

## NOTES, MANOS, SILS and other new laparoendoscopic techniques

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### Abstract

A new way of opening a body cavity can be a revolution in surgery. In 1980s, laparoscopy changed how surgeons had been working for years. Natural orifice transluminal endoscopic surgery (NOTES), minilaparoscopy-assisted natural orifice surgery (MANOS), single incision laparoscopic surgery (SILS) and other new techniques are the new paradigm in our way of operating in the 21<sup>st</sup> century. The development of these techniques began in the late 90s but they have not had enough impact to develop and evolve. Parallels between the first years of laparoscopy and NOTES can be made. Working for an invisible surgery, not only for cosmesis but for a less invasive surgery, is the target of NOTES, MANOS and SILS performed by surgeons and endoscopists over the last 10 years. The future flexible endoscopic platforms and the fusion between laparoscopic instruments and devices and robotic surgery will be a great advance for "scarless surgery".

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### BEGINNING OF A SURGICAL REVOLUTION: ENDOSCOPIC AND LAPAROSCOPIC SURGERY

Modern endoscopy began in 1805, when Phillip Bozzini first used a system to visualize the inside of the rectum and bladder through a mirror, a candle and a double-lumen ureteral catheter. The first source of inner light was invented by Bruck<sup>[1]</sup> in 1867 for examining the mouth using an electrical resistance with a platinum filament as a light source.

In 1878, Maximilian Carl-Friedrich Nitze introduced the first working cystoscope that contained a prismatic lens system and a channel through which you could insert a ureteral catheter, conducted in collaboration with Joseph Leiter. After the invention of the incandescent light lamp by Thomas A Edison in 1880, the endoscope became more practical. With the arrival of the twentieth

century, cystoscopy and other studies of open cavities such as esophagoscopy, laryngoscopy and proctoscopy were well established.

In 1909, Hans C. Jacobeus conducted the first human laparoscopies and thoracoscopies. In 1918, the importance of pneumoperitoneum was recognized after Goetze's works of his inflating needle. In 1938, Janos Veress developed a needle with a safety tip for the practice of therapeutic pneumothorax in tuberculosis. The cold light was a term used for several years before the fiber optic and light cables were in use. In 1953, Hopkins<sup>[2]</sup> led the invention of the cylindrical lenses system, which provided images with a greater clarity, brightness and color. The real advances in instrumentation and techniques of laparoscopic surgery were made by Kurt Semm in the mid 60s to the 80s when developing an automatic insufflator with a pressure monitor and a lot of devices for laparoscopy<sup>[3]</sup>. Familiar with Semm's works, Erich Mühe took interest in surgery of the gallbladder and designs a new laparoscope, called the "Galloscope". The tube diameter was larger and had a system for indirect vision and valves that prevent the loss of gas. On September 12th, 1985, Mühe performed the first laparoscopic cholecystectomy in the world.

Throughout this time, laparoscopic visualization was restricted exclusively to the surgeon. The greatest advance in this field was the development and coupling of the mini video-camera in 1987, which allowed assistants to observe surgeries and help more efficiently. Thus, in 1987, Philippe Mouret performed the first video-laparoscopic cholecystectomy. In subsequent years, Dubois published the first series of laparoscopic cholecystectomies and performed a great laparoscopic activity, developing new techniques such as vagotomy in the treatment of ulcer in 1989<sup>[4]</sup>. Other pioneers of video-laparoscopic surgery are John B. McKernan, WB Saye, Eddie Joe Reddick and Douglas Olsen (United States), Sir Alfred Cuschieri and Leslie K. Nathanson (United Kingdom) and Jacques Perrisat (France)<sup>[5,6]</sup>.

Parallel to the development of the clinical implementation of the laparoscopic approach to organs like the spleen, adrenals and stomach, mini-laparoscopy or acoscopic surgery was developed. This form of minimally invasive surgery attempts to make the least number of hits on the abdominal cavity using smaller diameter instrumentation. Instruments and 2.8 mm and 3 mm optics, which allow the same actions with an acceptable view, reproduce conventional laparoscopy with minimal parietal hits. Nowadays, these instruments have awakened interest as a support to hybrid approaches in trans-luminal surgery.

## APPEARANCE AND DEVELOPMENT OF NOTES

Defined as an acronym for "Natural orifice transluminal endoscopic surgery" (NOTES), the first description of NOTES in animals was made by the Kalloo<sup>[7]</sup> group

in 2004, communicating their successes on a porcine model to which a peritoneoscopy and liver biopsy by the transgastric route had been made. Rao and Reddy<sup>[8]</sup> performed a peritoneoscopy, hepatic procedures and on genitals with flexible peroral endoscopes with laparoscopic support. In 2006, Reddy and Rao reported the first human appendectomy by the transgastric route: this intervention aroused wide interest in the clinical application of NOTES.

