Universidade do Minho
Escola de Ciências da Saúde

Hélder Bruno Carvalho Ferreira

Contribution to Minimize the Aggressiveness of Laparoscopic Surgery in Gynecology

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Tese de Doutoramento em Medicina

Trabalho efectuado sobre a orientação do
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“Wisdom must be intuitive reason combined with scientific knowledge.”

Aristotle, *Nicomachean*

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Resumo

Nos últimos anos, múltiplos esforços têm vindo a ser desenvolvidos pelos cirurgiões para minimizar a invasão e o trauma cirúrgicos dos seus procedimentos. Neste contexto, na abordagem cirúrgica, três aspetos devem ser tidos em consideração: o acesso cirúrgico, a extensão da dissecção cirúrgica e a quantidade de tecido removido. A dimensão do acesso deve ser a mais reduzida possível de modo a causar o menor trauma cirúrgico. A extensão da dissecção operatória deverá ser a mínima necessária, de forma a evitar-se morbilidade adicional relacionada com o procedimento (p.e. linfocelo após linfadenectomia ou lesão nervosa após correção do prolapso genital). A quantidade de tecido excisado deverá ser apenas a adequada. Assim, a cirurgia deve ser orientada no sentido de se cumprirem os objetivos previamente expostos com o propósito final de reduzir ao mínimo possível a agressividade cirúrgica. Recentemente, a minilaparoscopia reapareceu como uma alternativa à laparoscopia convencional, dadas as potenciais vantagens cosméticas e a precisão cirúrgica associadas.
O nosso trabalho de investigação teve como objetivo demonstrar a viabilidade da minilaparoscopia em alguns procedimentos ginecológicos inovadores, tais como a abordagem guiada por imagem do gânglio sentinela e a correção laparoscópica do prolapso genital.
O nosso estudo evidenciou que a abordagem cirúrgica minilaparoscópica por via intraperitoneal na identificação, dissecção e excisão do gânglio sentinela é uma alternativa à abordagem laparoscópica tradicional, podendo reduzir a morbilidade decorrente dos procedimentos de estadiamento das neoplasias ginecológicas. Num estudo subsequente, foi confirmada a viabilidade e fiabilidade da abordagem minilaparoscópica por via extraperitoneal na identificação, dissecção e excisão do gânglio sentinela corado por indocianina verde, usando uma camera multiespectral de fluorescência.

Na correção do prolapso genital, a minilaparoscopia demonstrou ser uma opção viável na sacrocolpopexia apresentando benefícios cosméticos, mantendo a baixa morbilidade associada à abordagem laparoscópica convencional. Finalmente, num outro estudo descrevemos uma técnica inovadora de tratamento do prolapso genital que consistiu na sacrocervicopexia após histerectomia supra-cervical usando instrumentos minilaparoscópicos, com a remoção da peça operatória através do fundo de saco vaginal posterior (NOSE).

O nosso trabalho de investigação contribuiu para uma futura minimização da agressividade da cirurgia laparoscópica em ginecologia.

Abstract

In recent years, many efforts have been made by endoscopic surgeons to further minimize surgical trauma and invasiveness of their procedures.

In a surgical approach, three aspects should be taken into account: the surgical access, the extension of surgical dissection and the amount of excised tissue. The surgical access should be the smallest possible to cause the lowest operative damage. The extension of operative dissection should be the minimal required in order to avoid unnecessary trauma or morbidity related to the procedure (e.g. lymphocele after lymphadenectomy or nervous injury during genital prolapse correction). The amount of extirpated or excised tissue should be the strictly necessary. There is no need to remove extra tissue what may cause supplementary damage. Therefore, we should tailor the surgery to reach our three previous objectives for reducing the surgical aggressiveness to the minimum possible.

With a current emphasis on diminishing the visibility of scars, on increasing the surgical precision and on decreasing the amount of dissection, minilaparoscopy has reemerged as an appealing option for surgeons. Thus, in our research work we aimed to test the use of minilaparoscopic instruments in some innovative gynecological surgical procedures like the image-guided sentinel lymph node (SLN) approach and the genital prolapse correction.

In our experiments, we confirmed the feasibility of the minilaparoscopic surgical approach for identification, and excision of SLN by an intraperitoneal acess. Furthermore, the feasibility and reliability of an extraperitoneal minilaparoscopic approach for SLN excision using a near infrared imaging system and indocyanine green was demonstrated. These procedures might be considered a potentially better alternative to traditional laparoscopy during staging procedures for gynecological malignancies.

Concerning the genital prolapse correction, we demonstrated that minilaparoscopy is a reliable and attractive approach for sacrocolpopexy as it enhances cosmetics, keeping the low morbidity associated with the classical laparoscopic approaches. Moreover, we attested the feasibility of

minilaparoscopic sacrocervicopexy after supra-cervical hysterectomy with specimen removal through the posterior vaginal cul-de-sac (NOSE).

In our studies, we may have offered a contribution to minimize the aggressiveness of laparoscopic surgery in gynecology.

Abbreviations

BCE - Before Common Era or Before Christ
BMI - Body mass index
FDA - Food and Drug Administration
ICG - Indocyanine green
MB - Methylene blue
ML - Minilaparoscopy
MLSC - Minilaparoscopic sacrocolpopexy
MRI - Magnetic resonance imaging
NIR - Near-infrared
NOSE - Natural Orifice Specimen Extraction
POSAS - Patient and Observer Scar Assessment Scale
SLN - Sentinel lymph node
TH - Total abdominal hysterectomy
UHD - Ultra-high definition
VAPS - Visual Analog Pain Score

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PART I Introduction

1
Background

1.1 A brief history of gynecological surgery

In ancient Greece, gynecology originated in the myth of the first woman Pandora, whose beautiful appearance was seen to cover her dangerous 'insides' (King 1998). Gynecology finds its roots in the Ebers Papyrus (1500 Before Common Era, BCE) that described the uterus as a wandering animal, usually a tortoise, newt or crocodile, capable of movement within its host. Hippocrates perpetuated this animalistic concept, stating that the uterus often went wild when deprived of male semen (Francis Adams 1939).

From the initial days of recorded medical history, physicians struggled with the problems of uterine tumors and pelvic organ prolapse. The oldest published work on gynecology is attributed to Soranus (circa AD 98-138) of Ephesus in which he discusses the problem of uterine prolapse and, while acknowledging that this does not usually require surgical treatment, he advises "If the whole uterus has become black, one must cut it off in its entirety" (Temkin 1956). His writings provided the foundation for gynecologic texts up to the seventeenth century.

The ancients employed instruments fashioned from tin, iron, steel, lead, copper, bronze, wood and horn (Walters and Karram 2015). Those made of iron and steel were likely quite popular but very few survived the oxidation of more than two millennia. Gynecologic instruments including forceps, catheters, scalpels as well as massive bivalve, trivalve and quadrivalve vaginal specula from the first century BCE were unearthed at Pompeii (Walters and Karram 2015).

Bartholomeo Eustachio (1520-1574) furnished the earliest accurate delineation of the uterine cavity and cervical canal.

Pelvic surgical procedures and instruments of the seventeenth century are nicely portrayed by the drawings of Johannes Schultetus (1595-1645) in his Armamentarium Churugicum (Walters and Karram 2015). Included are examples of treatment of imperforate hymen, hematocolpos, clitoral hypertrophy and the use of a T-binder following vaginal surgery.

There are a number of references to vaginal ‘excision’ of the uterus in the sixteenth and seventeenth centuries. The first of these was in 1517 by the Italian anatomist, Giacomo Berengario da Carpi, who is said to have excised the uterus for prolapse (Garrison 1929). Most of the early surgical attempts to deal with cervical cancer and uterine prolapse were probably limited to removal of the cervix and lower part of the uterine corpus, such as Osiander’s eight cases of excision of the cervix for cancer (Garrison 1929).

In 1737, James Douglas (1675-1742) gave the first adequate description of the peritoneum, which helped to pave the way to retroperitoneal surgery and the concomitant decrease in peritonitis that typically plagued abdominal procedures (Walters and Karram 2015).

In April 1812 the Italian surgeon G.B. Palletta of Milan inadvertently performed a vaginal hysterectomy when planning to amputate the cervix for suspected cancer, only to find that he had excised the entire uterus (Baalbergen and Helmerhorst 2014). The patient died 3 days later from sepsis.

The first planned, successful vaginal hysterectomy was performed in 1813 by Conrad Langenbeck, although he did not report the case until 1817 (Baskett 2005). The patient was a 50-year-old woman with an ulcerated, possibly cancerous cervix. Langenbeck performed the procedure without anaesthesia or assistance (Baskett 2005).

An insufficient understanding of pelvic anatomy plagued practitioners prior to the nineteenth century. Ignorance of asepsis, the absence of anesthesia, faulty suture materials, inadequate instrumentation and difficult exposure delayed any consistent success until the mid-nineteenth century (De Alvarez 1977).

The first abdominal hysterectomy was a subtotal hysterectomy performed by Charles Clay in Manchester 1843. The procedure was indicated by an adnexal mass that in fact was a large fibroid and the corpus of the uterus was removed. Despite the successful operation the patient died on the 15th postoperative day (1977) (Shaw 1951). Since then, focus on the indications and methods for performing a hysterectomy have changed several times.

From the beginning, abdominal hysterectomy was always performed as a subtotal hysterectomy and a total abdominal hysterectomy (TH) of a cancerous uterus was first described in 1878 (Freund 1878). The technique of TH as we know it today was first introduced by Richardsson in 1929. He advocated the total procedure in order to prevent the development of cervical carcinoma (Richardsson 1929). Despite this, subtotal hysterectomy was by far the most common method until the 1950s. With the development and availability of antibiotics and blood transfusions the trend turned towards TH in order to prevent cervical carcinoma.

In 1898, Ernst Wertheim, a Viennese physician, developed the radical total hysterectomy with removal of the pelvic lymph nodes and the parametrium. (Kelso and Funnel 1967). In 1944, Meigs repopularized the surgical approach when he developed a modified Wertheim operation with removal of all pelvic nodes (Kelso and Funnel 1967, Verleye, Vergote et al. 2009).

To correct vaginal prolapse and when initially proposed, the sacrocolpopexy procedure was performed via laparotomy and the vaginal apex was anchored posteriorly, approximating the posterior uterine fundus to the anterior longitudinal ligament (Arthure and Savage 1957). Lane first advocated an intervening graft between the vagina and sacrum to overcome excessive tension (Lane 1962). Numerous modifications to the original technique have been made over the last 50 years. These modifications included Birnbaum's ill-advised anchoring of the mesh to the sacrum at the level of S3–S4 (Birnbaum 1973). After a life-threatening hemorrhage, Sutton et al. (Sutton, Addison et al. 1981) advocated anchoring the graft higher, at the S1–S2 level, where the sacral veins and middle sacral artery were more easily visualized and avoided. This change had no detectable negative effect on the vaginal axis.

1.2 A brief history of gynecological endoscopy

Endoscopy seen as the inspection (scope) of the inside (endo) of the human body dates back to Hippocrates (460-375 BCE). The Greek physician invented the first rectal speculum and original gynecological speculum dates from about the same time.

Yet, modern endoscopy is a nineteen-century's invention. Philipp Bozzini, a German physician, was the first to develop a light source to achieve adequate endoscopic illumination. Bozzini combined reflexing mirrors, a candle, and an urethral cannula to direct light into the internal cavities. The device was called the Lichtleiter, which means light conductor (Bozzini, 1806).

John D. Fisher (1798-1850) used the same physics principle to create an endoscope of his own, initially to inspect the vagina. Later, he modified it to examine the bladder and urethra (Picatoste et al., 1980). In 1853, Jean Desormeaux, a French surgeon, considered by most the father of endoscopy, used a lamp of gasogen (a mixture of alcohol and turpentine) as the light source and introduced the use of lens to focus. This is considered the first widespread cystoscope, as he used it mainly for urological purposes. In 1869, Commander Pantaleoni modified it to cauterize a hemorrhagic uterine growth. Thus, Pantaleoni performed the first therapeutic hysteroscopy (Gunning and Rosenzweig, 1991). By the same time, in 1868, Kussmaul performed the first rigid gastroscopy in a patient who was a professional sword swallower (Walk, 1996). Cruise and Gordon were the first to introduce a cystoscope through a pleurocutaneous fistula of a child suffering from chronic empyema, in 1866. However, this was not followed by any further practical utilization (Tassi and Tschopp, 2010).

In 1879, Thomas Edison invented the electrical light bulb. This relevant happening on human evolution was promptly used in favor of endoscopy. In 1886, both Maximilian Nitze from Germany and Josef Leiter from Vienna presented a cystoscope with a built-in light source formed from an electrically heated platinum wire, a multilens system, and a separate water circulation system for cooling (Moreira-Pinto 2014). In 1956, Hirschowitz presented the first flexible gastroduodenal endoscope using coherent fiber bundle.

During late 1910 and early 1911, Hans Jacobaeus, a Swedish internist, used the term "laparothoracoscopy" for the first time (Jacobeus, 1911). By 1912, he had performed closed-cavity endoscopy with a Nitze cystoscope in over 100 patients with ascitis and also described liver pathology, peritoneal tuberculosis, and tumors. A response by Georg Kelling appeared two months later, disputing Jacobaeus' claim to be the first to perform the procedure in humans, stating that he had successfully used celioscopy in two humans between 1901-1910 (Kelley 2008).

In the 1930s, the internist John Ruddock popularized laparoscopy in the United States. Using a forward-viewing scope similar to Kalk's, he extolled the virtues of diagnostic laparoscopy as a safer, less-invasive alternative to laparotomy.

In 1933, the gynecologist Karl Fervers described laparoscopic lysis of adhesions using cautery. Three years later, Boesch, a Swiss gynecologist, performed the first laparoscopic sterilization by electrocoagulation of the fallopian tubes. The evolution of laparoscopy from its origin with George

Kelling in 1901 to a therapeutic modality for Fervers and Boesch took one-third of a century (Kelley 2008).

Operative laparoscopy was also employed in gynecologic procedures by Raoul Palmer (1905-1985) in 1943. At a time when laparoscopy was largely the domain of surgeons, he established its role for evaluating infertility and visualizing pelvic organs by placing the patient in the Trendelenburg position and elevating the uterus by means of a trans-cervical manipulator.

Bozzini's invention of the cystoscope laid the foundation for laparoscopy a full century before the first transabdominal "celioscopy" was performed by Kelling (Kelley 2008). The development of laparoscopic surgery was clearly a gradual evolution and not a revolution. The early slow pace of endoscopic and laparoscopic evolution was in large part related to the limitations of technology. It was further slowed by skepticism of the medical and surgical communities (Kelley 2008). The early laparoscopic surgeons experienced many examples of repression by the old guard of traditional surgery.

During the mid-1960s and 1970s, the gynecologist Kurt Semm in Kiel, Germany, contributed greatly to laparoscopic technology. He perfected many technical refinements, including an automated insufflator, the suction irrigator, safer electrocoagulation instruments, intracorporeal and extracorporeal knot tying, and an electrical morcellator for myomas (Vecchio, MacFayden et al. 2000). In 1983, Kurt Semm performed the first laparoscopic appendectomy, bringing him criticism and censor rather than accolades. The German Board of Surgery condemned him (Perissat, Collet et al. 1998) (Semm 1983). In 1984, Semm suggested the use of laparoscopic technique in hysterectomy but, the first actual laparoscopic hysterectomy was reported by Reich in 1989 (Semm 1984) (Reich 1992). This was a total laparoscopic procedure.

The laparoscopically assisted vaginal hysterectomy (LAVH), described by Kovac in 1990, was soon adopted because of a less demanding surgical technique and shorter operating time (Kovac 1998).

By the late 2000s, with improvements in training and innovative adaptations of instruments and techniques, minimally invasive approaches for gynecologic malignancies started to be used more often (Frumovitz, Escobar et al. 2011).

The laparoscopic sacrocolpopexy, which evolved from the classical abdominal sacrocolpopexy, has been recognized as providing a shorter hospital stay, better hemostasis and less pain than the open procedure (Freeman, Pantazis et al. 2013). From a conceptual point of view, if abdominal sacrocolpopexy corresponds to a palliative treatment of genital organ prolapse, the laparoscopic approach provides a real reconstructive surgical procedure (Gadonneix, Ercoli et al. 2005).

1.3 State of the art in image-guided surgery

Advanced imaging technologies, such as multidetector computed tomography and three-dimensional magnetic resonance imaging, have introduced a new era in preoperative planning and treatment of gynecologic malignancies. However, as these imaging modalities are mainly used in the preoperative setting, translation of these images to the surgical theater is often challenging and does not always correspond to the intraoperative findings (Handgraaf, Verbeek et al. 2014).

Over the past years, near-infrared (NIR) fluorescence imaging has emerged as a promising complimentary technique for intraoperative visualization of tumor tissue, sentinel lymph nodes (SLN) and vital structures. This technology provides real-time images, which allows accurate guidance during surgery. In gynecologic oncology, NIR fluorescence imaging has been used for intraoperative identification of SLN in vulvar, cervical and endometrial cancer and imaging of vital structures such as the ureter (Vahrmeijer, Hutteman et al. 2013). Moreover, NIR fluorescence imaging systems for image-guided surgery are developing rapidly.

NIR fluorescence imaging uses NIR light, which is safe when used at the relatively low intensity needed for this technique. Requirements are a NIR fluorescent probe (fluorophore) combined with an imaging system, which is able to excite this fluorophore and to detect the emitted fluorescence. By displaying the detected fluorescence on a screen, it becomes visible to the human eye. Some systems are able to merge white light images with NIR fluorescence images, which enhance anatomical orientation (Schaafsma, Mieog et al. 2011). To date, indocyanine green (ICG) and methylene blue (MB) are the only fluorophores approved for clinical use by the Food and Drug Administration and the European Medicines Agency (Feindel, Yamamoto et al. 1967). ICG is cleared exclusively by the liver and emits light with awavelength of approximately 820 nm (Kraft and Ho 2014). MB is cleared simultaneously by liver and kidneys and emits light with a less optimal wavelength of approximately 700 nm, which has less tissue penetration capacity and more tissue autofluorescence (Verbeek, van der Vorst et al. 2013). Both ICG and MB are non-targeted dyes and their chemical structures do not allow conjugation to tumor specific ligands. Therefore, they are mainly suitable for indications such as SLN mapping, e.g. in vulvar and cervical cancer, since they do not bind to tumors, but only follow the lymphatic drainage pattern. Furthermore, they can be used for ureter or bile duct visualization.

