHU St Pierre, Brussels, Belgium) with the MONA robotic system since 1998.<sup>13</sup> The first robotic Nissen with the “da Vinci” system was published by Chapman in 2001 (North Carolina University, United States).<sup>14</sup> Giulianotti et al. Found that the surgical time and the incidence of conversion are similar, but with less morbidity and hospital stay in the robotic group.<sup>15</sup> The group Melvin (Ohio State University, USA) compared robotic Nissen vs laparoscopic Nissen, and they found robotic Funduplication had a 45 minutes more of duration on average, with no statistical difference.<sup>16</sup>

The strongest evidence comes from studies prospectively and randomly comparing robotic and laparoscopic Nissen. Morino et al. (University of Turin, Italy) carried out a comparative clinical study in 50 cases of Nissen. The surgical time was shorter in the laparoscopic group (131.3 versus 91.1;  $p < 0.001$ ). The cost of the robot-assisted procedure was significantly higher than that of the laparoscopic procedure (3,157 euros vs. 1,527 euros;  $p < 0.001$ ). There was no significant difference in clinical, endoscopic and functional results between the groups.<sup>17</sup> Nakadi (Hospital Erasme, Belgium) conducted a study to compare the benefits and costs associated with robotic and laparoscopic Nissen in 20 patients (9 robotic vs. 11 laparoscopic). The robot-assisted Nissen funduplication was associated with increased operating time and costs.<sup>18</sup> Likewise, Müller-Stitch (University of Heidelberg, Germany) studied 40 patients comparing operating time, costs and perioperative results. Here, the operative time was shorter for the robotic group (88 vs. 102 minutes;  $p=0.033$ ), without significant differences in clinical results, but with a higher cost for the robotic group.<sup>19</sup> A meta analysis published in 2010,<sup>20</sup> indicated that robot-assisted funduplication is a viable and safe alternative with some technical advantages. However it did not show a clear benefit in comparison to laparoscopy and provided the cost was increased.

### Heller myotomy

The first robotic Heller myotomy was performed in 2001 by the group Melvin (Ohio State University Medical Center, USA), and the same author published

in 2005 excellent results at 16 months follow-up in 104 cases without intraoperative perforation.<sup>21</sup>

Horgan et al. Conducted a prospective, non-randomized study in 121 patients with Achalasia. In this study 62 patients were treated with laparoscopic Heller myotomy, compared to 59 patients with robotic Heller myotomy. The operative time was longer for the robotic group (141 vs 122;  $p < 0.05$ ). However, in the last 30 cases there was no significant difference between the groups (108 minutes vs. 104 minutes). Intraoperative perforation was more frequent in the laparoscopic group (16% vs. 0%;  $p < 0.01$ ), with similar postoperative results.<sup>22</sup>

Other authors agree with these results. Iqbal published in 2006 his experience using the robot against conventional laparoscopic surgery in 70 patients with achalasia.<sup>23</sup> Huffman from the University of Cincinnati (Ohio, USA), carried out a comparative prospective analysis in 61 patients with achalasia: 37 laparoscopic Heller versus robotic.<sup>24</sup> They found better results in the quality indexes, without perforations in the robotic group, in contrast to three esophageal perforations in the laparoscopic group (8%).<sup>24</sup>

### Esophagectomy for cancer

In 2003, Horgan describes a transhiatal total esophagectomy with a robot. Six years later, the group of Van Hillegerberg at the Utrecht University Center (Netherlands), reported the results of 21 esophagectomies treated with robotic esophageal cancer. The mean operating time was 180 minutes (120-240). The authors considered that lymphadenectomy is effective, with little blood loss, they declared 48% of pulmonary complications and one death from tracheoesophageal fistula (5%).<sup>25</sup>

Galvani (University of Illinois, Chicago, USA) described his initial experience in transhiatal esophagectomy in 18 patients. The procedure was completed with assistance from the robot in all cases, the mean operating time was 267 minutes, the estimated blood loss was 54 ml (10-150 ml), an average of 12 nodes per piece (7-27) and 11 disease-free patients disease-free at 22-month follow-up.<sup>26</sup>

Dunn et al in 2013 performed 40 transhiatal esophagectomies (38 patients with esophageal cancer, 1 benign refractory stenosis, 1 high-grade dysplasia), R0 resection was achieved in 94.7% of cases. The mean operative time was 311 minutes, with minimal bleeding in 27 patients, and the most frequent complication was anastomosis stenosis. Authors emphasize the low morbidity despite be a demanding procedure.<sup>27</sup>

### Bariatric surgery

The first robotic bariatric surgery was performed with the MONA robot in 1999.<sup>28</sup> The subsequent experience published so far corresponds to North American groups.

