Robotic-assisted visceral surgery: Where is it?

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The robot overcomes the technical limitations of laparoscopy by restoring the feel of open surgery in a minimal invasive environment.

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Within the past decades, modern surgery has anticipated the concepts of evidence-based medicine. Also, within this development, initial postoperative course and pain has been adopted as important factors of the surgical outcome. Minimal invasive surgery demonstrated its superiority concerning the early postoperative course when compared to traditional open surgery. Still, minimal invasive surgery has not been overwhelmingly adopted and remains the less used method especially for advanced surgery in the US and Europe in all surgical fields. But why has the majority of surgeons not yet incorporated this patient-wise advantageous method of laparoscopy when evidence-based medicine support their use?

Laparoscopy is difficult to learn and to perform! Novices to the field of minimal invasive surgery face a significant learning curve. Many advanced procedures contain a level of difficulty even beyond the possibilities of traditional laparoscopic surgery mainly because of the technical limitations of laparoscopy: Two-dimensional imaging leads to impaired depth perception and disorientation. Laparoscopic rigid instrumentation offers a limited range of motion and fewer degrees of freedom when compared to the surgeon's hand. Fixed trocars act as a fulcrum and lead to motion reversal and motion scaling of the tip of the laparoscopic instrument. Due to the length of laparoscopic instruments, the surgeon's resting tremor is enhanced. Frequently, the surgeon is forced to perform in an uncomfortable and inefficient position and instruments, monitors and surgeon are misaligned.

But how can we overcome these technical limitations to provide secure minimal invasive surgery to benefit the patient's outcome? The solution has been developed over the past decades: Robotic surgery!

History of robotic surgery
Development of Robotic surgery started in the late 70ies and early 80ies and was mainly driven by two US institutions: The army and the NASA. The original motivator was to perform tele-surgery on patients in remote places such as a battle-field or the outer space. Both projects were more or less equally successful and lead to the development of two different robotic systems: the da Vinci Surgical System (US army in cooperation with the Stanford Research Institute) and the Zeus robot (NASA). Both projects were commercialized, the da Vinci Surgical System by Intuitive and the Zeus robot by Computer Motion, and received the FDA approval for laparoscopic abdominal surgery in the years 2000 and 2001, respectively. Even before FDA approval, a first robotic cholecystectomy was performed on a patient in Belgium with "Mona", the preliminary version of the da Vinci Surgical System. Another landmark in robotic surgery was the operation Lindbergh in 2001: The first trans-atlantic cholecystectomy took place with the surgeon operating in New York and the patient being treated in Strasbourg, France. This surgical event never received the deserved attention mainly because of the tragic events of 9/11 that happened only a few days after.

In the year 2003, Intuitive bought the company Computer Motion and set an end to the Zeus robot: All intellectual property was incorporated and products of Computer Motion were no longer available on the market. Since then all robotic surgeons face the unfavourable situation of Intuitive's indefeasible monopole with all its strategic effects such as outrageous pricing. But exactly because of this monopole, the da Vinci Surgical System was blessed with growing figures in sales and further developments. Until now, more than 650 surgical systems are in clinical use worldwide and new features are developed on a regular base. The latest technical innovation is the integration of a high definition visualization system which is already commercially available.

The Robotic system (daVinci®)
The da Vinci® Surgical System was specifically designed to address the technical limitations of conventional laparoscopic surgery: The robot delivers a high-quality, magnified, surgeon-controlled 3-dimensional, stable image, contains of instruments that allow intuitive control with tremor reduction, motion scaling and wristed movements. The robot contains 4 major elements: The surgeon's console, the surgical patient-side cart, EndoWrist® instruments and the laparoscopic tower. The surgeon's console is the work

Picture 1: The da Vinci® Surgical Console
space of the surgeon (picture 1). It contains the binocular viewers of the In­
site® Vision System (picture 2), joy-stick-like instrument controllers (picture 2) and foot-paddles for steering the camera and coagulation devices. On top of
this, the console allows the surgeon to control the setup and it is embedding
both, the computers hard- and software. Due to two three-chip cameras and
two optical channels creating two images as well as sophisticated image
processing equipment, the Insite® Vision System offers a spectacular high-
resolution true-to-life 3-D image (picture 2 and 3). Two light sources optimize
the light intensity and the surgeon himself can control focus and position
of the camera. Otherwise, the surgeon is sitting comfortable in an ergono­
mically optimal and comfortable position, controlling the instruments with
his fingers in the master controls (joy-sticks) below the display while having
elbows resting on a padded bar and the forehead against a pad above the
vision system. Approximation of thumb and index (or middle finger) operates
the jawed instruments in a completely intuitive fashion. The transmission of
surgical commands from the surgical console to the surgical cart is accom­
plicated by multiple wires.

