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Robotic-Assisted Laparoscopy: THE DA VINCI ® ROBOT General Principles

Dr Mohammed LAHFAOUI
Depatement of pediatric surgery
University MED I
Oujda, Morocco

Pr Mohammed Boughaleb
Departement of Mecatronic
University MED I
Oujda, Morocco

Pr Houssine Benhaddou
Depatement of pediatric surgery
University MED I
Oujda, Morocco

Abstract:- Since 1990, laparoscopy and minimally invasive techniques have revolutionized digestive surgery. Nevertheless, the use of conventional laparoscopy remains limited to procedures of low complexity (cholecystectomy, appendectomy) or intermediate complexity (fundoplicature, segmental colectomies). The aim of this article is to present the technical characteristics of the da Vinci® robot, and to better define its potential applications in digestive surgery. Indeed, if cholecystectomy as well as gastric fundoplicature lend themselves well to robotic surgery, robotic surgery in these indications does not offer any advantage over classical laparoscopy. The same is probably not true for more complex procedures such as gastric bypass or total mesorectal resection.

Keywords:- *Laparoscopy; Robotic surgery.*

I. INTRODUCTION

Over the last twenty years, the development of new technologies has significantly influenced surgical practice, often anticipating the demands of evidence-based medicine. So-called "minimally invasive" laparoscopic surgery has demonstrated its benefits, and sometimes its superiority in terms of postoperative comfort, over traditional surgery in many situations.1-3 However, in some indications, laparoscopic surgery has shown its limitations and has been slow to become established in routine clinical practice for several reasons. Firstly, learning laparoscopy is often laborious with prolonged operating times, due to the difficulty for the surgeon to find his or her anatomical landmarks on the two-dimensional image provided by the camera.4 The mobility of the instruments and the degree of freedom they allow are limited by the position of the trocars,5 and finally, the physiological tremor of the surgeon's hand is amplified by the length of the instruments.6 In this context, the development of robotically assisted surgery has been part of a process aimed at bringing the benefits of laparoscopy to patients, while overcoming the limitations inherent in this approach.7

II. BACKGROUND

The initial development of robotics and its surgical applications was carried out by NASA and the U.S. military, who in the 1970s and 1980s integrated telesurgery into their research programs with the aim of performing complex operations remotely, either on war wounded or on cosmonauts. These projects quickly led to the parallel development of two robotic systems: the da Vinci® system (of the US Army in collaboration with the Stanford research institute) and the Zeus robot (NASA).8 These two projects were patented and then marketed separately (da Vinci® by Intuitive surgical system and Zeus by Computer motion) after receiving the green light from the Food and Drug Administration (FDA) in 2001 for their use in digestive surgery.9

Almost simultaneously, the first telerobotic transatlantic cholecystectomy (called the Lindbergh operation) was performed using the Zeus robot in September 2001, with the operator in New York and the patient in Strasbourg.10 This first operation took place a few days before the tragic events of September 11 and unfortunately never received the media attention it deserved. In 2003, the company Computer Motion was bought by its competitor, which put an end to the existence of the robot Zeus and its derivative products. In fact, Intuitive surgical system now has an exclusive monopoly on this technology and is working hard to make its profits grow. Today, no less than 500 da Vinci® robots are in use worldwide (including two in Geneva) and technological advances are continuing while awaiting the launch of a new high-definition visualization system this autumn.

III. THE DA VINCI ® ROBOT\

The da Vinci® robotic system consists of three distinct elements: the surgical console (the control station), the mobile cart (the robot itself) and the imaging tower (identical to that used in "classic" laparoscopic surgery). The surgical console represents the surgeon's workspace (figure 1). The surgeon is seated in an ergonomically optimal position that allows him to control the movements of the surgical instruments via the electronic circuits connecting the two joysticks to the arms of the mobile cart. The console is equipped with a three-dimensional "Insite vision" optical system and two joysticks for remote manipulation of the three robot arms (four on the newer models), as well as a footswitch to manage the camera movements and to operate the unipolar coagulation control (figure 2).

Fig 1:- da Vinci Control Panel. The surgeon is comfortably installed, arms supported and eyes "immersed" in the operating field.