In the following year, several groups described various techniques in animal models that awakened interest in the feasibility and reproducibility of NOTES. Kaloo's group<sup>[9,10]</sup> reports its satisfactory results performing tubal ligation and transgastric gastrojejunostomies and Thompson's group<sup>[11]</sup> does the same with their abdominal exploration transgastric experiences and the resection of gynecological organs. In connection with the transgastric cholecystectomy, also in 2005, the groups of Swanstrom and Park<sup>[12,13]</sup> successfully performed cholecystectomies and transgastric cholecystogastrostomies with flexible endoscopes.

It took 2 years to awaken the interest for clinical application and, during that period of time, the difficulty of safely performing transgastric cholecystectomy was found in experimental animals and access through the vagina was considered and experimented with. The safety of clinical transvaginal NOTES approach was endorsed by its widespread use in the field of gynecology with culdoscopy and with the use of the vaginal route for the extraction of surgical specimens<sup>[14-18]</sup>.

In early March 2007, Zorron's group<sup>[19,20]</sup> made the first series of transvaginal NOTES cholecystectomies in 4 patients, based on previous experimental studies. Shortly afterwards in the same month, Bessler carried out a successful hybrid transvaginal cholecystectomy with 3 laparoscopic abdominal ports<sup>[21]</sup>. Marescaux<sup>[22]</sup>, in April 2007, conducted the purest NOTES cholecystectomy in a patient using only an abdominal port through which he introduced a Veress needle for pneumoperitoneum control and a gripper for the vesicular traction. Branco's<sup>[23,24]</sup> group reported their experience with hybrid cholecystectomy, performing a case with a single abdominal access trocar and then a transvaginal nephrectomy with two 5 mm abdominal trocars. At this time, new applications and a series of cases performed by NOTES take place<sup>[25-29]</sup>.

Transcolonic and transvesical access have been advocated by some researchers as more appropriate for the abdominal approach of supramesocolic structures that are often more difficult to achieve through a transgastric route. Lima's group used combined transgastric and transvesical approaches to increase the feasibility of moderate complexity procedures, such as nephrectomy and cholecystectomy in experimental animals<sup>[30]</sup>. Feussner<sup>[31]</sup> published his results on the transcolonic approach in experimental animals, creating potentially safe access to the peritoneal cavity replicable model through access via the sigmoid and upper rectum.

To minimize the access and transparietal support,

new techniques and tools have been developed to perform manoeuvres of traction and suspension of the target organ, such as magnets and tissue retractors attached to the parietal peritoneum. Scott's<sup>[32]</sup> group maintained the traction of the vesicular background with magnets in animals, avoiding the placement of a gateway in the abdominal wall. All these developments are being validated in animal and pilot clinical experiences, with the intention to perform pure NOTES procedures as soon as possible, equipped with the necessary clinical safety.

## NOTES: ALLIES AND ENEMIES

Since the clinical application of NOTES began in 2007, we soon realized it would be impossible at that time to perform pure techniques and that laparoscopic support was needed. The development of endoscopes was not progressing quickly and it was necessary to triangulate to manoeuvre correctly and safely into the abdomen and tools for hemostasis and sealing of structures that could not be used through the flexible endoscope were also needed. It was necessary to resign from pure NOTES and develop a hybrid NOTES, with more or less support through laparoscopic ports in the abdomen.

Thus, we have seen the techniques using natural orifices as forced allies of NOTES, although rigid material is introduced through them, and to Minilaparoscopy Assisted Natural Orifice Surgery (MANOS) techniques, which use natural orifices for some surgical gestures and the removal of the piece, with support from minilaparoscopy. Both modalities should not be considered as NOTES techniques as long as they do not use the flexible endoscope to perform surgical manoeuvres, but their similarity in relationship to the use of natural orifices and the use of minilaparoscopy on the access of the abdomen make this kind of surgery progress together through natural orifices, preferably through the vagina.