Horgan (University of Illinois, Chicago, USA) published excellent results in 2004 in a series of 110 gastric bypasses and 32 bands. Three strictures occurred in the gastric bypass group (no fistula) and one marginal ulcer in the band group. The authors highlight the reduction in surgical time after overcoming the learning curve.<sup>29</sup>

Ali from the University of California-Davis (Sacramento, California, USA) reported in 2008 a retrospective / comparative study of 140 robot-assisted bypasses (80 with Zeus and 60 with "da Vinci"). It concludes that the robotic system change does not affect surgical time or results.<sup>30</sup>

Mohr and colleagues from Stanford University (California, USA) made a retrospective review of 75 gastric bypasses assisted by robot. Results were compared between three residents to examine the learning curve. It concludes that the robotic gastric bypass is associated with a reduction in the learning curve.<sup>31</sup>

Finally Wilson in 2013 (University of Texas, Houston, USA) presents a retrospective review of 1100 robotic bypasses. It mentions an average surgical time of 155 minutes, a fistula (0.09%), 9 cases of staple line bleeding (0.82%), 2 cases of pulmonary thromboembolism (0.19%), without conversions.<sup>32</sup>

### Gastrectomy for cancer

Hashizume in Japan published his experience in 2002.<sup>33</sup> Then the group of Giulianotti reported 21 gastrectomies (8 subtotal gastrectomies and 10 total gastrectomies, 2 partial by ulcer and peptic ulcer gastrectomy from carcinoid tumour).<sup>14</sup>

Woo (Yonsei University College of Medicine, Seoul, Korea) presents a retrospective review of 827 gastric cancer patients (236 robotic gastrectomies versus 591 laparoscopic gastrectomies). The surgical time was greater for the robotic group (219 minutes vs. 170 minutes), with comparable preoperative results. The author highlights the technical feasibility of the procedure and the satisfactory results in patients in stage Ia and Ib.<sup>34</sup>

### Liver

Giulianotti in Chicago, USA, reports in 2011 his experience of 70 robotic liver resections. In 38% of the patients, major liver resections were performed ( $\geq 3$  liver segments). The average surgical time was 314

minutes, bleeding of 150 milliliters, low conversion rate (5%), and no deaths were reported.<sup>35</sup> Chan and collaborators have similar results in 2011 with 27 patients (morbidity of 7.4%).<sup>36</sup>

### Pancreas

Also Giulianotti reported in two centers (University of Illinois, USA / Ospedale Misericordia, Gosseto, Italy), a series of 134 robot assisted pancreatectomies (60W Hipple, 23 distal pancreatectomies, 23 distal pancreatectomies with spleen preservation, three middle ancreatectomies, one total pancreatectomy and three enucleations), with mean surgical time of 331 minutes, mortality of 2.3% and morbidity of 26%. The feasibility and safety of the procedure are emphasized, with results comparable to those of open surgery, but with the benefits of minimal invasion.<sup>37</sup>

### Colon and rectum

D'Annibale (Ospedale di Camposampiero, Padova Italy) published in 2004 the results of a series of 106 patients with benign and malignant diseases of the colon in different locations. The advantages of robotic technology in the critical steps of surgery are highlighted.<sup>38</sup>

De Souza in 2010 shows the results of a series of 40 right to robot-assisted hemicolectomies and compares them retrospectively with 135 patients with a laparoscopic approach. The robotic procedure is associated with longer operative time and higher costs.<sup>39</sup>

Deutsch (North Shore University Hospital, New York), presented in 2012 their experience with 171 patients (benign and malignant of the colon, 79 colectomies against 92 laparoscopic colectomies) no significant differences found as to hospital stay, postoperative results or complications.<sup>40</sup>

Kwak and his group in South Korea, retrospectively compared 118 patients with rectal cancer (59 with robot versus 59 with laparoscopy). The results from the oncological point of view were similar, the time was longer for the robotic group, without mortality. In addition to these experiences, there are systematic reviews that highlight the feasibility and safety of the robotic approach to the rectum.<sup>41</sup>

### Other specialties

Several specialties have published their experiences. In urology, the most recent meta-analyses are conclusive and demonstrate the benefits of prostatectomy: less postoperative pain, shorter stays, more comfortable postoperative evolution, and even better results of erectile function.<sup>42</sup> Some of the

gynecologic indications for robotic surgery are very specific such as tubarian anastomosis, myomectomy and radical hysterectomy with lymph node dissection.<sup>43</sup> The robotic system has also been used successfully for lobectomies, thymectomies, and resection of mediastinal tumors.<sup>44</sup>

### Discussion

The concept of Robotic Surgery defies the established dogma and proposes a new challenge to the surgical community. Our generation must define its posture between pressures and atavisms. Health systems and surgical organizations must necessarily rule on it. Economic interests cannot be the catalyst for change, but the scientifically proven benefit for the patient. Thus, the future of surgical robotics is only far limited by the imaginative capacity.

All over the world, groups of scientists, hand in hand with large corporations, work in countless lines of research: development of intelligent instruments, advances in vision (computer-assisted vision, real-time microscopic vision), surgery integrated with techniques of imaging (ultrasound, computed tomography, magnetic resonance), simulation of surgical procedures, robot miniaturization, development of flexible platforms for endoluminal surgery, robot locomotion, robotic neural control, surgery under suspended animation, surgery with virtual navigation, etc.<sup>5,45</sup>

We are convinced that radical attitudes in any sense do not favor a healthy balance when it comes to evaluating an innovation. We will have to consider that the technology we have today is only the first step in a long and exciting adventure, where the future of surgery will inevitably be closely linked to robots. In the area of General Surgery and very particularly in Gastrointestinal Surgery, robotics has a facilitating role, currently unattainable for most surgical centers, due to its high cost. It will be necessary to anticipate the future, capacitation of well established surgical teams, guided by scientific and ethical criteria, pending this accessible technology.

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