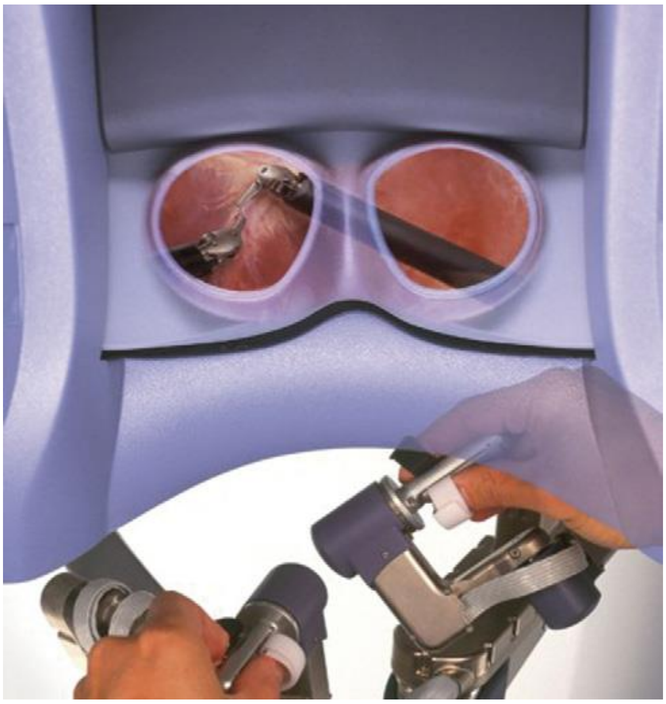

Fig 2 :- da Vinci Vision System. Two tri-CCD cameras provide real 3D vision. The hands are in the.

The mobile carriage has three or four arms (on the most recent model), two are dedicated to the instruments (clamps, coagulators) which have the important characteristic of having an intracorporeal joint, the third arm carrying the camera (figure 3). Each of these arms has several articulations that allow movement of the instruments in all planes of space. In addition, a whole range of specific instruments is available, all offering seven degrees of freedom and thus the possibility of reproducing, in the patient's abdomen, complex movements, such as those required to perform a digestive anastomosis (figure 4). All of these instruments can be re-sterilised about ten times, at an average cost of CHF 2,000. which is added to the cost of purchasing the system itself (CHF 1,500,000.) as well as the maintenance costs (about CHF 150,000. per year).

Finally, the imaging tower consists of a video column, with two light sources and thus two cameras, to which is added a CO2 insufflator and a control screen allowing the instrumentation technician and assistants to follow the intervention. In summary, the potential advantages of this robotic system are threefold:

- Increased dexterity due to the presence of seven degrees of freedom;
- suppression of physiological tremor;
- Three-dimensional vision of the surgical field.

This approach effectively combines the advantages of laparoscopy and open surgery, with the surgeon feeling as if he is working with his hands inside the patient's abdomen, with unlimited possibilities of movement and perfect vision.

It is therefore logical that the potential benefits of robotically assisted surgery should be reserved for technically difficult procedures or those taking place in limited spaces. The procedure that has benefited most from this technological advance is radical prostatectomy. Current data in the literature are consistent and report simpler postoperative outcomes, oncologically adequate resection margins, and results in terms of sexual or urinary function superior to those obtained with either open surgery or conventional laparoscopic surgery.

Fig 3:- da Vinci Robot "S" with four arms. Latest product from Intuitive Surgical, sold for 1,400,000 euros.

Fig 4:- da Vinci instruments. The 7 degrees of freedom reproduce those of the human upper limb.

IV. THE DA VINCI ® ROBOT IN DIGESTIVE SURGERY

It is now accepted that almost all common digestive surgery procedures can be performed with the da Vinci® robot.11,12 Numerous publications, unfortunately of irregular quality, or based on very limited series, report the experience of several teams for cholecystectomy, bariatric surgery, or even liver surgery. In fact, the long operating times (robot set-up can take up to thirty minutes) as well as cost problems for simple procedures such as cholecystectomy mean that these procedures will remain in the exclusive domain of classical laparoscopic surgery for the long term.13,14

With relation to the Nissen fundoplicature or splenectomy, there is also growing evidence that the results of robotic surgery are equivalent to those obtained by conventional laparoscopy, again with longer operating times and higher costs.15,16 However, the Heidelberg team recently presented the results of a randomized prospective study comparing conventional laparoscopy and robotic-assisted surgery in the Nissen fundoplicature. The robotic approach was associated with a shorter operating time, as the robot set-up could be performed increasingly quickly (about ten minutes in our institution), thanks to the experience gained by the operating room team. In fact, it is certain that these interventions of intermediate complexity will be useful in the future for the training of surgeons in robotic surgery. The potential benefits of robotics require more complex procedures, either because the two-dimensional visualization of conventional laparoscopy is a handicap or because the procedure requires manual anastomosis. Today, two operations meet either of these requirements: anterior rectal resection with total mesorectal resection (TME) and gastric bypass.