Access to the abdomen with rigid instruments from a natural orifice can only be done from a pelvic access. The vagina is the easiest access for its short canal, lack of complications in its access and ease of closing. This kind of rigid NOTES surgery developed by the German group Zornig *et al.*<sup>[28]</sup> has the possibility of using laparoscopic instrumentation and requires no training in handling the flexible endoscope. By contrast, with the MANOS technique, the access through the natural orifices can be done from any entry, not just the vagina, with the possibility of using the endoscope as an instrument that provides light, camera and the ability to help surgery, which is actually performed through minilaparoscopy with parietal abdominal ports. The first description was by Tsin in 2001 under the name of culdolaparoscopy but went unnoticed until the advent of NOTES surgery<sup>[33]</sup>. Recently, this surgical approach has been applied to the realization of colorectal, splenic and bariatric surgery<sup>[34-36]</sup>.

If these two types of minimally invasive approaches can be considered as allies to NOTES for the contribution to the development of natural orifice surgery, we

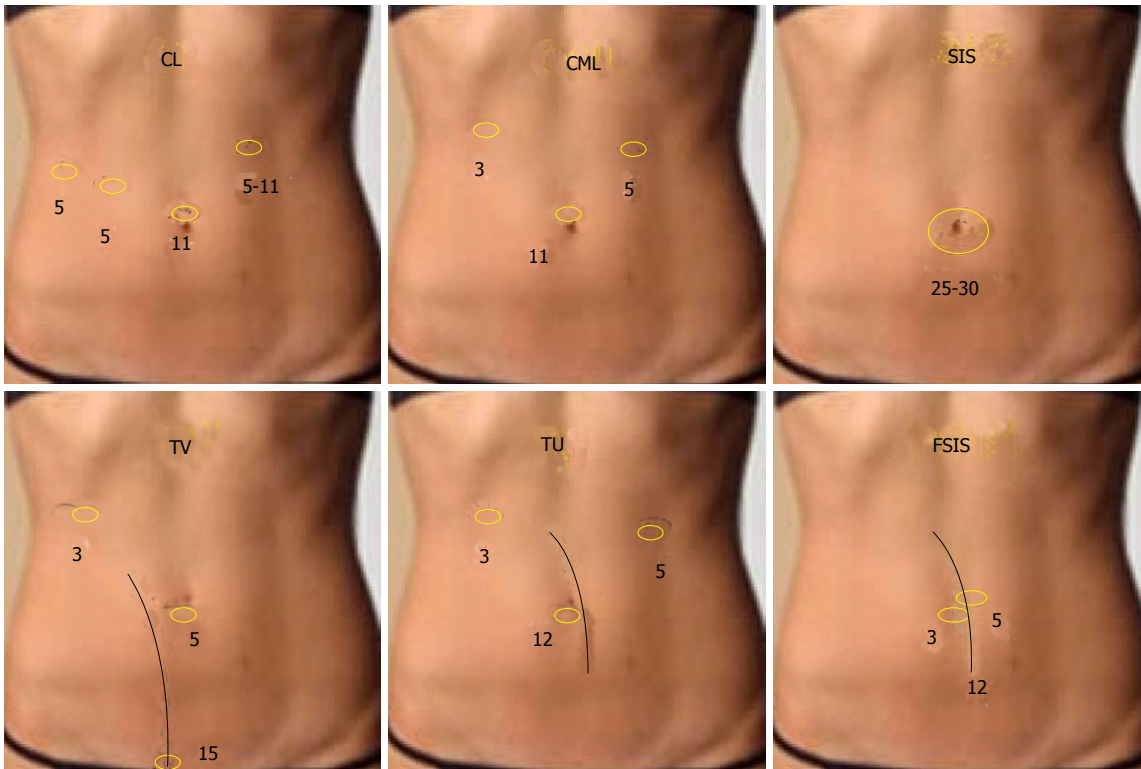
can also find some developments that may be considered as "enemies" to NOTES. Techniques of single incision and single port involve a major breakthrough for minimally invasive surgery, but they are a step backwards for the development of surgery without scars on the abdomen. It is a conceptual paradigm shift, a radical change in philosophy: from the desire to surgery without scars on the abdomen, to making a single incision but of considerable size and in an area such as the umbilical, with a high risk of incisional hernia<sup>[37]</sup>. With NOTES, we try to minimize incisions in the abdomen to the point where we can make them disappear. With single-incision surgery we try to hide a minilaparotomy in an area such as the navel. With NOTES, we aim to fight against wound infection and against the generation of hernias and post-surgical adhesions, avoiding trauma to the abdominal wall. With the single-incision surgery, we tend to minimize the importance of these aspects but we do not minimize the risk of their occurrence. Using the flexible endoscope through a transvaginal, transgastric or transumbilical approach is an interesting topic today because in the future, with new endoscopes and flexible endoscopic platforms, we will be able to perform a surgical procedure with them with a single abdominal access. In the meantime, as illustrated in Figure 1, we are evolving from a conventional laparoscopy to other more minimalist approaches.