The surgeon's cart provides either three or four mechanical arms (picture 4). The endoscope arm holds the camera and further instrument arms execute
the surgeon's commands. The arms carry a series of multiple positioning
joints which provide the excellent range of motion during surgery. A full range
of different surgical EndoWrist® instruments are available including energetic
instrumentation such as the Harmonic Ace or the Gyrus forceps (picture 5
and 6). Those instruments can be changed very rapidly by the patient-side
assistance without influencing the position of the robotic arms. All instru­
ments except the Harmonic Ace (Ultrasound technically cannot flow around
corners) offer six degrees of freedom at the tip plus the seventh degree by
the action of the instruments itself. All instruments are semi-disposable and
can be sterilized between 10 and 20 times.

What makes da Vinci special?
The laparoscopic tower incorporates all features of a standard endoscopic
stack such as assistant's monitor, insufflators, high-intensity illuminators and
a camera unit. For better conversation between the surgeon and his team,
the laparoscopic tower is furthermore equipped with both speakers and a
microphone. All in all, through the specific "da Vinci"-characteristics of 3-D
vision, motion scaling, tremor filtration, ambidexterity, hand-eye-alignment
and improved ergonomics, the robot overcomes the technical limitations of
laparoscopy by restoring the "feel" of open surgery in a minimal invasive
environment.

Therefore, robotic surgery is the most beneficial in procedures that are very
difficult or even not suitable to perform with the instruments of conventio­
nal laparoscopy. In the field of Urology, robotics already induced a dramatic
change: Traditionally by open surgery performed radical prostatectomy is
now more and more accomplished with the robot. Many studies suggest
that robotic prostatectomy may offer enhanced cancer control and lower
incidence of impotence and urinary incontinence when compared to both
open and conventional laparoscopic prostatectomy. These improved clinical
outcomes in combination with strategic marketing activities have established
robotic prostatectomy as a frequently desired approach by patients and dro­
ve to growing markets for robotic urologists. Especially in the US, traditional
urologists without robotic experience are facing more and more a dramatic
loss of patients.

Role of robotic-assisted surgery in visceral surgery
Unlike in Urology, an advantage of robotic-assisted surgery in the GI-tract
over laparoscopic or "open" surgery has yet to be shown. Despite an in­
creasing amount of literature about robotics in visceral surgery only few
studies offer valuable data. Case-reports account for most of the literature.
They indicate, that, robotic-assisted surgery is basically feasible for nearly all
intra-abdominal procedures. In view of the enhanced dexterity and the
improved vision of the device compared to laparoscopy, this is not surpri­
sing. The adaptation of the robotic system for interventions that have only
been possible with the open technique, are sometimes stunning and even
daring. Hemipatectomies, pancreatic resection including Whipple-Opera­
tions, gastrectomies for malignancy and oesophagus-resections have been
reported.
Our initial experience in Geneva and Bern is similar to the described literature. Postoperative pain, postoperative recovery or wound infection.

Our experience in Geneva and Bern

Our initial experience in Geneva and Bern is similar to the described literature. The extended OR-times are mainly due to a rather complex set-up of the robot and docking of the robot, both of which can be significantly reduced with increasing routine, not only of the surgeons in charge but also of the whole OR team. In rather easy interventions with short OR-time, the loss of time due to the above-mentioned factors cannot be overcome by a facilitated, hence, faster preparation. Evaluation of our first 50 procedures revealed a median robotic docking time of merely ten minutes, an insignificant amount of time for more complex procedures, like i.e. gastric bypass surgery.

Why then, should robotic surgery be performed for procedures that are laparoscopically easy to do (other than the, admittedly, thrill of handling a novel, 2Mio CHF gadget that looks cool?) (After all, we are surgeons...) – Despite being tagged “intuitive” by name, robotic surgery has to be learned and standardized, simple and frequent procedures are excellent training ground for the whole robotic team. The emphasis here is on “team”, meaning that “Lagerungspfleger, technische Op-Assistenten, Anästhesisten, Assistenten und Operateur”, all have to adapt to this new approach. Cholecystectomy and fundoplications are a great help in getting started with robotic surgery. However, our mutual experience in Geneva and Bern is that whereas cholecystectomies are, indeed, well standardized and frequent, “easy” might not completely reflect reality. A cholecystectomy, in our opinion, is one of a few procedures, that are actually harder to do with the robot than laparoscopically. This is due to the fact that many steps of the preparation are easier and faster done with true tactile feed-back (this is especially true in the presence of inflammation).