The difficulties associated with TME are well known:

- The need to work in a space (the small pelvis) of small dimensions;
- The need to obtain sufficient circumferential and distal resection margins to guarantee the quality of the oncological exeresis;
- The need to respect the integrity of the hypogastric plexus.

There are therefore two quality criteria for this type of surgery, one aimed at improving the vital prognosis, the other at preserving urogenital function.17 Our preliminary results on a series of seven patients with adenocarcinoma of the rectum confirmed those previously reported by Pigazzi et al.18 Compared with open surgery or conventional laparoscopy, robotically assisted MCT provides an oncologically adequate quality of resection, superior visualization of the structures of the small pelvis, and post-operative outcomes comparable to minimally invasive surgery.

The da Vinci® robot is particularly well suited for performing "hand-assisted" robotically assisted gastro-jejunal or jejuno-jejunal anastomoses. It is therefore not surprising that gastric bypass for morbid obesity (BMI L 40) is a potentially interesting application of robotics, since it is known that mechanical anastomoses (as performed today in conventional laparoscopic surgery) are burdened with significant morbidity either in the short term (anastomotic leakage) or in the medium term (anastomotic stenosis). 19-21 The first cases of obese patients who underwent gastric bypass by robotic surgery were reported in 2005, with good results from the outset, both in terms of the number of complications and in terms of operating times, often identical or shorter than in conventional laparoscopy.22-24 The da Vinci® System was integrated into our bariatric surgery program in the summer of 2006 and since then we have not experienced any complications related to gastro-jejunal anastomosis. This encouraging initial experience leads us to believe that the quality of anastomosis performed with the robot is superior to that performed with the circular staplers commonly used in conventional laparoscopic surgery.

In practice, over the past eighteen months, we have been integrating the da Vinci® robot into our surgical activity in the following way: we first familiarised ourselves with this new technology by performing simple procedures such as cholecystectomies, then, having gained confidence, we used it in operations according to Nissen, or to perform myotomies according to Heller.

We already feel that this approach allows us to perform these procedures more comfortably and precisely than with laparoscopy. Finally, we have developed prospective studies, the protocols of which have been approved by the Ethics Commission of the University Hospitals of Geneva, in order to verify the feasibility and safety for the patient of robotics in MCT and gastric bypass. These studies are still in progress, but it now appears that the benefits of robotically assisted surgery are especially notable in the latter indication. These preliminary data justify, in our opinion, continuing our efforts towards an ever-increasing use of the robot in bariatric surgery.

V. THE FUTURE OF ROBOTIC SURGERY

In the absence of scientifically established data, what are the arguments that allow us today to affirm that the da Vinci® robot, despite its prohibitive price, will represent a major technological advance in surgery over the next twenty years? First of all, on a conceptual level, the robot represents the integration of an information system with a machine capable of finely reproducing the surgeon's movements. In the near future, this system will benefit from advances in virtual imaging and will make it possible to integrate the images obtained by CT scan and thus, for example, to superimpose a three-dimensional image of the patient's liver and the contours of a liver tumour.25,26 It will certainly be possible to plan certain tasks of the robot in advance. It will also be possible to rely on developments in telecommunications, telesurgery and telementoring which will, in the near future, allow an expert to remotely control the movements of a less trained operator.27,28 Last but not least, both NASA and the US military continue, thanks to ever increasing budgets, to develop the tools that will be necessary for the optimal use of the robots, as we saw during the last "Explorer" mission to Mars.

VI. CONCLUSION

In short, we are at the dawn of a new era in medicine that will see the application of robotics in surgery. This will probably be combined with another aspect of surgical progress, namely interventions performed through natural orifices (Natural orifice transluminal endoscopic surgery NOTES). However, this will certainly require reducing the cost of these interventions, by challenging the monopoly currently held on this technology by American companies and the US military, another challenge and, certainly not the easiest to meet!

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