NIR fluorescence imaging has a steep learning curve, especially since most gynecologists are already trained in operating while using a monitor in laparoscopic surgery. If surgeons are able to identify structures more easily with help of NIR fluorescence imaging, operating and anesthesia time may be reduced, which simultaneously may reduce costs and associated risks (Handgraaf, Verbeek et al. 2014).

1.4 Minilaparoscopy

In the last two decades, recognition of laparoscopy has rapidly risen.

In recent years, many efforts have been made by endoscopic surgeons to further minimize surgical trauma and invasiveness of their procedures, mainly following three major directions: one is reducing the number of the access ports (as in the case of single-port surgery) (Fagotti, Boruta et al. 2012, Fanfani, Fagotti et al. 2013), the other is using natural orifice translumenal endoscopic surgery (Lima 2008, Henriques-Coelho 2011, Moreira-Pinto 2014) and, the third is decreasing the diameter of the trocars from 5–10 mm or more to 3 or 2 mm (as in the case of mini- or microlaparoscopy) (Ghezzi, Cromi et al. 2008) (Ghezzi, Uccella et al. 2014).

There is no consensus in the literature about the strict definition of “minilaparoscopy,” although several reports have suggested that the word be reserved only for laparoscopic operations performed entirely using 3-mm trocars with the only possible exception of the umbilical port (Ghezzi, Cromi et al. 2011) (Ghezzi, Cromi et al. 2013).

Minilaparoscopic surgery had been introduced several years ago, but it was initially reserved for exclusively diagnostic procedures, (Bruhat and Goldchmit 1998) whereas interventional use of 3-mm instruments was mainly considered as a mere complementary addition to standard 5–10-mm trocars.

In the beginning, minilaparoscopic instruments were problematic due to poor vision, loose grasping, easy bending, defective irrigation or suction, and decreased durability (Porpiglia, Morra et al. 2012). With the enhancement of surgical endoscopic techniques and the advances in equipment and materials, considerable numbers of procedures have become possible using minilaparoscopic instrumentation only. A second generation of minilaparoscopic instruments has addressed the former drawbacks, and currently, a wide range of instruments has been added in the armamentarium of endoscopic surgeons, such as bipolar graspers, dissectors, needle holders and suction–irrigation devices. This, added to a better training of the surgeons, has increased the applicability of minilaparoscopic surgery, and it gained force in some gynecological conditions, especially for those patients seeking for better cosmesis (Krpata and Ponsky 2013).

In the field of gynecologic surgery, the first operative applications regarded adnexal procedures (Ghezzi, Cromi et al. 2005) and standard hysterectomies (Wattiez, Goldchmit et al. 1999, Ghezzi, Cromi et al. 2008, Ghezzi, Cromi et al. 2011) (Fanfani, Fagotti et al. 2012). Surgeons then proceeded to intraperitoneal lymphadenectomy (Ghezzi, Cromi et al. 2009), ending up (for the time being) with total minilaparoscopic radical hysterectomy (Ghezzi, Cromi et al. 2011, Fanfani, Gallotta et al. 2013) (Ghezzi, Fanfani et al. 2013).

The introduction of 3-mm trocars for laparoscopic hysterectomy procedures has proven to be as effective as standard-caliber accesses (Ghezzi, Cromi et al. 2011) (Ghezzi, Cromi et al. 2008). One of the main contributors to these advancements has been the introduction of efficient 3 mm bipolar coagulation that can warrant adequate hemostatic control of moderate-caliber blood vessels, as in the case of the uterine pedicles.

As witnessed by an increasing body of literature, miniaturization of the instruments has allowed for maximization of the well-known benefits of standard minimally invasive techniques (smaller surgical scars, reduced blood loss, less pain following surgery, shorter hospital stay, faster return to normal activity, reduced risk of infection and herniation) (Bisgaard, Klarskov et al. 2000) (Carvalho, Loureiro et al. 2011).

With the availability of refined minilaparoscopic instruments and following the trend of further improving laparoscopic morbidity, minilaparoscopy has recently gained significant popularity (Table 1).

Table 1 – Main achievements in history of minilaparoscopic approach in Gynecology

1998 - Diagnostic minilaparoscopy (Bruhat and Goldchmit 1998)
1999 - First minilaparoscopic hysterectomy (Wattiez)
2005 - First minilaparoscopic operative applications regarding adnexal procedures (Ghezzi, Cromi et al. 2005)
2009 - First minilaparoscopic intraperitoneal lymphadenectomy (Ghezzi, Cromi et al. 2009)
2011 - Total minilaparoscopic radical hysterectomy (Ghezzi, Cromi et al. 2011, Fanfani, Gallotta et al. 2013) (Ghezzi, Fanfani et al. 2013)

1.5. The role of lymphadenectomy in gynecological uterine malignancies

Cervical cancer is the second most common malignancy in women worldwide (Jemal, Bray et al. 2011). Cervical cancer is clinically staged, but assessment of pelvic and paraaortic lymph nodes is performed with lymphadenectomy and/or imaging. In surgically treated patients with early cervical cancer, lymph node metastasis is the most important risk factor for recurrence and death (Creasman and Kohler 2004) (Delgado, Bundy et al. 1990) (Biewenga, van der Velden et al. 2011).

In developed countries, endometrial cancer is the most common gynecologic malignancy (Jemal, Bray et al. 2011). Pelvic and paraaortic lymph node evaluation is a major component of the surgical staging procedure for endometrial carcinoma (Papadia, Remorgida et al. 2004).

The surgical and oncologic goals of the lymph node dissection are to define the extent of disease, and thereby, to guide further treatment. Lymphadenectomy may also have a therapeutic goal in conditions in which removing nodes harboring metastatic disease improves survival (Cosin, Fowler et al. 1998) (Gold, Tian et al. 2008) (Goff, Muntz et al. 1999) (Kilgore, Partridge et al. 1995).

The lymphatic system transports excess intracellular fluid that will be recirculated or excreted. It is able to drain larger sized debris compared with the vascular system. Small lymphatic capillaries drain organs and merge into larger vessels that eventually drain into lymph nodes. The ultimate destination of this drainage and filtration system is the thoracic duct, which empties into the venous system.

Malignant tumor can invade the lymphatic endothelium, forming emboli that may be carried to regional or distant lymph nodes. The lymph nodes of interest in a pelvic and paraaortic dissection lie along, upon, or in between the great vessels of the pelvis and abdomen. Lymph nodes are divided into regions based upon arbitrary anatomic boundaries for the purpose of staging of cancers and for defining the boundaries of surgical dissection.

Lymphatic drainage from the pelvic viscera may proceed in a step-wise fashion from the pelvic to the lower and then upper aortic lymph nodes; however, lymphatic channels from the ovaries, fallopian tubes, and uterus may also drain directly into the lower and upper paraaortic nodes.

The pelvic lymph nodes include the lower portion of the common iliac, external and internal iliac, obturator, sacral, and pararectal nodes. It is uncommon the sacral and pararectal nodes to be included in a lymph node dissection for a gynecologic malignancy. According to the Gynecologic Oncology Group Surgical Procedures Manual (Whitney et al., 2009), pelvic node dissection includes bilateral removal of nodal tissue from the distal one-half of each common iliac artery, the anterior and medial aspect of the proximal half of the external iliac artery and vein, and the distal half of the obturator fat pad anterior to the obturator nerve. Most of the pelvic lymph nodes lie anterior, medially, and posteriorly to the external and internal iliac vessels and the obturator nerve. There are a few nodes that lie lateral to these structures, between the vessels and the pelvic sidewall, and these are generally removed in a complete dissection.

According to the Gynecologic Oncology Group Surgical Procedures Manual (Whitney et al., 2009), paraaortic node dissection consists of resection of nodal tissue over the distal vena cava from the level of the inferior mesenteric artery to the mid right common iliac artery and between the aorta and the left ureter from the inferior mesenteric artery to the left mid common iliac artery. By convention, many staging protocols limit the superior extent of dissection for gynecologic malignancies to the level of the inferior mesenteric artery. However, uterine fundal, fallopian tube, and ovarian lymphatics can drain directly to the paraaortic nodes above the level of the inferior mesenteric artery. The lymphatic drainage from pelvic viscera to the paraaortic nodes is complex and involves both ipsilateral and contralateral connections in addition to direct lymphatic channels that may bypass the pelvic drainage basin.

A lymph node dissection (also referred to as lymphadenectomy) is intended to clear all lymph nodes from a specified area defined by anatomic boundaries.

In early-stage cervical cancer, information regarding lymph node involvement helps to guide whether the primary therapy will be radical hysterectomy or chemoradiation, and if adjuvant chemoradiation should be given. In addition, the information impacts the anatomic level chosen for volume-directed radiation therapy in both early- and advanced-stage disease (Delgado, Bundy et al. 1990) (Tanaka, Sawada et al. 1984) (Tinga, Timmer et al. 1990).

Endometrial cancer is surgically staged. One of the most important prognostic factors for endometrial carcinoma is the presence of extrauterine disease, particularly pelvic and paraaortic lymph node metastases. Evaluation of pelvic and paraaortic lymph nodes is required as part of staging, but there is ongoing controversy about the mode of evaluation, particularly in women presumed to have early-stage disease. Possible approaches include pelvic and paraaortic node palpation and sampling, selective lymphadenectomy based on frozen section criteria (grade, tumor size, and depth of invasion), complete lymphadenectomy, or sentinel node evaluation. The presence of pelvic and/or paraaortic lymph node metastases determines whether postoperative radiation and/or chemotherapy is indicated and to what level the radiation may possibly be given (Kilgore, Partridge et al. 1995) (Mariani, Webb et al. 2000).

Lymphadenectomy is associated with risks and side effects (prolonged operation duration, increased blood loss, infection, nerve injury, lymphoceles formation, vascular injury, venous thromboembolism, and lower extremity lymphedema), which may negatively impact the patient's quality of life (Levenback, Coleman et al. 2002) (Matsuura, Kawagoe et al. 2006). Minimally invasive techniques have become the gold standard of care as they decrease morbidity, hospital stay and period of return to normal activity. The majority of the cases are performed by a transperitoneal approach; however, recently extraperitoneal approach has been used.

The retroperitoneal space is a potential space that is accessed via a transperitoneal incision, or directly via an extraperitoneal approach. The kidneys, ureters, bladder, great vessels, lymphatic channels, lymph nodes, nerves, and muscles lie underneath the peritoneum and are enveloped in loose areolar connective tissue. Knowledge of the anatomy of the retroperitoneum and the surgical ability to dissect and develop these potential spaces greatly facilitates radical gynecologic surgery and pelvic and paraaortic lymph node dissection. The pararectal and paravesical pelvic spaces and the retroperitoneum of the lower abdomen are developed by the surgeon in order to define the boundaries of the lymph nodes and facilitate the surgical dissection.

1.5.1 Intraperitoneal/Transperitoneal Approach

A transperitoneal approach offers excelent access to the pelvic nodes and variable access to the paraaortic nodes. Access to the paraaortic nodes is primarily dependent on whether the patient is obese and the experience of the surgeon. Paraaortic lymphadenectomy is more difficult in obese patients because the bowel and omentum store a great deal of fat. These structures need to be mobilized and retracted out of the field of dissection to access the paraaortic nodes.

1.5.2 Extraperitoneal/Retroperitoneal Approach

An extraperitoneal approach offers excellent exposure to the paraaortic nodes, even in obese patients. The extraperitoneal access in comparison to the standard transperitoneal one presents a number of potential advantages. Firstly, the approach to the retroperitoneal space provides the possibility to limit and tamponate possible leaks of either blood or urine, avoiding the direct contact of urine or blood with bowel that can cause ileus (Madi, Daignault et al. 2007). The possibility of either vascular or intestinal injury is also decreased. Moreover, avoiding the entry into the peritoneal cavity can minimize the post-operative adhesions and hernia complications (Huang, Slomovitz et al. 2009). The CO_2 insufflated into the working space is of lower pressure (about 12 mmHg lower) and quantity in relation to the transperitoneal technique. Thus, complications related to CO_2 passage into peritoneal cavity, such as subcutaneous emphysema, pneumothorax or even vagus nerve irritation, are quite negligible at the extraperitoneal technique. Additionally, the extraperitoneal approach reduces the necessity of extreme Trendelenburg position due to the fact that the abdominal viscera are retracted by peritoneum, offering a clear view of the surgical field. This is crucial in obese or elderly patients with comorbidities (Atug, Castle et al. 2006). In particular, the decreased inclination during Trendelenburg position reduces the negative impact on ventilation and the usually increased peak pressure in the group of obese patients. However, the extraperitoneal technique may also present a few drawbacks. The restricted working space can be a serious issue.

From a technical point of view, the main strength of the extraperitoneal para-aortic lymphadenectomy is avoidance of intra-abdominal entry. This allows for relatively rapid access to the vascular axes, in particular to the left aortic group of lymph nodes until the level of the renal vein, without being bothered by bowel loops (Vasilev and McGonigle 1996). This makes the extraperitoneal approach particularly suitable in obese patients in whom exposure of major retroperitoneal vessels in a transperitoneal laparoscopy can be a major problem.

1.6. Sentinel lymph node

Although the definition of the sentinel lymph node was presented by Cabanas in 1977, the idea of the sentinel node had been earlier described by Braithwaite in 1923, and the term 'the sentinel node' was first used by Gould in 1960 (Gould, Winship et al. 1960). Dynamic development of the SLN biopsy technique began in 1992, when Morton published their report on the use of this method in patients with skin melanoma (Morton, Wen et al. 1992).

A SLN is defined as a lymph node that has a direct connection to the primary tumor through a lymphatic channel and represents the lymph node(s) most likely to first receive metastases from the primary tumor (Gould, Winship et al. 1960). SLN detection has proven feasible and safe in select cancers such as vulvar cancer, breast cancer, early gastric cancer and melanoma (Loar and Reynolds 2007) (Kelder, Nimura et al. 2010).

In endometrial and cervical cancers the SLN finding is becoming more common (Echt, Finan et al. 1999) (Frumovitz, Ramirez et al. 2008) (Oonk, van de Nieuwenhof et al. 2009) (van de Lande, Torrenga et al. 2007) (Abu-Rustum, Khoury-Collado et al. 2008). A few centers are performing SLN outside research protocols; however, comparisons of cost effectiveness, complications, and overall survival between women who have had SLN versus traditional lymphadenectomy or lymph node sampling have not been completed.

The rationale for SLN mapping is to identify patients with lymph node metastases and avoid the morbidity of a full lymphadenectomy in patients with negative SLNs. In addition, SLN mapping may also be considered a technique that may identify occult metastatic disease not otherwise identified by a standard lymphadenectomy. This may occur if the node lies outside of the usual boundaries of pelvic or paraaortic lymph node dissection. Also, the SLN evaluation process typically includes ultra-section of the SLN and immunohistochemical staining, which may be more sensitive than the traditional hematoxylin and eosin evaluation.

The most common technique for identification of sentinel nodes is the injection of vital blue dyes (eg, methilen blue) and/or radioisotope (eg, Technetium-99) around the tumor. These techniques are relatively well established for patients diagnosed with vulvar carcinoma. The combination of technetium radiocolloid and blue dye demonstrated better results in SLN mapping in both early stage cervical and endometrial cancer. The detection rate reported in recent literature ranges from 70% to 93% (Khoury-Collado, Murray et al. 2011) (Bats, Frati et al. 2015). This injection can be performed intraoperatively with or without preoperative lymphoscintigraphy, and hand-held and laparoscopic instruments (gamma-probe) are available. However, the complexity of the procedures and the related costs are pushing for a more feasible and efficient tracer research.

Recently, there is increasing interest in the use of the fluorescent dye, indocyanine green (ICG) that is a tricarbocyanine dye that fluoresces in the NIR spectrum when illuminated with 806 nm light. The fluorescent light is then captured using a special video camera device that enables the ICG to be displayed in the visible light spectrum. ICG is highly water-soluble and rapidly binds to albumin, and therefore has a propensity for lymphatic tissue (Levinson, Mahdi et al. 2013). ICG may be used for SLN detection in the setting of open, laparoscopic, or robotic surgery.

ICG offers a novel tool to identify sentinel nodes avoiding radioactivity and demonstrating superior rates of unilateral and bilateral SLN detection (Darin, Gomez-Hidalgo et al. 2015) (Jewell, Huang et al. 2014) (Plante, Touhami et al. 2015) (How, Gotlieb et al. 2015)(Ditto, Martinelli et al. 2015).

Recently, it was confirmed that cervical injection of ICG achieved a higher detection rate and a similar anatomic nodal distribution as hysteroscopic injection for SLN mapping in endometrial cancer patients (Rossi, Jackson et al. 2013). Furthermore, the rationale of using the cervix as injection site for SLN mapping has been confirmed by classic morphological studies. A well-known lymphatic pathway is composed of a complex network of bilaterally independent lymphatic channels, draining the uterine cervix and the corpus primarily from the lateral parametrial regions (Ercoli, Delmas et al. 2010). The cervical injection still remains the easiest and most reproducible way to perform SLN mapping but at the same time, hysteroscopy injection in well skilled hands represents a valid alternative (Buda, Lissoni et al. 2016).

The best surgical approach to identify and excise the SLN (laparotomy, laparoscopy, and robotics) is still under evaluation (Mais, Peiretti et al. 2010) (Rossi, Ivanova et al. 2012). Currently, efforts of laparoscopic surgeons are aimed at further reducing the morbidity associated with minimally invasive technology, while maintaining the same high standard of surgical results. With a recent focus on minimizing the visibility of scars, minilaparoscopy has reemerged as an attractive option for surgeons because it limits tissue trauma and offers improved cosmetics.