What are we training for?

If simple laparoscopic interventions only serve as training, one question still remains: “what are we training for”? Where would robotic surgery be reasonable to do? We have little doubt that the more complex and difficult to access an intervention is, the better will robotic surgery perform against other means of surgery. Limitations are the extent of the OR field due to the limited range of motion of the robot (with the new DaVinci S system, this range has greatly improved) and the higher magnification (10x vs. 4x with standard laparoscope). Hence, the oesophagus, upper gastric region, pelvis and retroperitoneum are operation sites where the robotic system can excel.

From the currently available data, that show similar clinical outcome after laparoscopic or robotic interventions, one could deduce, that the relatively novel approach of robotic surgery has a) a very steep learning curve (is easier to perform) compared to laparoscopy and/or b) will have a clinically better outcome in time, compared to laparoscopic procedure, which developed over the last 18 years to the levels of today. In other words could we compare laparoscopic results from the first hours to the results achieved with the robot today, the advantage of the latter would be obvious. The assumption that robotic surgery will ultimately become favourable over laparoscopy in more complex procedures, is, however, only correct, if the current robots will be continuously improved.

Lessons learned

With all the praise from the last paragraph, why is not everybody doing robotic surgery? After all, nor Geneva nor Bern have been at the forefront of robotic surgery. Why were robots bought, used, put in the storage room and then forgotten (we are talking about visceral surgery here. Urologist and gynaecologist have quickly learned to integrate the additional opportunities of robotic surgery in their daily business). – The two main reasons often were miscommunication and lack of focus. Even if a surgical director realized the potential of robotic surgery, the patience and dedication to reach the expertise of positioning the robot and performing operations where it could make a difference was minimal and enthusiasm was quickly replaced by scepticism. More often robots in visceral surgery were doomed due to the lack of communication: OR team members and colleagues alike did not realize that, in order to acquire the skills above mentioned, the robot had to be introduced in standardized, simple and frequent operations. This initial phase led to the perception, that robotic surgery is a costly, time-consuming gadget that yields at best the same results as the fast and simple laparoscopy. Subsequently, the robot-assisted operations were limited to times when the OR was not used. The resulting low frequency of these operations did not allow the OR personal to familiarize with the equipment, hence, robotic set-up persistently used very much time, amplifying the negative perception.

We experienced, that once it has been clearly communicated to all OR personal, that there will be a longish initial phase, during which time and money has to be invested to reach the next level and that, ultimately, robotic surgery will be useful for more complex interventions, critical voices diminis-
hed significantly. Interestingly, the OR personal are now adept to install the necessary equipment in short time and they are keen to be part of robotic interventions.

Future of robotic surgery

Still, missing data is generally a great problem of robotics in digestive surgery. We have promising preliminary results from feasibility studies, but we lack of further scientific evidence as available in urology for radical prostatectomy. Main reason for this is that only a few digestive centres operate with the system. Furthermore, many digestive procedures are not as standardized as a radical prostatectomy which makes multcenter randomization an extremely difficult undertaking, if not even impossible. Another concern is the large number of patients needed for a properly powered prospective, randomized trial comparing robotic versus laparoscopic procedures. All in all, satisfying outcomes are nearly impossible to create at this point.

But, if data is not perfectly convincing and the da Vinci® Surgical System so massively expensive, why should we bother working with the robot? Where is our benefit? Let’s change the point of view: The robot is not just the overpriced, time-consuming toy that brings no actual benefit to the clinic; the robot is our future by resembling an information system with arms. Mid and long term, we will be able to integrate all surgical functions into our information system “robot”[16]. We will be able to superimpose scans and x-rays onto the robotic vision system and we will use such technology for intra-operative navigation. Furthermore, exact planning of procedures and preparing of crucial steps will be possible. On top of this, surgical training will be conducted very easily and in an extremely effective fashion with the help of the robot[19]. Another underestimated issue in robotics is the possibility of tele-surgery[20,21,22]. Highly specialized procedures can be transmitted to remote areas and by doing so, quality of surgical care can be increased dramatically.

In summary, we are at the doorstep to a new era in surgery. The whole surgical landscape will change dramatically. The next big step towards the surgical future will be the breakdown of the currently very strong patents in laparoscopic robotics that are held by one company causing the massive costs of robotic surgery. Imagine that surgical robots sooner or later will be affordable for everybody. We will easy be able to create enough scientific data and the progress will go ahead! We can either invest in this revolutionary technology or watch the others taking over the lead! So, let’s go for the future!

References

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Picture 6: Examples of 8 mm da Vinci® Instruments