Many studies are needed so that we can ascertain whether it is better to group trocars into a single incision or keep them separate under a better triangulation in surgery and patient safety. In surgeries where a minilaparotomy for the removal of the piece is not needed, it is difficult to justify the use of this modality; however, in surgeries such as colectomy, splenectomy and other similar surgeries with the extraction of limited size pieces, the use of this access seems very appealing.

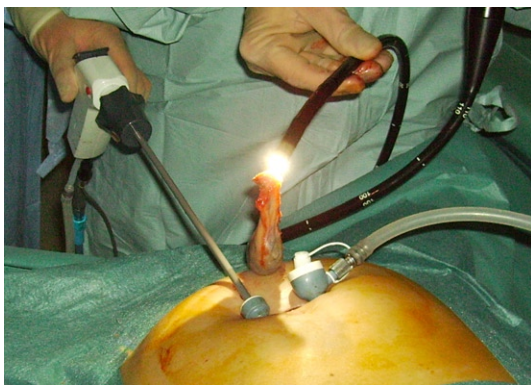
## INVISIBLE SURGERY IN THE LABORATORY

NOTES surgery has slowed its development for several reasons, among which we can refer to the appearance of single-incision surgery and the fateful economical period of time in which it has been developed. It is a new type of therapeutic procedure with a high dependence on technology that requires a significant investment to develop new platforms, vision systems and instrumentation. The appearance of the single-incision surgery, which manages to reach a wide range of surgical procedures and seems to be more accessible to the entire surgical community with little investment in technology, is going to make us wait for its development and implementation to re-awaken the growing interest in NOTES. Despite all this, transluminal surgery should be further developed. It is necessary that the groups that first began its development carry on with the technique, establishing the needs and specifying the target diseases. Thus, when we are ready to re-address the technological develop-





**Figure 1** Distribution of the entry-ports by approach to perform cholecystectomy. CL: Conventional laparoscopy. CML: Conventional minilaparoscopy; SIS: Single incision surgery; TV: Flexible or rigid transvaginal endoscopy; TU: Transumbilical flexible endoscopy; FSIS: Flexible single incision surgery.



**Figure 2** Cholecystectomy by flexible single incision surgery. Umbilical single incision and direct approach with the flexible endoscope without complementary device. Two parallel 5 mm ports are needed to perform a secure procedure.

ment of NOTES, there will be groups who are willing to put the technologies in use which are now sleeping in the labs. While we wait for this new technology, the combination of the flexible endoscopy and minimally invasive access can give us some benefits with a low cost, as can be seen in Figure 2.

Among these new instruments and equipment that are in preclinical research, those which seem to have more interest are the new scopes, the platforms for NOTES and minirobots. The new endoscopes have in common the development of several working channels, up to four, with the intention to give input to instruments in two of them, and at least, to another instru-

mental working channel to implement elements of coagulation, washing and vacuuming. These new endoscopes can control the pneumoperitoneum and enable joint working tools, getting the necessary triangulation, even in limited space<sup>[38,39]</sup>. The new miniaturized terminals for bipolar coagulation, tissue sealing, ultrasounds and radio-frequency are shown as very promising elements to facilitate dissection, hemostasis and sealing. Possible future application energies, such as lasers and microwaves, may also have their place through the flexible endoscope.

On the other hand, flexible endoscopes are progressing and the classical concept of a long flexible tube is being substituted by a concept of a transluminal surgery platform which seeks to overcome the difficulties of navigation by stabilizing the transporter of the instruments and allowing a greater skill in movements, endowing a more accurate triangulation and precision<sup>[40,41]</sup>. These new platforms try to allow the surgeon to make gestures of great similarity to those made in laparoscopic surgery, supported largely by the application of robotics to facilitate accuracy of movements.

Finally, robotics seems to be the technology that will achieve the breakthrough for this type of intracavitary surgery in the not too distant future. The miniature robots are intended to give a step further, putting our vision in intracavitary or intraluminal situation, as well as our tools and the conveyor platform. The simplest ones incorporate the light source and the camera, but the more advanced ones are configured with two arms that even allow surgical manoeuvres to be performed<sup>[42]</sup>.

While all these developments come into our hands, it is necessary to promote the combined use of all minimally invasive techniques available to us, as well as team collaboration, which is a fast way of exchanging information and brings the chance to quickly transfer new indications to techniques and specific equipment. The knowledge of the advantages and limitations of each approach allows the development of hybrid techniques where the process cannot be performed without involving both techniques.

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