The combination of the SLN technique and minilaparoscopy could be a future alternative to achieve the goal of a less aggressive surgical procedure. The former is the least invasive method to assess lymph nodes by histologic examination and the latter seems to be one of the least invasive surgical approaches.

2
Aims

Aiming to minimize the aggressiveness of laparoscopic surgery in gynecology, the following specific aims were pursued in this thesis:

1 - To add the advantage of minilaparoscopy to the benefit of the SLN concept in uterine malignancies, we:

a) evaluated the feasibility of SLN intraperitoneal/transperitoneal excision by minilaparoscopy, and we compared it with the conventional laparoscopic 5 mm instruments approach in a porcine model

b) assessed the reliability of SLN excision by minilaparoscopy using an extraperitoneal approach, and we compared it with the conventional laparoscopic 5 mm instruments approach in a preclinical study

i) evaluated if those smaller minilaparoscopic instruments could offer a better surgical approach in the narrow and restricted extraperitoneal space

2 - To test the feasibility of indocyanin green fluorescent dye for SLN identification by an extraperitoneal access using a special video camera in a porcine model

3 - To carry out minilaparoscopic sacrocolpopexy and sacrocervicopexy (nerve sparing technique) to correct genital prolapse in humans.

PART II Results

3
Minilaparoscopy and sentinel lymph node - intraperitoneal image-guided approach

Minilaparoscopy and Sentinel Lymph Node in Uterine Cancer-Preclinical Study.
Ferreira H, Nogueira-Silva C, Miranda A, Correia-Pinto J.
CRSLS e2014.00055. DOI: 10.4293/CRSLS.2014.00055

CASE REPORT CRSLS

Minilaparoscopy and Sentinel Lymph Node in Uterine Cancer

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ABSTRACT

Background: The sentinel lymph node (SLN) concept might minimize surgical aggressiveness in gynecological oncology, namely in cervical and endometrial malignancies. Therefore, we assessed the feasibility of SLN identification, dissection, and harvesting by using minilaparoscopic surgical instruments in an animal model. We compared the minilaparoscopic approach, which is known to bring important advantages, with the use of conventional laparoscopic instruments.

Methods: Two groups of 7 female pigs were enrolled in this experiment that was performed by the same surgical team. In group A, all animals were approached by a similar minilaparoscopic surgical instrumentation, namely a 5-mm 30° endoscope (supraumbilical port) and 3 ancillary 3.5-mm trocars. In group B, a 5-mm conventional laparoscopic instrument set was used. The patent blue (4.0 mL) was injected on the paracervical region. The time for SLN coloring, identification, localization, dissection, and excision, as well as complications were recorded. The sealing of the lymphatic vessels was observed in the 2 groups. During this experiment, and for the both groups, the Trendelenburg position was kept the same, as well as the carbon dioxide–pneumoperitoneum pressure. Finally, a laparotomy was then performed to evaluate whether any stained SLN still remained.

Results: All endoscopic procedures were performed without major complications. SLN were identified and excised in all animals in both groups. The SLN localization varied between animals from external iliac to preaortic regions. The surgical times, from skin incision to SLN removal, was 28.4 ± 5.6 minutes for minilaparoscopy and 25.3 ± 6.8 minutes for conventional laparoscopy ($P = .36$). In group B, 1 stained SLN remained and was only detected by laparotomy.

Conclusions: We confirmed the feasibility of the minilaparoscopic surgical approach for identification, dissection, and excision of SLN, as well as for sealing the lymphatic vessels that supply the nodes. This procedure might be considered a potentially better alternative to reduce morbidity during staging procedures for gynecological malignancies.

Key Words: Gynecology, Instrumentation, Malignancy, Minilaparoscopy, Sentinel lymph node, Surgery

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INTRODUCTION

Gynecologists pioneered the laparoscopic approach to abdominal surgical procedures. By the late 2000s, with improvements in training and innovative adaptations of instruments and techniques, minimally invasive approaches for gynecologic malignancies started to be used more often.[1]

Cancer of the cervix is the second most common malignancy in women worldwide.[2] In surgically treated patients with early cervical cancer, lymph node metastasis is the most important risk factor for recurrence and death.[3–5] On the other hand, in developed countries, endometrial cancer is the most common gynecologic malignancy.[2] Evaluation of lymphatic spread in cervical and endometrial cancers staging remains an ongoing area of controversy in the field of gynecologic oncology. Traditionally, to obtain histological diagnosis of nodal spread, the entire lymphatic basin draining a tumor is removed (resulting in prolonged operation duration, increased blood loss, infection, nerve injury, lymphocyst formation, vascular injury, venous thromboembolism, and lower extremity lymphedema).[6,7]

A sentinel lymph node (SLN) is any lymph node that receives direct drainage from the tumor site and is identified by a procedure called lymphatic mapping. SLN biopsy techniques have been developed to decrease complications related to entire lymphadenectomy, to improve detection of micrometastatic disease, and to fine-tune our lymphadenectomy anatomic templates. SLN mapping has been studied in cervical and endometrial cancer with encouraging data.[8–12] The best surgical approach to identify and excise the SLN (laparotomy, laparoscopy, and robotics) is still under evaluation.[13,14]

Currently, efforts of laparoscopic surgeons are aimed at further reducing the morbidity associated with minimally invasive technology, while maintaining the same high standard of surgical results. With a recent focus on minimizing the visibility of scars, minilaparoscopy has re-emerged as an attractive option for surgeons because it limits tissue trauma and offers improved cosmetics.

The combination of the SLN technique and minilaparoscopy could be an alternative to achieve the goal of a less aggressive surgical procedure. The former is the least invasive method to assess lymph nodes by histologic examination and the latter seems to be one of the least invasive surgical approaches. To add the advantage of minilaparoscopic approach to the benefit of the SLN concept on an oncologic staging system, we evaluated the feasibility of SLN excision by minilaparoscopy in a porcine model, and we compared it with the conventional laparoscopic approach.

MATERIALS AND METHODS

The aim of the study was to test, using an in vivo porcine model, the feasibility of minilaparoscopic approach for SLN identification, dissection, and excision using the new 3.5-mm rotating bipolar coagulator. We did the same experiments in a second control group with 5-mm conventional laparoscopic instruments. Animal experiments were performed following EU Directive 2010/63/EU and the Portuguese law for animal welfare (*Diário da República*, Portaria 1005/92).

Animal Model

To accomplish the aim, 18 female pigs (*Sus scrofus domesticus*) weighing between 35 and 45 kg were submitted for the surgical procedure. The first 4 animals, used to establish anatomical landmarks and technical steps, were not included in the following protocol. Two animal groups were formed with 7 animals each. Group A was submitted for minilaparoscopy and group B for conventional laparoscopy. Animals were randomly assigned to groups and the animals' mean weight was 38 ± 2.1 kg in group A and 38 ± 3.2 kg in group B. All the pigs were 12 weeks of age.

Pig Preparation

All procedures were performed with the animals under general anesthesia with endotracheal intubation and mechanical ventilation. The pigs had no access to food (8 hour) nor water (4 hour) before the surgical procedure. Animals were premedicated with a combination of azaperone (4 mg/kg, intramuscularly [IM]), midazolam (1 mg/kg, IM), and atropine (0.05 mg/kg, IM). Anesthesia was induced with propofol (6 mg/kg, intravenously) and maintained with continuous propofol infusion (20 mg/kg/h, intravenously) and buprenorphine (0.05 mg/kg, IM).

Surgical Procedures

The animals were placed in exactly the same Trendelenburg position (25°) and immobilized. In group A, the pneumoperitoneum (14 mm Hg) was created using a Veress needle at a supraumbilical position, where an optical trocar (30160GC; Karl Storz 6-mm trocar set; Karl Storz, Tuttlingen, Germany) was introduced and a 5-mm 30° endoscope (26046BA; HOPKINS II forward oblique telescope; Karl Storz) was used to have a general view of the abdominal cavity. After observing the pelvis, under direct visualization, 3 3-mm ancillary trocars (30114GZL; Karl Storz minilaparoscopy trocar set) were inserted, 1 suprapubically and 2 laterally to the epigastric arteries, in the left and right lower abdominal quadrants, respectively. The bladder was fixed to the anterior abdominal wall with a *TLIFT* (VECTEC, Vichy, France) to get a better exposure of the surgical field. Internal iliac vessels were visualized followed by the identification of external iliac vessels, aorta, and vena cava. Patent-V blue (4 mL) was injected in the paracervical region (Spinocan 26G 120 mm; Braun, Melsungen, Germany). A few minutes after blue injection on the paracervical region, the lymphatic mapping was observed, showing the colored lymphatic channels toward the lymph nodes that retained the blue dye. In this experience, 36-cm-long minilaparoscopic instruments (Karl Storz Endoskope minilaparoscopy instruments set) were used, choosing among graspers, cold scissors, suction/irrigation, and the recent 3.5-mm bipolar coagulator (Karl Storz Robi).

After opening the retroperitoneum, all blue-stained lymph nodes were classified as sentinel and were finely dissected and excised separately with minilaparoscopic instruments. Any small bleeding was immediately controlled with the bipolar instrument that was used also for sealing the lymphatic vessels.

The procedure time, defined as the interval between the start of skin incisions to SLN removal, was recorded as well as difficulties and complications at each step of the procedure. The intraoperative complications were defined as bowel, bladder, ureteral, or vascular injuries, and an estimated blood loss > 200 mL. Estimated blood loss was estimated from the contents of suction devices.

After SLN extraction, bilateral dissection was performed to achieve visualization of the aorta and the vena cava and, subsequent completion of pelvic and para-aortic lymphadenectomy was carried out. Finally, a laparotomy was then performed to evaluate whether there was any remaining SLN. After the procedure, the pigs were euthanized by anesthesia overdose.

In group B, exactly the same procedure, by the same surgical team, was performed but with 5-mm conventional laparoscopic instruments. To avoid possible bias comparing the groups, all the experiments were performed by the same surgical team.

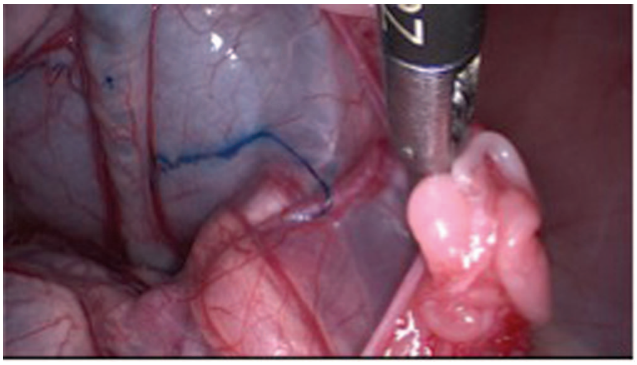

Figure 1. Lymphatic afferent vessels colored by blue dye after cervical injection.

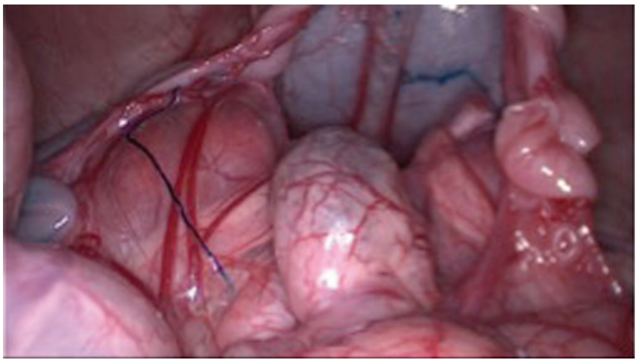

Figure 2. Lymphatic afferent vessels colored by blue dye to the sentinel lymph node.

Data Recording

All surgical endoscopic procedures were recorded on an advanced image and data archiving (AIDA) device from Karl Storz. Vital and physiological parameters (heart rate, arterial pressure, and respiratory distress) were monitored by the research team.

Histologic Analysis

The lymph nodes were analyzed without freezing. Lymph nodes were fixed in neutral buffered formaldehyde for 24 to 72 hours, then cut into 0.1-cm-thick slices, and embedded in a paraffin block per node. Multiple sections were prepared from each block. A set of 3 4-μm-thick sections was cut every 250 μm. Sections were stained with hematoxylin and eosin.

Statistical Analysis

All quantitative data are presented as mean ± SD. Statistical analysis was performed using the statistical software SigmaStat (version 3.5; Systat Software Inc, San Jose, California).

Independent samples Student *t* test analysis was used to compare surgical times, and statistical significance was set at $P < .05$. We also present Cohen *d* measure of effect size, whereby 0.2 equates to a small effect, 0.5 equates to a medium effect, and effects > 0.8 equate to large effects.[15]

RESULTS

Following the blue dye injection on the paracervical region, the blue lymphatic channels were identified **(Figures 1 and 2)** as well as the ending blue lymph node, which was considered the SLN. The average time for coloring of the SLNs was 7.9 ± 1.1 minutes in group A and 7.3 ± 1.1 minutes in group B [$t(12) = 0.98$; $P = .35$, $d = 0.524$ – medium effect size]. The retroperitoneum was accessed in the standard fashion with care to avoid bleeding from vessels and capillaries, which might stain the retroperitoneum, resulting in greater difficulty in following the blue lymphatic channels. Identification, dissection, and excision of SLNs were performed with success in all pigs. The overall results of our study are summarized in **Table 1.** The average times to perform the experiments were 28.4 ± 5.6 minutes in group A and 25.3 ± 6.8 minutes in group B [$t(12) = 0.94$; $P = .36$, $d = 0.507$ – medium effect size]. From every animal, at least one colored lymph node was excised; in some cases, 2 lymph nodes were. Concerning the SLN locations, most of the SLNs were found in the right iliac and left iliac vessels regions, 3 on the promontory region, 1 on the right obturator, and 1 on the preaortic region. Lymphatic vessels were sealed with the rotating bipolar instruments. According to our feedback, the minilaparoscopic bipolar dissector offered better small vessel hemostasis and a more efficient sealing of the afferent lymphatics **(Figure 3).** The colored lymph nodes were sent to histology

Table 1.
Individual Data After Patent Blue Injection and SLN Detection

Group	SLN			Complications	Operative Time, min
	Coloring Time, min	*n*	Location		
A: minilaparoscopy					
1	8	1	Right iliac vessels		35
2	8	1	Right obturator		36
3	6	2	1 promontory; 1 right iliac vessels	Bleeding 30 mL	31
4	9	1	Left iliac vessels		27
5	9	2	Left iliac vessels		22
6	8	1	Preaortic		25
7	7	1	Right iliac vessels		23
Mean ± SD	7.86 ± 1.07				28.43 ± 5.65
B: conventional laparoscopy					
1	7	1	Left iliac vessels		38
2	6	1	Left iliac vessels		16
3	8	1	Promontory		23
4	8	1	Right iliac vessels		26
5	6	1	Left iliac vessels		22
6	7	2	Right iliac vessels and left iliac vessels		24
7	9	1	Promontory		28
Mean ± SD	7.29 ± 1.11				25.29 ± 6.75
P	.35				.36
Cohen *d*	0.524				0.507

Abbreviation: SLN, sentinel lymph node.

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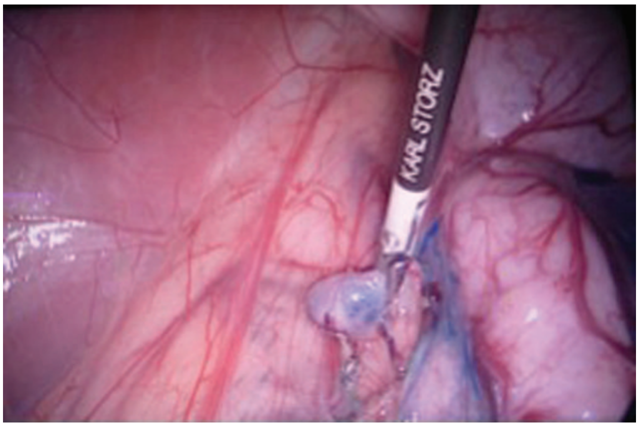

Figure 3. Minilaparoscopic sentinel lymph node identification and dissection with 3.5-mm Robi Kelly forceps.

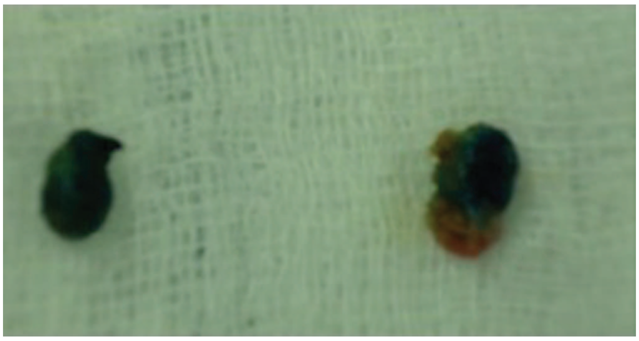

Figure 4. Lymph node colored in blue.

(Figures 4, 5, and 6). No major complications were observed in our series. Neither urinary nor digestive tract injuries were reported. There was 1 case of intraoperative bleeding (30 mL), which was controlled by minilaparoscopic instruments. Minilaparoscopic port sites required no suture closure. After the experiments, all animals were submitted to laparotomy. In the group B, there was 1 SLN that was only detected after laparotomy.

DISCUSSION

SLN techniques are now part of the standard treatment for breast cancer,[16] melanoma,[17] and selected cases of vulvar cancer.[18] The application of the SLN concept for malignancies of intra-abdominal organs is still under evaluation and testing. SLN biopsy has been one of the most important innovations in surgical oncology in recent years; it is being reported as a less invasive procedure that brings more information to clinicians.[9,10]

In SLN biopsy–negative patients, regional lymphadenectomy may no longer be a requirement, promising fewer potential complications such as lymphedema, lymphocysts, nerve injury, vascular injury, and venous thromboembolism. In uterine cancers, SLN biopsy holds the hope of more accurate identification of uterine drainage and staging of the primary tumor, as well as, potential applications in fertility-sparing surgical procedures.[19]

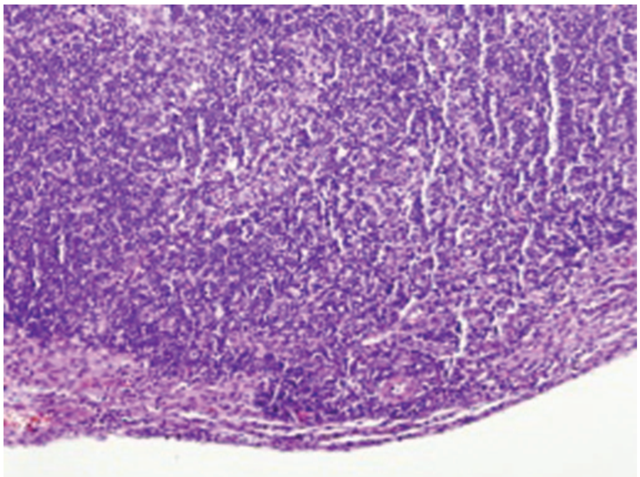

Figure 5. Excised sentinel lymph node. (Hematoxylin and eosin 4×).

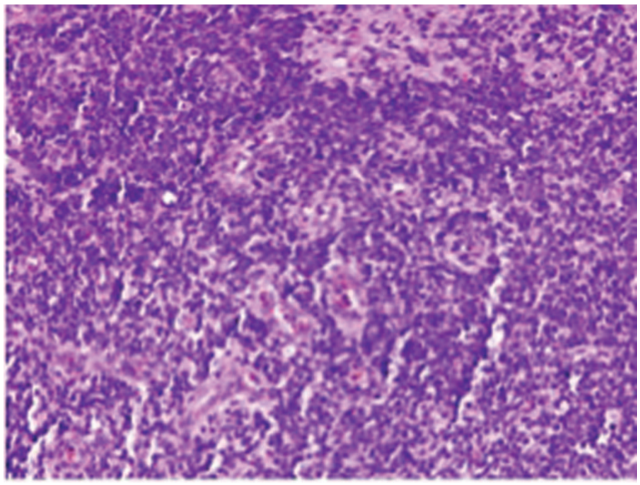

Figure 6. Excised sentinel lymph node. (Hematoxylin and eosin 20×).

The SLN detection rate is significantly higher through laparoscopy than through laparotomy after vital dye pericervical injection.[13] In cervical cancer, lymphatic mapping can be conducted by laparotomic or laparoscopic approaches. It would appear perfectly logical to perform lymphatic mapping laparoscopically. The ad-

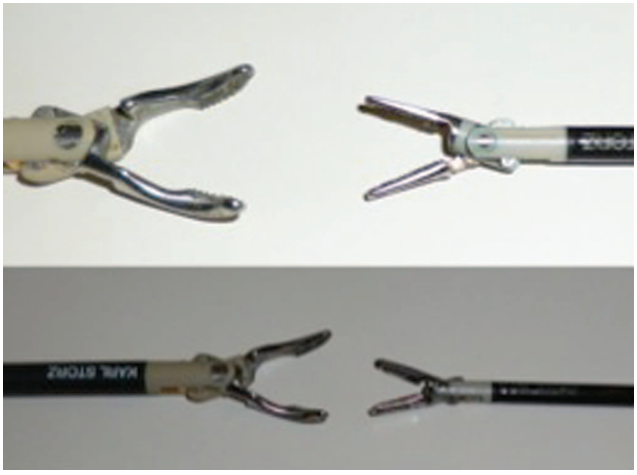

Figure 7. The 5-mm rotating bipolar versus minilaparoscopic Robi Kelly.

vantages are several and obvious: first, the laparoscopic surgical approach allows a more delicate and bloodless dissection of the retroperitoneum; second, laparoscopy permits magnification of the image, which facilitates visualization of blue lymphatic vessels; and third, if positive nodes are identified, the surgeon has the opportunity to end the procedure, thus avoiding radical hysterectomy, and offer to patients chemoradiation with minimal delay and reduced morbidity compared with laparotomy.

Minilaparoscopy re-emerged has an even better approach involving the use of miniaturized scopes and instruments to further reduce perioperative morbidity and enhance cosmetic healing.

Most surgeons have been hesitant to adopt minilaparoscopy into their practice expressing concerns regarding the instruments (not functional or not strong enough). Furthermore, some have complained that 3-mm instruments do not offer the same array of end-effector options or functionality of the 5-mm instruments. Recently, minilaparoscopic surgical techniques have benefited from additional product development with a focus on improving instrument strength and optics. The transition from 10- to 5-mm ports was a change from big to small, whereas the transition from 5 to 3 mm is visible to invisible.[20]

During these experiments, the research team found those thinner instruments to be very functional with no increase in complexity. The new minilaparoscopic rotating bipolar instrument **(Figure 7)** greatly facilitates a bloodless, precise tissue dissection, shortens the operation time, prevents unnecessary application of intraperitoneal foreign bodies, reduces the costs, and brings more convenience to the surgeon.

Another advantage of minilaparoscopy is the possibility of performing it under local anesthesia, generally with sedation, thus avoiding general anesthesia complications.[21] It may be easier to schedule and reduce the costs of SLN excision. It decreases the extent of intraoperative injury, avoids incisional herniation, and reduces postoperative pain.

In addition, the use of small-diameter laparoscopes and instruments is feasible with low carbon dioxide pressures,[22] thereby reducing possible complications related to pneumoperitoneum.

This is the first study that compares minilaparoscopic versus conventional laparoscopic approaches for this type of procedure. Further studies with larger samples, lower carbon dioxide pressures, and local anesthesia should be done. Also, human studies should be performed.

The minilaparoscopic approach to SLN is a promising concept in the minimally invasive surgical domain.

CONCLUSIONS

Minilaparoscopic approach to SLN identification, dissection, and excision is a feasible and reproducible procedure. Our comparative study revealed no statistically significant time difference between the minilaparoscopic and conventional laparoscopic procedures. With the smaller tools, a gentle and fine dissection of the anatomical planes, lymphatic nodes, and vessels was observed. Additionally, better sealing of lymphatic afferent vessels that supply the nodes was obtained.

This procedure can be considered a potentially better alternative to reduce morbidity during staging procedures for gynecologic malignancies.

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4

Minilaparoscopy and sentinel lymph node – extraperitoneal image-guided approach

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Resection of Sentinel Lymph Nodes by an Extraperitoneal Minilaparoscopic Approach Using Indocyanine Green for Uterine Malignancies: A Preclinical Comparative Study

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Abstract

Background. The sentinel lymph node (SLN) concept might minimize surgical aggressiveness in cervical and endometrial malignancies. The aim of the study was to test the feasibility and reliability of minilaparoscopic extraperitoneal SLN excision after indocyanine green (ICG) cervical injection using a high-definition near infrared (NIR) imaging system in an in vivo porcine model. The same procedure was performed using conventional laparoscopic instruments and both outcomes were compared. *Methods*. Twenty-four animals were equally and randomly divided into a minilaparoscopic group (group A) and a 5-mm conventional laparoscopic group (group B). A high-definition NIR imaging system and a 30° ICG endoscope were used. First, ICG (0.5 mL) was injected in the paracervical region. The SLN coloring time was recorded. An extraperitoneal approach to the SLN was executed with the same CO_2 retropneumoperitoneum pressures (10 mm Hg). In both groups, the times for SLN localization and excision, as well as complications, were registered. Finally, a laparotomy was then done to evaluate whether any stained SLN still remained. The same surgical team performed all experiments. *Results*. SLNs were identified and extraperitoneally excised in all animals without major complications. The SLN localization varied between animals from external iliac to preaortic regions. The surgical times were shorter with minilaparoscopy (39.3 ± 13 minutes) than with conventional 5-mm instruments (51.3 ± 14.17 minutes; P = .042). In group B, one stained SLN remained and was only detected by laparotomy. *Conclusions*. We confirmed the feasibility and reliability of extraperitoneal minilaparoscopic approach for identification, dissection, and excision of SLN using an NIR imaging system and ICG.

Keywords

gynecologic laparoscopy, surgical oncology, evidence-based medicine/surgery

Introduction

The evaluation of lymphatic metastases in the staging of cervical and endometrial cancers continues to be controversial in gynecologic oncology. By convention, the entire lymphatic basin draining a tumor is excised (resulting in prolonged operation duration, increased blood loss, infection, nerve injury, lymphocyst formation, vascular injury, venous thromboembolism, and lower extremity lymphedema) to obtain histological diagnosis of lymphatic metastases.[1,2] The development of sentinel lymph node (SLN) biopsy techniques have reduced the number of complications compared to traditional lymphadenectomy. SLN improves detection of micrometastatic disease and fine-tunes our lymphadenectomy anatomic templates.[3-7] The gold standard assessment of SLN in cervical and endometrial cancers is still to be established. SLN assessment has been performed with laparotomy, conventional laparoscopy,[8] robotics,[9] and minilaparoscopy,[10] always via transperitoneal or intraperitoneal approach.

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The benefits conferred by an extraperitoneal, laparoscopic lymphadenectomy include a short learning curve, decreased adhesion formation, feasibility in obese patients, patients with peritoneal adhesions, and reduced bowel complications associated with postoperative adjuvant irradiation.[11]

To the authors' knowledge, the combination of extraperitoneal minilaparoscopy in SLN assessment has not previously been described. There are no data referring to the use of these smaller instruments in the reduced extraperitoneal space. The aim of the study was to test the feasibility and reliability of minilaparoscopic extraperitoneal SLN excision after indocyanine green (ICG) cervical injection using a high-definition near infrared (NIR) imaging system in an in vivo porcine model. The same procedure was performed using 5-mm conventional laparoscopic instruments and both outcomes were compared.

Materials and Methods

Animal experiments were performed following EU Directive 2010/63/EU and the Portuguese law for animal welfare (Diário da República, Portaria 1005/92).

Animal Model

Our cohort included 27 female pigs (*Sus scrofus domesticus*) weighing between 35 and 45 kg. The first 3 pigs were used to establish anatomical landmarks and technical steps and therefore were not included in the subsequent protocol. Twenty-four pigs were equally and randomly divided into a minilaparoscopic group (group A) and a conventional laparoscopic group (group B). The mean weight of the pigs was 37 ± 2.1 kg in group A and 37 ± 1.6 kg in group B. All pigs were 12 weeks of age.

Pig Preparation

All procedures were performed with the pigs under general anesthesia, with endotracheal intubation and mechanical ventilation. The pigs were preoperatively starved of food for 8 hours and water for 4 hours. Animals were premedicated with a combination of azaperone (4 mg/kg, intramuscularly [IM]), midazolam (1 mg/kg, IM), and atropine (0.05 mg/kg, IM). The pigs were initially anaesthetized with intravenous propofol (6 mg/kg). Anesthesia was maintained with continuous intravenous propofol infusion (20 mg/kg/h) and intramuscular buprenorphine (0.05 mg/kg).

Surgical Procedures

After anaesthetization of the pigs, the pigs were positioned in a dorsal Trendelenburg position and immobilized. In both groups, pneumoperitoneum was created using a Veress needle.

A special laparoscope (26003 BGA, Karl Storz GmbH & Co KG, Tuttlingen, Germany) with a 30° angle of view, incorporating observation filters that allowed NIR and white light imaging without changing the telescope. The powerful xenon light source (D-LIGHT P SCB, Karl Storz) provided both visible and NIR excitation light. A pedal controlled by the surgeon was used to switch from standard light to NIR. The use of a fluid light cable ensured high light transmission. A dedicated, infrared-sensitive camera head (IMAGE 1 H3-Z FI, Karl Storz) in conjunction with a full high-definition camera control unit (IMAGE 1, Karl Storz) was used to process the genuine NIR fluorescence.

First, a laparoscope was introduced by a supraumbilical trocar and 0.5 mL of ICG solution (25 mg of ICG [Pulsion Medical Systems AG, Munchen, Germany] diluted in 10 mL of 0.9% NaCl solution) was injected on the paracervical region using a long needle (Spinocan 26G 120 mm; Braun, Melsungen, Germany). A few minutes after ICG injection, the colored lymphatic channels were mapped and followed toward nodes that retained the ICG dye. A stopwatch was used to calculate the time required for coloring of the nodes.

Second, a 12-mm incision, 2 cm superomedial to the anterosuperior iliac spine was made to develop an extraperitoneal space. Once the peritoneal layer was visualized, the surgeon introduced one finger into the incision and performed blunt dissection to separate the peritoneal layer from the abdominal wall, which was constantly visualized via the umbilical port. Subsequently, a 10-mm, single use, blunt tip trocar (OMST10BT, AutoSuture, Covidien) was placed through the incision to develop an extraperitoneal space. The abdomen was deflated, and the laparoscope was brought to the balloon-tipped trocar in the extraperitoneal space, which was then insufflated. The retroperitoneum was insufflated with carbon dioxide (CO_2) with a pressure not exceeding 10 mm Hg. The loose, areolar tissue in the extraperitoneal space was dissected freely using the laparoscope. Special attention was taken to prevent perforating the peritoneum, which could compromise the retropneumoperitoneum.

In the minilaparoscopic approach (group A), a 3.5-mm trocar was introduced into the extraperitoneal space along the midaxillary line, under the subcostal margin, approximately 5 cm above the initial trocar. An additional 3.5-mm trocar was then placed 3 to 4 cm cephalad to the balloon-tipped trocar in the preperitoneal space under endoscopic guidance. Utmost care was taken to ensure accurate trocar placement without perforating the peritoneum, which would make the remaining procedure difficult. While advancing to the retroperitoneum, CO_2 was administered via the balloon trocar channel to keep good

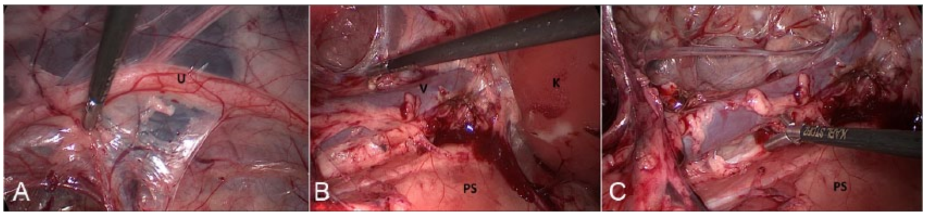

Figure 1. Extraperitoneal view (U, ureter; V, vena cava; PS, psoas muscle; K, kidney).

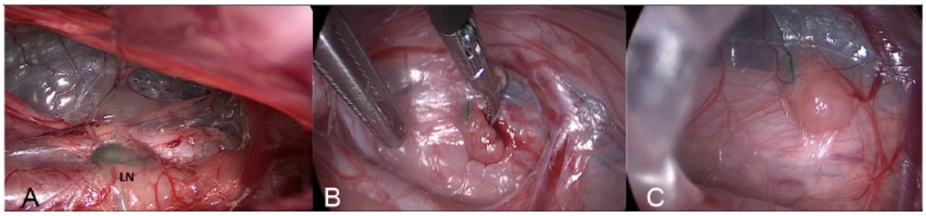

Figure 2. Lymphatics and lymph nodes (LN) colored by ICG.

exposure. The instrumental trocars accommodated 36-cm-long minilaparoscopic instruments (Karl Storz Endoskope minilaparoscopy instruments set), including graspers, cold scissors, suction/irrigation, and the recent 3.5-mm bipolar coagulator (Karl Storz Robi).

Once the extraperitoneal space was adequately insufflated, the left psoas muscle, ureter, gonadal vessels, and common iliac artery were easily identified (Figure 1). The retroperitoneum was accessed with care to avoid bleeding from vessels and capillaries, which could stain the retroperitoneum, making it difficult to follow the colored lymphatic channels. The lumbar and iliac segments of the ureter were lifted along with the peritoneal sac. The lateral aspect of the iliac artery was used as a guide to dissect caudally to the level of its bifurcation, up to the aortic bifurcation and lastly to the renal vessels. The operative field was thoroughly evaluated to look for colored retroperitoneal lymph nodes (Figure 2). The ureters and promontory were 2 useful landmarks in following the path of the lumboaortic lymph nodes. At the level of the kidneys, we identified paracaval, aortocaval, and preaortic lymph nodes. The laparoscopic fluorescence imaging system could visualize the lymphatic channels and nodes by stepping on the pedal (Figure 3). The distance between the laparoscope tip and target when applying the fluorescence was standardized at 2 to 3 cm. Once a colored lymph node was confirmed, it was grasped and gently separated from the attached lymphatic tissue (Figure 4). The peritoneal sac was elevated from the left common iliac vein and then from the sacral promontory. The bifurcation of the inferior vena cava was identified. The right

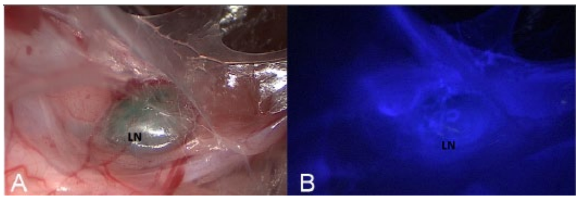

Figure 3. (A) Lymph node colored by ICG. (B) Lymph node in NIR light.

common iliac vein followed by the right common iliac artery were freed using blunt dissection. The right ureter was then elevated and separated from the iliac vessels and the psoas muscle. At this time, the right lateral common iliac, presacral, and precaval nodes were identified. Lymphatic vessels were sealed with the bipolar dissector (Figure 5). The resected SLNs were extracted from the extraperitoneal cavity with an endoscopic bag through the 10-mm port under direct vision of a 3-mm endoscope inserted at one of the 3.5-mm ports. Careful hemostasis with bipolar energy was used at the end of the procedure. At this time, the extraperitoneal space was deflated, and the abdominal cavity was insufflated. The laparoscope was once again placed through the supraumbilical port. Finally, a laparotomy was then performed to evaluate whether there were any remaining SLNs. After the procedure, the pigs were euthanized with an overdose of anesthesia. The procedure time (defined as interval between skin incision to SLN removal), difficulties, and complications at each step of the procedure were recorded. The

Figure 4. (A) SLN extracted with a minilaparoscopic grasper. (B and C) Lymph node in NIR light.

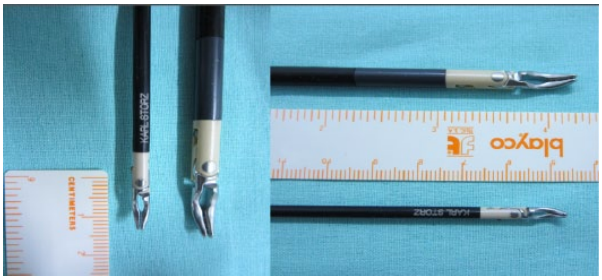

Figure 5. Standard 5-mm rotating bipolar *versus* minilaparoscopic bipolar dissector.

intraoperative complications were defined as bowel, bladder, ureteral, or vascular injuries, and an estimated blood loss >200 mL. Estimated blood loss was assessed from the contents of suction devices. The procedure can be broken into 4 parts: diagnostic laparoscopy to observe lymphatic mapping and rule out intraperitoneal disease; the insertion of the retroperitoneal minilaparoscopic trocars; the development of the retroperitoneal space; and the identification, dissection, and resection of SLNs.

In the conventional laparoscopic group (group B), the exact same procedure was performed but with 5-mm conventional laparoscopic instruments. To avoid possible bias between the groups, the same surgical team performed all the experiments.

Histologic Analysis

The lymph nodes were analyzed without freezing. Each lymph node was fixed in neutral buffered formaldehyde for 72 hours, cut into 0.1-cm-thick slices, and embedded in a paraffin block. Multiple sections were prepared from each block. A set of 3- to 4-μm-thick sections was cut every 250 μm. Sections were stained with hematoxylin and eosin. The images were taken with an Olympus microscope BX61 (Olympus, Tokyo, Japan).

Statistical Analysis

All quantitative data are presented as mean ± SD. Statistical analysis was performed using the statistical software SigmaStat (version 3.5; Systat Software Inc, San Jose, CA). Independent samples Student *t*-test analysis was used to compare surgical times, and statistical significance was set at $P < .05$. We also present Cohen *d* measure of effect size, whereby 0.2 equates to a small effect, 0.5 equates to a medium effect, and effects >0.8 equates to large effects.[12]

Results

Following the ICG injection in the paracervical region, the green lymphatic channels were identified, as well as the ending colored lymph nodes, which were considered SLNs. The average time to coloring was 3.58 ± 1.38 minutes in group A and 3.25 ±1.42 minutes in group B (t[22] = 0.58; $P = .57$, $d = 0.23$—small effect size). Extraperitoneal dissection and excision of SLNs with 3-mm instruments were performed with success in all pigs. The overall results of our study are summarized in Table 1.

The average times to perform the experiments were 39.3 ± 10.7 minutes in group A and 51.3 ± 14.17 minutes in group B ($P = .042$). From experiment 1 to experiment 12, the operative time was dramatically reduced (from 65 to 25 minutes in group A and from 79 to 34 minutes in group B) presumably due to improved experience and identification of the anatomic landmarks.

In group A, the intraoperative complications included intraoperative bleeding (40 and 30 mL) in 2 cases, which was controlled by minilaparoscopic instruments, and 1 diffuse anterior abdominal wall emphysema. In group B, there were 2 cases of intraoperative bleeding (60 and 40 mL), 1 case of abdominal wall emphysema, and 2 pneumoperitoneums (one of which was associated with peritoneal perforation and both were evacuated by Veress needle insertion). There were no cases with urinary and digestive tract injuries. During the procedures, the heart rate, arterial pressure, and respiratory function were stable. In group B, there was only SLNs detected after laparotomy.

Microscopic examination of the sentinel nodes removed with minilaparoscopy revealed intact nodes with complete preservation of nodal architecture and no evidence of thermal or mechanical damage.

Table 1. Perioperative Data After ICG Injection and SLN Removal.

Perioperative Variables			Group A: Minilaparoscopy (n = 24)	Group B: Conventional Laparoscopy (n = 24)	*P* Value[a]	Cohen's *d*
SLN	Coloring time (minutes), mean ± SD (range)		3.58 ± 1.38 (1-6)	3.25 ± 1.42 (1-6)	.57	0.23
	Number removed, mean ± SD (range)		1.9 ± 0.8 (1-3)	2 ± 0.74 (1-3)		
	Location	Preaortic	3	6		
		Left iliac vessels	9	7		
		Right iliac vessels	5	6		
		Promontory	4	4		
		Right obturator fossa	1	-		
		Left obturator fossa	1	1		
Operative time (minutes), mean ± SD (range)			39.3 ± 13.02 (25-65)	51.3 ± 14.17 (34-79)	.042	0.85

Abbreviations: ICG, indocyanine green; SLN, sentinel lymph node.
[a]Student's *t* test.

Discussion

SLN techniques are now part of the standard treatment for breast cancer,[13] melanoma,[14] and selected cases of vulvar cancer.[15,16] SLN biopsy has been one of the more recent, important innovations in surgical oncology. It has been established as less invasive and more informative to clinicians.[4,5] In uterine cancers, SLN biopsy can potentially provide more accurate identification of uterine drainage, primary tumor staging, and may have applications in fertility-sparing surgical procedures.[17]

In our study, the feasibility and reliability of SLN removal by a retroperitoneoscopic approach using minilaparoscopic instrumentation after ICG dye cervical injection were assessed. This was also compared with conventional 5-mm laparoscopic instruments.

The ICG fluorescent dye relies on a fluorometrically capable camera and appears green when excited by light in the NIR range. It has the potential advantage of being readily visible through visceral fat and has a higher detection rate than blue dye in SLNs.[18] NIR fluorescence imaging using ICG may improve SLN technology in cervical and endometrial cancers by increasing the rate of bilateral SLN mapping without the added cost and inconvenience of technetium.[19]

Dargent and Salvat reported the first use of conventional laparoscopic instruments for extraperitoneal lymphadenectomy in women with gynecologic cancers.[20,21] Occelli et al found that compared with transperitoneal approach in animal studies, extraperitoneal laparoscopy leads to fewer postoperative adhesions, lowering the risk of postoperative radiation-related complications.[11] Additionally, as the peritoneal cavity is untouched, complications such as postoperative ileus, intraperitoneal adhesions, and intestinal obstruction are eliminated.[22] A further important advantage of the extraperitoneal route is the protection of the bowel provided by the peritoneal sac.[23] It is anatomically and surgically more logical as it is carried out on the left-hand side (providing better access to the aortic territory lymph nodes).[24] Previous abdominal surgery, radiotherapy, and chemotherapy do not complicate the extraperitoneal approach. The low incidence of postoperative complications and minimal hospital stay promote early initiation of adjuvant therapy. Extraperitoneal techniques may reduce the time taken to access the lymphatic channels since adhesiolysis and bowel mobilization is unnecessary. There is decreased risk of electrosurgical bowel injury and there is no risk for unrecognized enterotomy due to traction or dissection.[22] The ureters is automatically mobilized out of the dissection field by attachment to the peritoneal envelope. Since the peritoneal sac acts as a natural retractor, fewer instruments may be needed. Finally, there is potentially less pain caused by diaphragmatic irritation from CO_2 gas. Potential drawbacks may include subcutaneous emphysema with retropneumoperitoneum, possibly leading to pneumothorax via potential spaces and mediastinal anatomic pathways.[22,25]

Minilaparoscopy, using miniaturized instruments, further reduces perioperative morbidity, enhances cosmetic healing, and avoids incisional herniation. Recently, minilaparoscopic surgical techniques have benefited from additional product development with a focus on improving instrument strength.[26] During these experiments, researchers found thinner instruments to be functional with no increase in complications. The new minilaparoscopic rotating bipolar instrument allows precise tissue dissection and fine coagulation. The use of small-diameter instruments is feasible with low CO_2 pressures, thereby reducing possible complications related to pneumoperitoneum.[27]

In our comparative study, the operating time with minilaparoscopic instruments was shorter than with 5-mm conventional instruments ($P = .042$) without major complications. These smaller instruments may offer the possibility of working better in restricted and narrow spaces like the retroperitoneum with lower CO_2 pressures.

This is the first study that compares minilaparoscopic versus conventional laparoscopic extraperitoneal approach in SLN removal.

The strengths of our study include the controlled setting in which only a single variable (instruments size) was altered. The same team of surgeons performed all procedures. The most important limitation perhaps is its preclinical nature. Further studies with larger samples, lower CO_2 pressures, and local anesthesia[28] should be done. Our findings may help focus future human studies.

Conclusions

The resection of SLN by a minilaparoscopic extraperitoneal approach after ICG cervical injection was performed successfully with no major complications. In this preclinical study, the operative technique was feasible and reliable. The surgical time with the minilaparoscopic instruments was shorter than with 5-mm conventional instruments (P = .042). This procedure may reduce morbidity during staging of gynecologic malignancies. Further studies are needed to confirm our results.

Author Contributions

Study concept and design: Hélder Ferreira
Acquisition of data: Hélder Ferreira, Alice Miranda and Cristina Nogueira-Silva
Analysis and interpretation: Hélder Ferreira, Cristina Nogueira-Silva, Alice Miranda and Jorge Correia-Pinto
Study supervision: Jorge Correia-Pinto and Cristina Nogueira-Silva

Authors' Note

Animal experiments were performed following EU Directive 2010/63/EU and the Portuguese law for animal welfare (Diário da República, Portaria 1005/92).

Declaration of Conflicting Interests

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5
Minilaparoscopy and genital prolapse correction – initial experience

Minilaparoscopic Sacrocolpopexy for Vaginal Prolapse after Hysterectomy.
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Minilaparoscopic Sacrocolpopexy for Vaginal Prolapse after Hysterectomy

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ABSTRACT

Genital prolapse repair is one of the most common indications for benign gynecologic surgery. The lifetime risk of undergoing a single operation for prolapse in the female population is rising. Many different surgical techniques have been described.

We report 4 cases of minilaparoscopic sacrocolpopexy to correct vaginal apical prolapse after previous total hysterectomy. For each patient we collected some socio-demographic data, vaginal apical prolapse grade using the Pelvic Organ Prolapse Quantification (POP-Q), intraoperative details and postoperative outcomes. Operative time was recorded as well as difficulties and complications (Clavien-Dindo Classification) at each step of the procedure.

The range of women's ages was from 57 to 71 years old. The mean BMI was 24.75 ± 3.2 Kg. Three patients had a stage III POP-Q prolapses and there was one case of a symptomatic stage II POP-Q prolapse. The mean surgical time was 119 minutes and there were no intraoperative complications. The postoperative pain assessment revealed very positive recovery in every patient. An ambulatory consult and an anatomic

assessment were done 1 and 3 months after surgery. The incision scars were almost invisible after 1 month, and the anatomic cure rate was 100%.

We confirmed the feasibility of a minilaparoscopic surgical approach for vaginal vault prolapse after total hysterectomy.

INTRODUCTION

Genital prolapse repair is one of the most common indications for benign gynecologic surgery. As average life span increases, pelvic floor disorders are more common in the female population. It is estimated that up to 50% of all women over 50 years of age are affected by pelvic organ prolapse (POP).[1] The lifetime risk of undergoing a single operation for prolapse or incontinence by age 80 was 11.1%.[2] Women who seek treatment strive for an improvement in body image and quality of life.[3]

Many different surgical techniques to correct POP have been described in the past 60 years. The aim of this surgery is to restore physiologic anatomy, as well as to preserve lower urinary tract, intestinal, and sexual functions. Sacrocolpopexy (SC) has shown superior outcomes for correcting apical prolapse after total hysterectomy when compared with a variety of other vaginal procedures including sacrospinous colpopexy, uterosacral colpopexy, and transvaginal mesh.[4]

SC was traditionally performed through an open abdominal approach associated with higher rates of morbidity (longer time to return to daily activities, more postoperative pain, and unaesthetic scars). To avoid the need for a large abdominal incision and to minimize bowel manipulation and recovery time, laparoscopic sacrocolpopexy emerged as a great promise with all these advantages.

With the continuous focus on minimizing the visibility of scars new technological advances were developed in order to create smaller diameter endoscopes (5 mm) and surgical instruments (3 mm). Minilaparoscopy limits tissue trauma and postoperative pain, and improves cosmesis.

We report our initial experience in performing minilaparoscopic sacrocolpopexies to correct vaginal apical prolapse after previous total hysterectomy.

MATERIALS AND METHODS

We report 4 cases of minilaparoscopic sacrocolpopexy to correct vaginal apical prolapse after previous total hysterectomy. For each patient we collected some socio-demographic data, vaginal apical prolapse grade using the Pelvic Organ Prolapse Quantification (POP-Q), intraoperative details, and postoperative outcomes. Operative time (OT), defined as the interval between incision start to closure, was recorded, as well as difficulties and complications (Clavien-Dindo Classification) at each step of the procedure. Estimated blood loss was estimated from the contents of suction devices. The length of hospital stay was also recorded.

Surgical Procedures

A first-generation cephalosporin was administrated to all patients 30 minutes before induction of general anesthesia in supine position. The patient was prepped from the nipples to proximal thigh including the vagina.

The pneumoperitoneum was created using a Veress needle at an umbilical position up to 12 mmHg, where an optical trocar (30160GC; Karl Storz 6-mm trocar set; Karl Storz, Tuttlingen, Germany) was introduced and a 5-mm, 30-degree endoscope (26046BA; HOPKINS II Forward Oblique telescope, Karl Storz) was used to have a general view of the abdominal cavity. After observing the pelvis, under direct visualization, three 3-mm ancillary trocars (30114GZL; Karl Storz minilaparoscopy trocar set) were inserted, 1 suprapubically and 2 laterally to the epigastric arteries, in the left and right lower abdominal quadrants, respectively (Fig. 1).

The bowel was fixed to the left upper quadrant of the abdominal wall with a T-Lift® (VECTEC, Vichy, France) in order to better expose the right pelvis and the sacral promontory.

A flat, flexible, handheld vaginal retractor was used to expose the vaginal cuff and facilitate the dissection. The vesicovaginal space was developed up to

Figure 1. Minilaparoscopic trocars' positions.

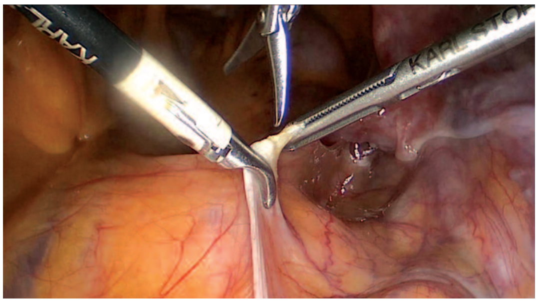

Figure 2. Opening the peritoneum over the promontorium.

Figure 3a. Posterior and anterior meshes.

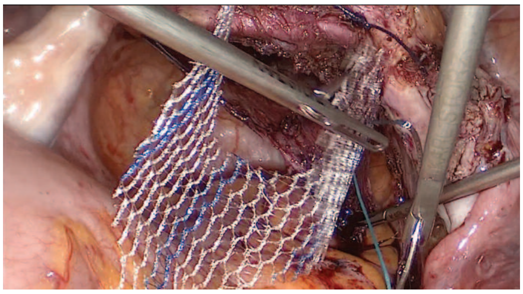

Figure 3b. Posterior mesh.

the bladder neck, which was identified using the balloon of the Foley catheter. Both pararectal fossa were opened by gentle dissection up to the levator ani muscles.

In these procedures, 36-cm-long minilaparoscopic instruments (Karl Storz Endoskope Minilaparoscopy Instruments Set) were used, choosing among graspers, cold scissors, suction/irrigation, and the recent 3.5-mm bipolar coagulator (Karl Storz Robi®) (Fig. 2).

Puborectalis muscles were exposed bilaterally using rotating bipolar forceps and a suction-irrigation device for blunt dissection, with identification of the middle rectal artery.

The promomtorium was well dissected with large exposition of the anterior sacral longitudinal ligament. The peritoneum was opened from promontorium up to the right uterossacral ligament, between the ureter and the right inferior hypogastric nerve. A wide dissection was performed. We used a polypropylene mesh (Gynemesh PS, Ethicon, Sommersville, NJ) that was cut in two parts, one for the anterior compartment and the other for the posterior compartment. The anterior part has a terminal triangular shape and a long arm that comes up to the promontorium. The posterior part has a bifurcation to fix on both levator ani muscles (puborectalis) (Figs. 3a & 3b).

The apex of the anterior triangular shape mesh was fixed in the dissected vesico-vaginal space with a nonabsorbable, braided surgical suture composed of polyethylene terephthalate, Ethibond Excel suture (Ethicon, Somerville, NJ). Sutures to the vagina were performed tangentially to minimize the risk of postoperative erosion of the suture material.

The 2 arms of the posterior mesh were fixed with 2 Ethibond® sutures in both puborectalis muscles bilaterally.

A suture was used to fix the anterior mesh to the left uterosacral ligament and the posterior mesh, and a second suture was used to fix the anterior mesh to the right uterosacral ligament and the posterior mesh. The anterior and posterior meshes were used to replace the damaged fascias. After both meshes were attached, the long arm of the anterior mesh was fixed on the promontory with a unique suture that passed through all the ligament thickness (Fig. 4).

The surgeon tested sacral fixation. The peritoneum involving the arm of the mesh was closed with a monofilament absorbable suture. All the mesh was covered by peritoneum.

The dissection, coagulation, and intracorporeal sutures were performed only with minilaparoscopic instruments. Any small bleeding was immediately controlled with the bipolar instrument.

The threads were removed from abdominal cavity by a unique transabdominal hole using a Berci needle (Karl Storz, Tuttlingen, Germany).

Postoperative Follow-up

Postoperative pain assessment (during the immediate postoperative period and seventh day postoperatively) was performed in all patients by using a validated visual analog scale (VAS) and scored from 0 to 10 (0 = no pain; 10 = agonizing pain). All patients were managed with the same standardized anesthetic protocol and postoperative

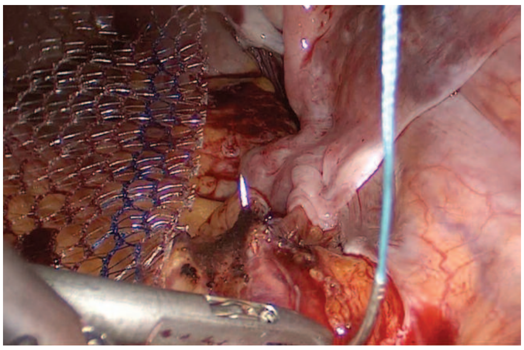

Figure 4. Anterior sacral longitudinal ligament fixation.

Figure 5. Minilaparoscopic incision scar.

Table I
Perioperative and postoperative parameters and complications

Patient	Surgery time (min)	Intraoperative complications	Blood loss	Complications according to Clavien-Dindo Classification	Postoperative pain assessment (max. VAS)	
					1st day	7th day
1	125	-	50 mL	Grade I	3/10	0/10
2	110	-	40 mL	Grade I	2/10	0/10
3	135	-	50 mL	Grade I	4/10	0/10
4	105	-	40 mL	Grade I	3/10	0/10

analgesic therapy. Patients were allowed to go home when they were fully mobile, apyrexial, and passing urine satisfactorily.

An ambulatory consult and an anatomic assessment were done after 1 and 3 months. *De novo* symptoms, defined as symptoms that were not present before surgery but were present on subsequent visits, were evaluated. Subjective amelioration, sexual function, and anatomic cure, defined as the absence of stage II prolapse or more at any anatomical site, were also assessed.

Data Recording

All surgical endoscopic procedures were recorded on an AIDA® (Advanced Image and Data Archiving System) device from Karl Storz. Vital and physiological parameters (heart rate, arterial pressure, and respiratory distress) were monitored by the anesthesiological team.

RESULTS

At our institution, during the last semester of 2014, four patients were submitted to minilaparoscopic sacrocolpopexies due to apical prolapse. The range of age was from 57 to 71 years old. The mean BMI was 24.75 ± 3.2 Kg. Three patients had stage III POP-Q prolapses, and one patient had a symptomatic stage II POP-Q prolapse.

The length of hospital stay was 48 hours in 3 cases and 72 hours in 1 case (patients entered the day before for bowel preparation and analytical study). Vital and physiological parameters (heart rate, arterial pressure, and respiratory distress) were always stable.

Perioperative and postoperative parameters and complications are summarized in Table I.

At first month consultation, the patients had no complaints of pain, and the incisions scars were almost invisible (Fig. 5).

At third month, all the patients were subjectively ameliorated and very satisfied with the cosmetic outcomes. The anatomic cure rate was also 100%.

DISCUSSION

Minilaparoscopy reemerged has an even better approach involving the use of miniaturized scopes and instruments to further reduce perioperative morbidity and enhance cosmetic results. The transition from 10-mm to 5-mm ports was a change from big to small, whereas the transition from 5 mm to 3 mm is visible to invisible.[5]

Most surgeons have been hesitant to adopt minilaparoscopy into their practice because of concerns regarding the instruments (not functional or not strong enough). Furthermore, some have complained that 3-mm instruments do not offer the same array of end-effector options or functionality as the 5-mm instruments.[5] Recently, minilaparoscopic surgery has benefited from additional product development with a focus on improving instrument strength and optics. With this new armamentarium, surgeons are trying to adapt all laparoscopic procedures already validated to this milimetric approach.

Minilaparoscopic hysterectomy, diagnostic laparoscopy, pain mapping, and ovarian biopsy have also been described in gynecology.[6–9]

To our knowledge, this is the first report that describes a minilaparoscopic approach for this type of procedure to correct vaginal apical prolapse after hysterectomy. During all the procedures, the surgical team found those thinner instruments very functional. Actually, no difficulty was found in terms of field vision, grasping, dissection, irrigation, or suction. The new rotating bipolar is a very efficient dissector and a very precise coagulator instrument. The minilaparoscopic needle holders are also very ergonomic and functionally similar to the conventional 5-mm ones.

Every sacrocolpopexy implicates many sutures. In order to avoid multiple trocar movements of thread extraction and reintroduction, a Berci® needle was used to remove the threads from inside the abdominal cavity, preventing trocar incision enlargement. In order to prevent ischemia and pain, the surgeons avoided putting too much tension on the mesh.

The main advance offered by the use of needlescopic instruments is the reduction of intraoperative injury and abdominal wall trauma. The latter not only benefits postoperative cosmetic outcome (minimal postoperative scarring) but most important eradicates the risk for postoperative hernia formation and potentially causes less postoperative pain and faster rehabilitation. In addition, the use of small diameter laparoscopes and instruments is feasible with lower CO_2 pressures, reducing possible complications related to pneumoperitoneum.[10] An additional advantage of this technology is that upon adaptation there is no need for a new learning curve as minilaparoscopy maintains the principles of instrument triangulation and resembles conventional laparoscopic experience.

CONCLUSION

Minilaparoscopy is an attractive approach for sacrocolpopexy in view of its advantages, such as reduced morbidities and enhanced cosmesis. We confirmed the feasibility of minilaparoscopic approach for vaginal vault prolapse after total hysterectomy. The procedure can be performed safely but further studies with larger samples should be presented. STI

AUTHORS' DISCLOSURES

The authors have no conflicts of interest to disclose.

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6
Minilaparoscopy and genital prolapse correction – comparative study

Minilaparoscopic Versus Conventional Laparoscopic Sacrocolpopexy: A Comparative Study.
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Technical Reports

Minilaparoscopic Versus Conventional Laparoscopic Sacrocolpopexy: A Comparative Study

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Antonio Tomé, MD, PhD,[1] Serafim Guimarães, MD,[1] and Jorge Correia-Pinto, MD, PhD[2,3,6]

Abstract

Introduction and Aims: We aim to compare clinical and surgical outcomes between minilaparoscopic sacrocolpopexy (MLSC) and conventional laparoscopic sacrocolpopexy (LSC). As far as we know, no comparative study exists between these two minimal invasive procedures to correct vaginal prolapse.
Design and Setting: An observational and comparative study with 20 individuals submitted to vaginal vault prolapse correction between June and December of 2014 in our tertiary referral unit. Nine women were submitted to 3-mm MLSC and the others were approached by a standard 5-mm laparoscopic technique.
Materials and Methods: Women's demographic data and prolapse grade were evaluated preoperatively using the Pelvic Organ Prolapse Quantification score. Operative parameters (surgical time, blood loss, and complications under Satava and Clavien–Dindo classification) and length of hospitalization were also compared. Postoperative pain and surgical scar satisfaction were measured using Visual Analog Pain Scale and Patient and Observer Scar Assessment Questionnaire, respectively.
Results: MLSC took approximately the same time as LSC ($P > .05$). No significant differences in operative time, blood loss, length of hospitalization, and complications (Satava, Clavien–Dindo) were observed between both groups. Pain score after surgery was similar in MLSC and LSC ($P > .05$). Surgical scar monitoring at 3 months established that MLSC produced better overall results than LSC ($P < .05$). Anatomic cure rate was 100%.
Conclusion: Minilaparoscopy is a feasible and attractive approach for sacrocolpopexy as it enhances cosmetics, keeping the low morbidity associated with the classical laparoscopic approaches.

Introduction

The lifetime risk of experiencing a single operation for prolapse or incontinence by age 80 was 11.1%.[1] Women seek treatment in an attempt to improve body image and quality of life.[2] Many different surgical techniques to correct pelvic organ prolapse (POP) have been described in the past 60 years. The aim of this surgery is to restore physiologic anatomy as well as to preserve lower urinary tract, intestinal, and sexual functions. Sacrocolpopexy (SC) has shown superior outcomes for correcting apical prolapse after total hysterectomy when compared with a variety of other vaginal procedures, including sacrospinous colpopexy, uterosacral colpopexy, and transvaginal mesh.[3] SC was traditionally performed through an open abdominal approach associated with high rates of morbidity (longer time to return to daily activities, more postoperative pain, and unesthetic scars). Laparoscopic procedures in prolapse surgery have gained increasing importance within the past few years. Reduced morbidity, good cosmetic results, and a shorter stationary period are advantages generally offered by laparoscopy.[4] With the continuous focus on minimizing the visibility of scars, new technological advances were developed to create smaller diameter endoscopes (5 mm) and surgical instruments (3 mm).

Observational data have revealed that minilaparoscopic cholecystectomy is associated with less postoperative analgesia

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and even better cosmesis when compared with traditional laparoscopic surgeries.[5,6] During the last years, several minilaparoscopic procedures have been successfully performed in various surgical fields.[7–10]

Ultrahigh-definition cameras are appearing and the precision offered by this new image technology may push surgery to smaller instruments that allow a more accurate approach.

It was recently presented as the first case of minilaparoscopic SC,[11] but, up to now, no comparative study exists between minilaparoscopic versus conventional laparoscopic sacrocolpopexy (LSC). We aim to report a short comparison of clinical and surgical outcomes between these two minimally invasive approaches.

Materials and Methods

This is a prospective, observational comparative study between patients who submitted to vaginal vault prolapse correction by 3-mm minilaparoscopic sacrocolpopexy (MLSC) and patients of identical characteristics treated by the conventional 5-mm laparoscopic approach. Inclusion criteria included BMI <30, aged 50–70 years, and symptomatic vault prolapse (minimally presenting as stage 2 prolapse of the apex or upper posterior wall of the vagina). Approval of the Local Ethics Committee was obtained.

Preoperative evaluation

Anatomic findings were scored according to the POP Quantification classification.[12]

Subjects

Twenty patients participated in the protocol. For prolapse correction, nine women were assigned for a minilaparoscopic approach and 11 for a conventional 5-mm LSC technique. The study went on from June 2014 to December 2014.

Decision of surgical technique

The surgical technique was determined through a preference-based, shared decision-making system. The patient was informed about the evidence to support the benefits and disadvantages of each available surgical choice. The surgeon did not recommend any specific surgical option to patients. According to the patient's preference and shared decision, the patient was allocated to either the LSC alone group or the MLSC group. All patients gave their informed consent. The same surgeon performed all surgical procedures.

Surgical technique

A first-generation cephalosporin was administrated to all patients 30 minutes before induction of general anesthesia in the supine position. The patient was prepped from the nipples to proximal thigh, including the vagina. The pneumoperitoneum was created using a Veress needle at an umbilical position up to 12 mmHg, where an optical trocar (30160GC; Karl Storz 6-mm trocar set; Karl Storz, Tuttlingen, Germany) was introduced and a 5-mm 30-degree endoscope (26046BA; HOPKINS II Forward Oblique telescope, Karl Storz) was used to have a general view of the abdominal cavity. After observing the pelvis, under direct visualization, three 3-mm ancillary trocars (30114GZL; Karl Storz minilaparoscopy trocar set) were inserted, one suprapubically and two laterally to the epigastric arteries, in the left and right lower abdominal quadrants, respectively (Fig. 1). The bowel was fixed to the left upper quadrant of the abdominal wall with a T-Lift® (VECTEC, Vichy, France) to better expose the right pelvis and the sacral promontory. A flat, flexible, handheld vaginal retractor was used to expose the vaginal cuff and facilitate the dissection. The vesicovaginal space was developed up to the bladder neck, which was identified using the balloon of the Foley catheter. Both pararectal fossa were opened by gentle

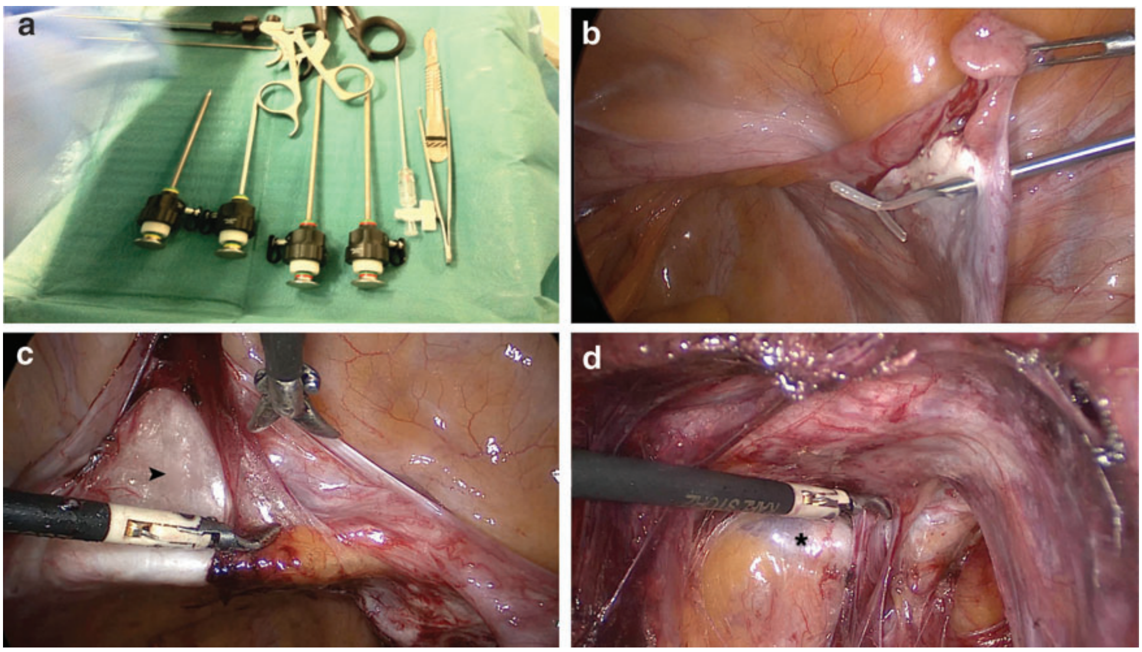

FIG. 1. **(a)** Minilaparoscopic trocars; **(b)** Right ovarian suspension with a T-Lift exposing right pararectal space; **(c)** Opening of the vesicovaginal space (arrowhead); **(d)** Opening of the rectovaginal space (asterisk).

dissection up to the levator ani muscles. In these procedures, 36-cm-long minilaparoscopic instruments (Karl Storz Endoskope Minilaparoscopy Instruments Set) were used, choosing among graspers, cold scissors, suction/irrigation, and the recent 3.5-mm bipolar coagulator (Karl Storz Robi®) (Fig. 1). Puborectalis muscles were exposed bilaterally using rotating bipolar forceps and a suction–irrigation device for blunt dissection, with identification of the middle rectal artery. The promomtorium was dissected with large exposition of the anterior sacral longitudinal ligament. The peritoneum was opened from promontorium up to the right uterossacral ligament, between the ureter and the right inferior hypogastric nerve. A wide dissection was performed. We used a polypropylene mesh (Gynemesh PS; Ethicon, Sommersville, NJ) that was cut in two parts, one for the anterior compartment and the other for the posterior compartment. The mesh and the sutures (26 mm ½ circle needle Ethibond Excel suture; Ethicon) were introduced in the abdominal cavity through the optical trocar. The anterior part has a terminal triangular shape and a long arm that comes up to the promontorium. The posterior part has a bifurcation to fix on both levator ani muscles (puborectalis) (Fig. 2).

The apex of the anterior triangular-shaped mesh was fixed in the dissected vesicovaginal space with a nonabsorbable, braided surgical suture comprising polyethylene terephthalate, Ethibond Excel suture (Ethicon). Sutures to the vagina were performed tangentially to minimize the risk of postoperative erosion of the suture material. The two arms of the posterior mesh were fixed with two Ethibond® sutures in both puborectalis muscles bilaterally.

A suture was used to fix the anterior mesh to the left uterosacral ligament and the posterior mesh, and a second suture was used to fix the anterior mesh to the right uterosacral ligament and the posterior mesh. The anterior and posterior meshes were used to replace the damaged fascias. After both meshes were attached, the long arm of the anterior mesh was fixed on the promontory with a unique suture that passed through all of the ligament thickness (Fig. 3).

The surgeon tested sacral fixation. The peritoneum involving the arm of the mesh was closed with a monofilament absorbable suture. All of the mesh was covered by peritoneum.

In the MLSC group, dissection, coagulation, and intracorporeal sutures were performed only with 3-mm instruments. Any small bleeding was immediately controlled with the bipolar instrument. The threads and needles were removed from abdominal cavity by a unique very small transabdominal hole using a BERCI fascial closure instrument (Karl Storz). This technique for suture removal was used to avoid excessive minitrocar manipulations that could interfere with the efficient performance of the procedure.

In the conventional laparoscopy group, 5-mm conventional laparoscopic instruments (Karl Storz Endoskope Instruments Set) were used and the technique was similar to the one described before with the smaller instruments.

All surgical endoscopic procedures were recorded on an AIDA® (Advanced Image and Data Archiving System) device from Karl Storz.

Duration of operation was defined as the interval between the initial skin incision and skin closure. Intraoperative and postoperative surgical complications were classified as described by Satava[13] and Dindo et al.,[14] respectively. Hospital stay was defined as the number of days spent in the hospital after surgery. Estimated blood loss was assessed from the contents of suction devices.

Postoperative follow-up

All patients were managed with the same standardized anesthetic protocol and postoperative analgesic therapy.

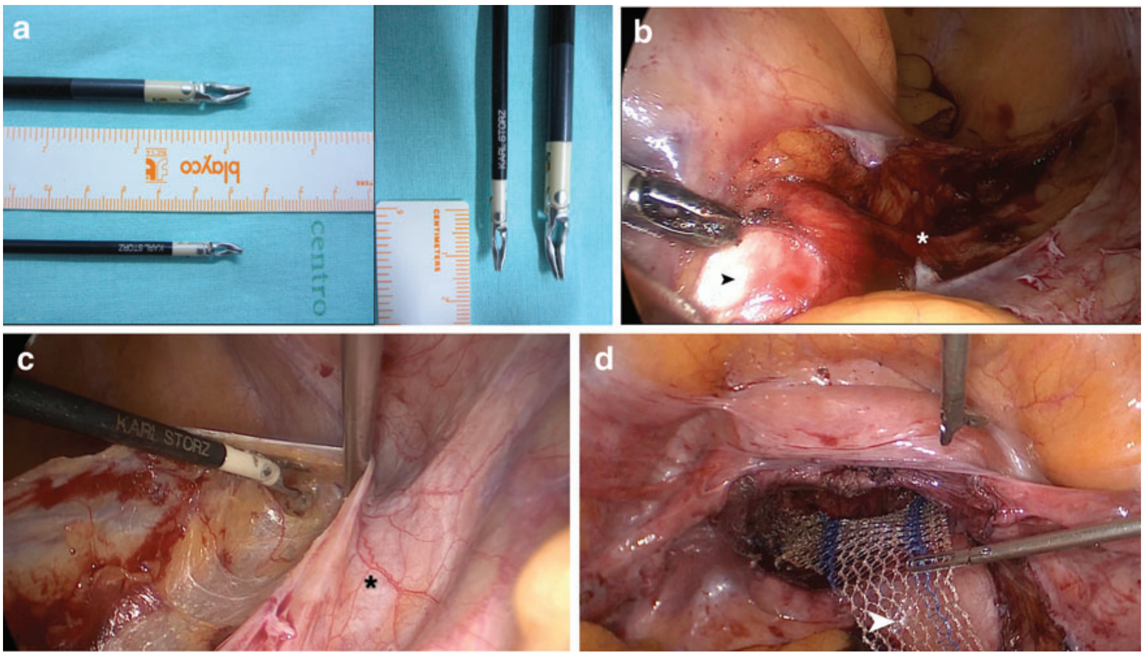

FIG. 2. **(a)** Minilaparoscopic versus conventional rotating bipolar dissectors; **(b)** Promontorium dissected: longitudinal sacral ligament (arrowhead), superior hypogastric nerve (asterisk); **(c)** Dissection of the right pararectal fossa, right ureter (asterisk); **(d)** Posterior mesh (arrowhead).

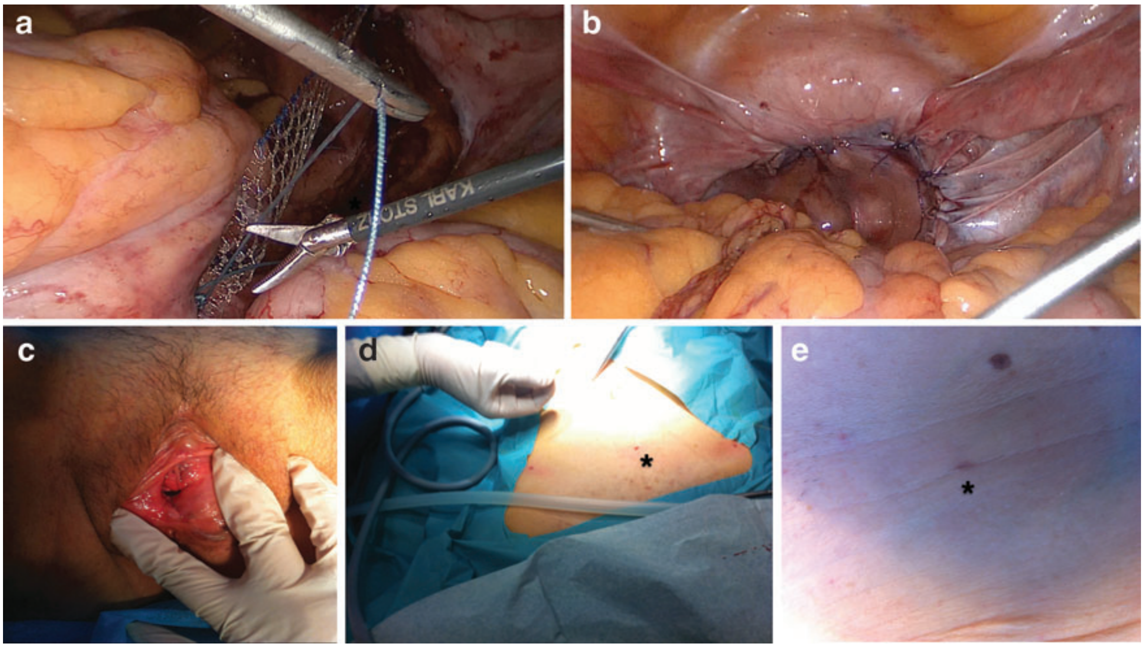

FIG. 3. **(a)** Cutting the thread that fixed the mesh to the promontorium; **(b)** Final view after mesh peritonization; **(c)** Anatomic cure 30 days after minilaparoscopic sacrocolpopexy; **(d)** scars (asterisk) immediately after 3-mm trocar removal; **(e)** scar assessment 7 days after surgery (asterisk).

Postoperative pain assessment (at 12 hours after surgery and at discharge) was performed in all patients by using a validated Visual Analog Pain Scale (VAPS) scored from 0 to 10 (0 = no pain; 10 = agonizing pain). Patients were allowed to go home when they were fully mobile, apyrexial, and passing urine satisfactorily.

The Patient and Observer Scar Assessment Questionnaire (POSAS)[15] was filled by the patients and observer after 3 months on ambulatory regime. The observer was a blinded nurse that accepted to participate in the study. An ambulatory consultation and an anatomic assessment were also done after this period. *De novo* symptoms, defined as symptoms that were not present before surgery, but were present on subsequent visits, were evaluated. Anatomic cure, defined as the absence of stage II prolapse or more at any anatomical site, was also assessed.

Statistical analyses

The IBM® Statistical Package for Social Sciences (SPSS), version 20, was used for statistical analysis. Chi-square test was used for categorical variables. Age, body–mass index (BMI), operative time, blood loss, and hospital stay were compared using Student's *t*-test for independent groups. POSAS parameters were studied using the Mann–Whitney test. The criterion for statistical significance was set at $P < .05$ for all comparisons.

Results

Twenty patients underwent minimally invasive SC, 11 by conventional laparoscopy and nine by minilaparoscopy. All of them were performed by the same surgical team at our institution with the use of 5- or 3-mm instruments (Karl Storz), respectively. The two groups were similar with respect to sex, age, BMI, prolapse grade, and surgical history (Table 1).

Conventional LSC took approximately the same time as MLSC, 172 (148–197) minutes versus 166 (149–183) minutes; however, higher BMIs seem to be associated with longer operative times, mainly in the MLSC group ($P < .05$). Four patients in the MLSC group were discharged home within less than 24 hours after surgery; however, no statistical differences were found between the two groups in terms of hospitalization length. There were no cases of middle sacral or pararectal fossa vessel bleeding and no bowel, bladder, or ureteral injuries. One patient, in the MLSC group, had a small bleeding from the vagina during the vesicovaginal dissection

TABLE 1. CLINICAL AND DEMOGRAPHIC DATA

	Conventional laparoscopic sacrocolpopexy	*Minilaparoscopic sacrocolpopexy*	P
Total patients, *n*	11	9	ns
Mean age, years (SD)	60.7 ± 7.5	61.5 ± 8	ns
Mean BMI, Kg/m^2 (SD)	25.2 ± 2.7	24.1 ± 2.7	ns
POP-Q			
I	—	—	ns
II	4	5	ns
III	5	3	ns
IV	2	3	ns
Previous abdominal hysterectomy	4	6	ns
Previous vaginal hysterectomy	7	5	ns
Cesarean section	8	4	ns

BMI, body–mass index; ns, nonsignificant ($P > .05$); POP-Q, Pelvic Organ Prolapse Quantification.

immediately controlled by a minilaparoscopic bipolar dissector. Overall, there was no relevant intra- or postoperative complication (Table 2).

The pain scores (VAPS) at 12 hours after surgery and at discharge were similar in conventional laparoscopy and MLSC ($P > .05$) (Table 3). At 3 months' consultation, patients were asymptomatic, the anatomic cure rate was 100%, and there was a statistically significant reduction in nearly all the POSAS parameters when comparing LSC and MLSC ($P < .05$) (Table 4).

Discussion

Laparoscopic surgery has developed rapidly in recent years. The LSC, which evolved from the classical abdominal SC, provides a shorter hospital stay, better hemostasis, and less pain than the open procedure. Better hemostasis is due to fine dissection and better visualization of the presacral, pararectal, and common iliac vessels. From a conceptual point of view, if abdominal SC corresponds to a palliative treatment of genital organ prolapse, the laparoscopic approach will actually provide a real reconstructive surgical procedure.[16]

A recent, randomized controlled trial confirmed that LSC is equally effective as open abdominal SC.[17] With a recent emphasis on diminishing the visibility of scars, minilaparoscopy has reemerged as an appealing option for surgeons. As far as ML hysterectomy is concerned, Ghezzi et al.[18] showed that ports could safely be reduced in size without a negative impact on the surgeon's ability to perform hysterectomy in patients with early-stage endometrial cancer. Our first reported cases of MLSC[11] have been reevaluated and they presented very positive anatomical and functional results.

The present preliminary study suggests that minilaparoscopy can be successfully and safely applied to SC for vaginal vault prolapse after hysterectomy, with similar perioperative outcomes compared with standard laparoscopy. In particular, no significant differences in operative time, blood loss, and pelvic prolapse correction, as well as complications (Satava, Clavien–Dindo), were observed between LCSC and MLSC groups.

The shorter hospital stay in the minilaparoscopic group may be a cost-effective alternative in the way that it may be scheduled in an ambulatory surgery regime (<24 hours of hospitalization).

In a prospective comparative study, Porpiglia et al. showed that patients who underwent minilaparoscopic pyeloplasty were significantly more satisfied with their cosmetic outcomes than those who were submitted to a standard laparoscopic approach.[19] A better cosmetic outcome using smaller trocars has also been reported in general surgery literature through comparative studies on standard laparoscopic cholecystectomy.[5,20] At 3 months' consultation, after POSAS Questionnaire,[15] we reported significantly better scores in the MLSC group than in the patients approached by traditional laparoscopic instruments.

Possible mystifications regarding 3-mm instruments may include poor grasping ability, weak manipulation, and difficulty during dissection and development of anatomical spaces.[8,10] Nevertheless, several investigations in the field of gynecologic and nongynecologic surgery suggest that downsizing abdominal ports allows equal or better surgical results compared with standard laparoscopic procedures.[9,21–24] In addition, the use of small-diameter laparoscopes and instruments

Table 2. Surgical Outcomes

	Conventional laparoscopic sacrocolpopexy	*Minilaparoscopic sacrocolpopexy*	P
Mean operative time, minutes (range)	166 (149–183)	172 (148–197)	ns
Mean operative blood loss, mL (range)	80 (55–115)	75 (50–130)	ns
Mean hospital stay, days (SD)	2.2 ± 0.6	1.7 ± 0.64	ns
Intraoperative complications			
None	11	8	ns
Satava grade 1	0	1	ns
Satava grade 2	0	0	ns
Postoperative complications			
None	11	9	ns
Clavien–Dindo grade I	0	0	ns
Clavien–Dindo grade II	0	0	ns

Table 3. Pain Assessment

	Conventional laparoscopic sacrocolpopexy	*Minilaparoscopic sacrocolpopexy*	P
VAPS			
Postoperative 12 hours	2.36 (0.81)	2.09 (0.94)	ns
Discharge	1.1 (0.7)	0.81 (0.75)	ns

VAPS, Visual Analog Pain Scale (0–10 Numeric Pain Rating Scale).

Table 4. Minilaparoscopic and Laparoscopic Patient and Observer Scar Assessment Questionnaire Values (Mann–Whitney Test for Statistical Analysis)

Parameter	*Conventional laparoscopic sacrocolpopexy (median value)*	*Minilaparoscopic sacrocolpopexy (median value)*	P
Vascularity	3	2	.2
Pigmentation	4	1	.05
Thickness	4	2	.03
Relief	4	2	.02
Pliability	4	2	.06
Overall (observer)	4	2	.03
Pain	3	2	.08
Itching	3	2	.12
Color	5	3	<.01
Hardness	4	2	.02
Thickness	4	2	<.01
Shape	5	2	<.01
Overall (patient)	4	2	.01

is feasible with low carbon dioxide pressures,[25] thereby reducing possible complications related to pneumoperitoneum.

We recognize some specificities and possible limitations of minilaparoscopic instruments, such as higher susceptibility to bending, resulting in an increased difficulty when dissection is carried out on a very hard fibrous tissue. Obesity may represent a challenge to minilaparoscopic instruments because intraperitoneal access could be more demanding and low insufflation pressures can be insufficient to lift the weight of the abdomen and provide a good view. However, these potential technical problems did not alter our ability to safely and effectively perform MLSC. In the present study, we observed that minilaparoscopic instruments were very efficient in suturing vessels and nerve identification, allowing precise hemostasis and nerve preservation.

We can assume that the adequacy of SC is mainly determined by the expertise of the surgeon rather than by the caliber of the instruments used. Indeed, we decided to adopt a minilaparoscopic approach to SC only after overcoming our learning curve with conventional laparoscopy. Under this view, our findings must be interpreted cautiously since generalization of these results in less experienced hands is far from guaranteed. Finally, costs of minilaparoscopic instruments overlap conventional ones, although with expected shorter durability. The smaller incisions and miniature tools involved in minilaparoscopy may provide somewhat better cosmetic results and shorter hospital stays that should be balanced at the end.

In a very short future, the new ultrahigh-definition cameras will succeed in surgery, therefore more precise and delicate instruments must follow this better image resolution. We are firmly convinced that these minilaparoscopic instruments will have a strong role in this next video camera generation. It will be possible to join a more accurate picture to a more precise tool. As described recently, LSC should be a nerve-sparing technique.[26] This more precise combined approach will help in nerve preservation and other anatomical delicate structure identification.

Some study limitations should be acknowledged such as the sample size and the absence of randomization. The experience with this technique is very small and follow-up limited. Despite these restraints, to the best of our knowledge, this represents the first study that compares minilaparoscopic versus LSC using validated assessment tools (i.e., POSAS, VAPS) and our results indicate that the ML approach might offer a better surgical scar from the patient's and observer's point of view. Thus, further studies are necessary in this field.

By reproducing the principles of standard laparoscopy, and with predictable improvements of 3-mm instruments and higher definition cameras, we predict that MLSC can be regarded as an excellent option to POP correction.

Conclusions

Minilaparoscopy is a feasible and attractive approach for SC as it enhances cosmetics, keeping the low morbidity associated with the classical laparoscopic approaches.

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Disclosure Statement

No competing financial interests exist.

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7
Minilaparoscopy and genital prolapse correction – NOSE

Minilaparoscopic Sacrocervicopexy After Supracervical Hysterectomy and Specimen Extraction Through Posterior Vaginal Cul-De-Sac.
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VIDEOUROLOGY

Minilaparoscopic Sacrocervicopexy After Supracervical Hysterectomy and Specimen Extraction Through Posterior Vaginal Cul-De-Sac

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Abstract

Introduction: Sacrocervicopexy is a procedure similar to sacrocolpopexy, in which a graft material is used to suspend the cervix to the anterior longitudinal ligament of the sacrum. Sacrocervicopexy can be performed either with uterine preservation or after supracervical hysterectomy.[1–3] This procedure definitely avoids the risk of mesh erosion. Moreover, it preserves the integrity of the uterosacral and cardinal ligaments, which are the main supports of the vaginal apex.[4] Minilaparoscopy limits tissue trauma and improves cosmesis.[5]

Design: We report a video explaining the technique and evaluated the effectiveness of our first four cases of minilaparoscopic subtotal hysterectomy (MLSH) and sacrocervicopexy to resolve isolated pelvic central compartment uterine prolapse, with posterior cul-de-sac specimen extraction.[6] We assessed the reduction of prolapse-related symptoms, operative and postoperative complications, and patient satisfaction.

Setting: A tertiary university hospital.

Patients: Four women with symptomatic isolated pelvic central compartment uterine prolapse (pelvic organ prolapse quantitative stage 2) without urinary complaints.

Interventions: Four ports were made in all patients: a 5-mm infraumbilical port for the laparoscope and three 3.5-mm ports (right and left paraumbilical and suprapubic). MLSH was performed using a 3-mm bipolar grasping dissector device and reusable monopolar scissors. Uterus was transected from cervical stump using monopolar. Sacrocervicopexy was performed using a triangle-shaped polypropylene mesh with one right arm that was fixed on the vagina and on the sacral promontory with a nonabsorbable braided surgical suture. Reperitonealization over the mesh was performed using a running monofilament absorbable suture. Finally, the posterior cul-de-sac was incised, the specimen was removed vaginally, and the cuff was closed.

Results: The mean age of the patients was 61.3 years. The operation was performed successfully with no intraoperative or postoperative complication in all cases. Mean operative time was 123 $\pm$ 28 minutes and mean blood loss was 34 mL. At the patients' fourth week postoperative visits, no prolapse in any compartment was identified. There were no operative complications related to colpotomy incision and no cases of postoperative vaginal cellulitis or pelvic infection were reported. Patients reported only minimal pain on the day after the surgery and were overall very satisfied especially with the cosmetic results. No new onsets of urinary symptoms following the procedure were found.

Conclusion: This video demonstrates a feasible method for performing supracervical hysterectomy and sacrocervicopexy using minilaparoscopic instruments with specimen removal through the posterior vaginal cul-de-sac.

No competing financial interests exist.

Runtime of video: 8 mins 18 secs

Cite this video

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PART III Discussion and Conclusions

8 Discussion

The term disease broadly refers to any condition that impairs the normal functioning of the body. For this reason, diseases are associated with dysfunctioning of the body's normal homeostatic process (Emson 1987).

During our daily medical practice, we as physicians work intensively to offer the best treatment outcomes to our patients. To reach this final goal, the best approach strategy for each patient and his disease should be well organized. According to our point of view, there are three aspects that we should routinely take into consideration. The first point that should be focused is the disease itself. We should be aware of the disease pathology and its biological behavior in order to offer the most efficient treatment as soon as indicated. The second aspect we have to consider is the evaluation of the patient health beyond the disease (extra-disease health or health reserve). Health is the ability of individuals or communities to adapt and self-manage when facing physical, mental or social challenges (Huber, Knottnerus et al. 2011). When confronted with physiological stress, a healthy organism is able to mount a protective response, to reduce the potential for harm, and restore an (adapted) equilibrium (McEwen 2003). Therefore, we should assess the patient's "health reserve" while planning his treatment. We must tailor our disease management to reduce the amount of collateral damage, or side effects, what would impair the patient's extra-disease health. Therefore, if the health reserve is low we should not be radical, but offer an accurate and selective approach towards the disease and always balance the benefit-risk relationship before deciding an intervention. The third phase should consist in organizing the finest strategy for treatment approach. The disease management can include medical or surgical treatments.

In a surgical approach, three aspects should be taken into account: i) surgical access; ii) extension of surgical dissection and; iii) amount of extirpated/excised material/tissue.

The size or dimension of the surgical access should be the smallest possible to cause the lowest operative damage.

The extension of operative dissection should be the minimal required in order to avoid unnecessary trauma or morbidity related to the procedure (e.g. lymphocele after lymphadenectomy or nervous injury during genital prolapse correction).

The amount of extirpated or excised material should be the lowest necessary. No need to remove extra tissue what may cause supplementary damage.

We should tailor the surgery to reach our three previous aims for reducing the surgical aggressiveness to the minimum possible.

The surgical evolution that happened in last century has dramatically changed the treatment outcomes of many diseases. This transformation has been transversal to the different medical specialties. Not many years ago, it was possible to hear a quotation that described surgeons' views of themselves: "Big hole, big surgeon." In other words, the collateral damage of incisions for access was not relevant to the surgeon. Meanwhile, several surgeons contributions began a "change", where bigger is no longer better, and what is easy for the patient dictates their views.

In recent years, the laparoscopic progression has been remarkably rapid. No longer is the default procedure an open one; it is fair to say that the current state of the art in most surgical scenarios makes the standard procedure one done with scopes. The entire field of minimal access surgery and its application has not been just a set of tools and technologies but a new way of thinking (Nezhat, Nezhat et al. 2013).

In the gynecology field, minimally invasive surgery has also faced a convincing progress. From the time that the surgeon looked through the scope up to the time that we are using minilaparoscopic instruments, the technology has offered the possibility to decrease the instruments size, the surgical trauma, the post-operative pain and recovery time.

Recently, minilaparoscopic surgical techniques have benefited from additional products development with a focus on improving instruments strength and optics. The transition from 10- to 5-mm ports was a change from big to small, whereas the transition from 5 to 3 mm is visible to invisible (Krpata and Ponsky 2013). The main advance of minilaparoscopic surgery, involving the use of miniaturized scopes and instruments, is the reduction in abdominal trauma, consequently causing less postoperative pain and better cosmesis, since 3-mm incisions generate minimal scarring (Porpiglia, Morra et al. 2012) (Pini, Goezen et al. 2012). Furthermore, minilaparoscopy offers lower risk of abdominal wall vascular injuries and minimizes the possibility of wound infection (Tagaya and Kubota 2012) (Cheah, Lenzi et al. 2001) (Lau and Lee 2002). No incisional hernia has been described after a minilaparoscopic procedure, differently from conventional laparoscopy approach with 5 mm and/or 10-12 mm ports (Toub and Campion 1994) (Yamamoto, Minikel et al. 2011) (Tonouchi, Ohmori et al. 2004, Hosono and Osaka 2007, Sajid, Khan et al. 2009, Yamamoto, Minikel et al. 2011) (Ghezzi, Cromi et al. 2005, Ghezzi, Cromi et al. 2009). An additional advantage of this technology is that there is no need for a new challenging learning curve, since it maintains the same principals of triangulation resembling standard laparoscopic surgery (Pini, Goezen et al. 2012, Porpiglia, Morra et al. 2012, Krpata and Ponsky 2013).

Trying to minimize the aggressiveness of laparoscopic surgery in gynecology, we aimed to test the feasibility of minilaparoscopic instruments to perform innovative procedures in the gynecology field like SLN approach and nerve sparing genital prolapse correction.

The SLN is the hypothetical first lymph node or group of nodes draining a cancer. In case of established cancerous dissemination it is postulated that the SLN/s is/are the target organs primarily reached by metastasizing cancer cells from the tumor. Thus, SLN can be totally void of cancer because they were detected prior to dissemination. SLN biopsy has been one of the most important innovations in surgical oncology in recent years; it is being reported as a less invasive procedure that brings more information to clinicians (Frumovitz, Ramirez et al. 2008) (Oonk, van de Nieuwenhof et al. 2009). SLN techniques are now part of the standard treatment for breast cancer (Carlson, Allred et al. 2011), melanoma (Coit, Andtbacka et al. 2013), and selected cases of vulvar cancer (Van der Zee, Oonk et al. 2008).

The application of the SLN concept for malignancies of intra-abdominal organs is still under evaluation and testing. In uterine cancers, SLN biopsy holds the hope of more accurate identification of uterine drainage and staging of the primary tumor, as well as, potential applications in fertility-sparing surgical procedures (Levenback 2008). In SLN biopsy–negative patients, regional lymphadenectomy may no longer be a requirement, promising fewer potential complications such as lymphedema, lymphocele, nerve injury, vascular injury, and venous thromboembolism. The concept of SLN mapping is gaining interest and credibility in the management of uterine cancer as a valuable compromise between complete lymphadenectomy and no lymph node dissection at all (Abu-Rustum 2013). It is considered a more accurate staging procedure due to its increased surgical precision through image-guided detection and enhanced pathological accuracy through meticulous ultrastaging (Abu-Rustum 2013). In uterine malignancies the SLN detection rate is significantly higher through laparoscopy than through laparotomy after vital dye pericervical injection (Mais, Peiretti et al. 2010). It would appear perfectly logical to perform lymphatic mapping laparoscopically. The advantages are several and obvious: first, the laparoscopic surgical approach allows a more delicate and bloodless dissection of the retroperitoneum; second, laparoscopy permits magnification of the image, which facilitates visualization of colored lymphatic vessels; and third, if positive nodes are identified, the surgeon has the opportunity to end the procedure, thus avoiding radical hysterectomy, and offer to patients chemoradiation with minimal delay and reduced morbidity compared with laparotomy.

We attempted to combine the SLN concept with another minimally invasive approach like is the application of 3 mm minilaparoscopic instruments (Figure 1). For this purpose, we prepared a protocol where we used these smaller instruments for SLN harvesting in porcine models after uterine cervical injection of a dye.

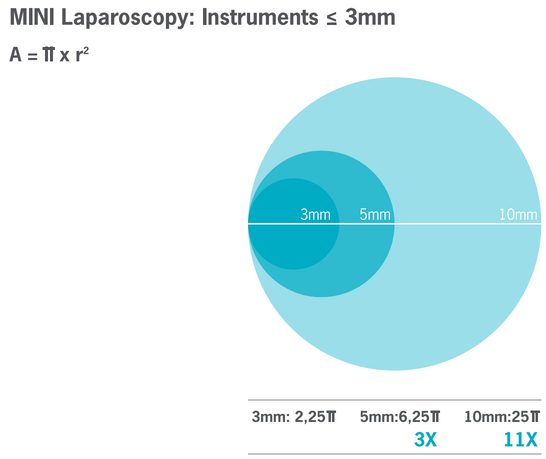

Figure 1 – The instruments cross sectional area is estimated by $A=\pi r^2$. The 5mm caliber instruments have approximatively three times more area than the 3 mm ones. The 10 mm caliber instruments have approximatively eleven times more area than the 3 mm caliber instruments.

In the first experimental series, we used blue dye for SLN identification and a transperitoneal/intraperitoneal access for SLN harvesting by minilaparoscopy **(Aim 1a - Chapter 3)**.

The transperitoneal approach for lymphadenectomy has been the traditional choice. The extensive working field and the relative easy port placement as well as the minimal risk of lymphocele are some of the strong points of the transperitoneal approach (Pakish, Soliman et al. 2014). The potential disadvantages of the transperitoneal technique could include the risk of bowel injury or accidental perforation, the risk of vascular injuries, the need of severe Trendelenburg positioning of the patient that may have deep impact especially on patients with cardiopulmonary problems and increased intraocular pressure (Chon, Bush et al. 2012) (Gkegkes, Karydis et al. 2014). In case of previous surgeries or radiotherapy, the high risk of intraperitoneal adhesions may severely impair a transperitoneal approach to the lymph nodes.

We attested the feasibility of the minilaparoscopic surgical approach for identification, dissection, and excision of SLN after blue dye cervical injection. This procedure might be considered a potentially better alternative to reduce morbidity during staging procedures for gynecological malignancies

In towards to explore different SLN approaches, a second phase of experiments was performed to test the feasibility of SLN identification and removal by an extraperitoneal access using ICG dye and a special video camera in a porcine model **(Aim 1b - Chapter 4)**. According to previous literature, the restricted and narrow extraperitoneal space can cause an additional difficulty in standard use of 5mm laparoscopic instruments (Carvalho, Cavazzola et al. 2013). Therefore, our research team tried those smaller 3 mm instruments in that limited space and SLN harvesting by an extraperitoneal access.

Dargent and Salvat reported the first use of conventional 5mm laparoscopic instruments for extraperitoneal lymphadenectomy in women with gynecologic cancers (Querleu, Dargent et al. 2000). The extraperitoneal approach in comparison to the standard transperitoneal one presents a number of potential advantages. Extraperitoneal laparoscopy leads to fewer postoperative adhesions than transperitoneal approach, lowering the risk of postoperative radiation-related complications (Occelli, Narducci et al. 2000). Additionally, as the peritoneal cavity is untouched (bowel protected by the peritoneal sac), complications such as postoperative ileus, intestinal obstruction, electrosurgical bowel injury or unrecognized enterotomy due to traction or dissection are eliminated (Ramirez and Milam 2007)(Dargent, Ansquer et al. 2000). Extraperitoneal techniques may reduce the time taken to access the lymphatic channels since adhesiolysis and bowel mobilization is unnecessary. The ureter is automatically mobilized out of the dissection field by attachment to the peritoneal envelope. Previous abdominal surgery, radiotherapy, and chemotherapy do not complicate the extraperitoneal approach. Since the peritoneal sac acts as a natural retractor, fewer instruments may be needed. It is anatomically and surgically more logical as it is carried out on the left-hand side (providing better access to the aortic territory lymph nodes) (Franco-Camps, Cabrera et al. 2010). Finally, there is potentially less pain caused by diaphragmatic irritation from CO_2 gas. The low incidence of postoperative complications and minimal hospital stay promote early initiation of adjuvant therapy.

The ICG has revealed to be an excellent alternative to the combination of blue dye and technetium radionuclide for SLN identification (Spear 2011). It has widespread uses in hepatic, cardiac, and ophthalmologic studies, and its use in analyzing tissue perfusion and identifying SLN in cancer staging is recently gaining popularity (Reinhart, Huntington et al. 2015). The ICG fluorescent dye relies on a fluorometrically capable camera and appears green when excited by light in the NIR range. It has the potential advantage of being readily visible through visceral fat and has a higher detection rate than blue dye in SLNs. The increasing body mass index (BMI) is negatively associated with successful mapping after blue dye use, but not with ICG application (Sinno, Fader et al. 2014). NIR fluorescence imaging using ICG may improve SLN technology in cervical and endometrial cancers by increasing the rate of bilateral SLN mapping without the added cost and inconvenience of technetium (Jewell, Huang et al. 2014) (Ditto, Martinelli et al. 2015). This technique has proven feasible both in breast and skin cancer patients, with comparable to or slightly better detection rates than conventional techniques like ^{99m}Tc (Troyan, Kianzad et al. 2009) (Fujiwara, Mizukami et al. 2009).

In our research, we confirmed that it is feasible and reliable the SLN removal by a retroperitoneoscopic approach using minilaparoscopic instrumentation after ICG dye cervical injection. This was also compared with conventional 5-mm laparoscopic instruments **(Aim 1b - Chapter 4)**. During these experiments, researchers found that those smaller minilaparoscopic instruments could offer a better surgical approach in the narrow and restricted extraperitoneal space. In our comparative study, the operating time with minilaparoscopic instruments was shorter than with the 5-mm conventional instruments (P=.042) without major complications. According to the best of authors' knowledge, this was the first comparative study that compared the use of mini (3mm) laparoscopic instruments with the use of conventional (5 mm) laparoscopic instruments in an extraperitoneal approach for SLN removal.

In these previously described two studies **(Chapters 3, 4)**, we used two different accesses (intraperitoneal and extraperitoneal) for SLN resection and two distinctive dies for SLN coloring (methylene blue and indocyanine green). In both works, we compared the use of the 3 mm minilaparoscopic instruments versus the standard 5 mm laparoscopic devices. The research team found those thinner instruments to be very functional with no increase in complexity. The new minilaparoscopic rotating bipolar instrument greatly facilitates a bloodless, precise tissue dissection, shortens the operation time, prevents unnecessary application of intraperitoneal foreign bodies, reduces the costs, and brings more convenience to the surgeon. Sealing of lymphatic channels with bipolar minilaparoscopic grasper was also tried and apparently well accomplished. We concluded that the use of the smaller instruments is feasible and may be advantageous in comparison to the conventional ones. After a literature review, we should state that these are the initial studies that compare mini laparoscopic versus conventional laparoscopic approaches for these types of procedures.

We confirmed the enhanced view referred in previous studies offered by the use of these smaller instruments. A surgeon who uses minilaparoscopy can work much closer to the subject without being disturbed by the 5-mm forceps (Carvalho, Cavazzola et al. 2013). Mathematically speaking, we can find gains up to 2.7 times in magnification when using minilaparoscopic instruments, as the thinner instruments occupy less of the visual field (Carvalho, Loureiro et al. 2011, Carvalho, Loureiro et al. 2012). In endoscopic surgery, peripheral vision is limited by the visual field of the laparoscope. In this tunnel vision, thinner instruments occupy less space, and a much better view can be obtained (Carvalho, Cavazzola et al. 2013). The increase in vision scale seen in laparoscopy does not find a perfect partnership with conventional 5-mm instruments, and they become coarse instruments for dealing with more delicate situations, such as biliary anastomosis, resection of a sympathetic ganglion adherent to the vena cava, or dissection of the deferens duct from the hernia sac during hernia surgery (Carvalho, Loureiro et al. 2011, Carvalho, Loureiro et al. 2012).

We tested and confirmed the feasibility of indocyanin green fluorescent dye for SLN identification by an extraperitoneal access using a special video camera in a porcine model **(Aim 2 - Chapter 4)**. The ICG use was of paramount importance to decrease the surgical time adopting a new image guided surgery concept. Also, it diminished the amount of extirpated tissue offering less aggressiveness in our surgical approach.

The strengths of our SLN studies include the controlled setting in which only a single variable (instruments size) was altered and the same team of surgeons performed all procedures.

In a third study, we tested these reduced size instruments for genital prolapse correction **(Aim 3 - Chapters 5, 6, 7)**. We carried out a minilaparoscopic approach for sacrocolpopexy in humans and we compared it with the conventional 5-mm laparoscopic instruments. It was also accomplished sacrocervicopexy after supracervical hysterectomy using the smaller 3 mm tools. In these procedures, those finer tools were additionally observed for precise dissection and nerve sparing.

Sacrocolpopexy is the gold standard treatment for vaginal vault prolapse (Barber and Maher 2013). Pelvic organ prolapse has a prevalence of 3–6% when based on symptoms and up to 50 % when based on vaginal examination (Barber and Maher 2013). Specifically, prevalence of apical prolapse ranges between 0.2% and 43% (Toozs-Hobson, Boos et al. 1998).

The laparoscopic sacrocolpopexy, which allows a quicker recovery, can be considered a safe and effective procedure for the treatment of vaginal vault prolapse with a success rate of 95% (Granese, Candiani et al. 2009). It has demonstrated excellent anatomic and functional outcomes (Sarlos, Brandner et al. 2008) (Sarlos, Kots et al. 2014) (Maher, Feiner et al. 2011). However, de novo pelvic organ dysfunction has been reported after laparoscopic sacrocolpopexy (Sarlos, Brandner et al. 2008) (Sarlos, Kots et al. 2014) (Maher, Feiner et al. 2011) (Forsgren, Zetterstrom et al. 2010) (Bradley, Nygaard et al. 2007) and may be due to compromise of nerve fibers of the superior hypogastric plexus (Shiozawa, Huebner et al. 2010, Cosma, Menato et al. 2013). At laparoscopic sacrocolpopexy particularly, dissection of the presacral space can compromise fibers of the superior hypogastric plexus and contribute to postoperative problems such as incomplete voiding, defecatory dysfunction, pain, and sensory problems (Bradley, Nygaard et al. 2007) (Shiozawa, Huebner et al. 2010, Cosma, Menato et al. 2013). The key step is visualization, gentle displacement and precise preservation of fibers of the superior hypogastric plexus at the level of the promontory and right pelvic sidewall.

Sacrocervicopexy is a procedure similar to sacrocolpopexy, in which a graft material is used to suspend the cervix to the anterior longitudinal ligament of the sacrum. Sacrocervicopexy can be performed either with uterine preservation or after supracervical hysterectomy. This procedure definitely avoids the risk of mesh erosion (Rosati, Bramante et al. 2013). Moreover, it preserves the integrity of the uterosacral and cardinal ligaments, which are the main supports of the vaginal apex (Rosati, Bramante et al. 2013).

Our first reported cases of minilaparoscopic sacrocolpopexy (MLSC) presented post-operatively very positive anatomical and functional results **(Chapter 5)**. Moreover, our comparative study suggested that minilaparoscopy can be successfully and safely applied to sacrocolpopexy for vaginal vault prolapse after hysterectomy, with similar perioperative outcomes in comparison to the standard laparoscopy **(Chapter 6)**. In particular, no significant differences in operative time, blood loss, pelvic prolapse correction, as well as complications (Satava, Clavien-Dindo) were observed between conventional laparoscopic sacrocolpopexy and MLSC groups (Satava 2005) (Dindo, Demartines et al. 2004). The shorter hospital stay in the MLSC group may be a cost effective alternative in the way that it may be scheduled in an ambulatory surgery regime (less than 24 hours of hospitalization). At three months consultation, after Patient and Observer Scar Assessment Scale (POSAS) Questionnaire (van de Kar, Corion et al. 2005) we reported significantly better scores in the MLSC group than in the patients approached by traditional laparoscopic instruments **(Chapter 6)**. Possible mystifications regarding 3-mm instruments may include poor grasping ability, weak manipulation, and difficulty during dissection and development of anatomical spaces (Berci 1998)(Gagner and Garcia-Ruiz 1998). Nevertheless, several investigations in the field of gynecologic and nongynecologic surgery suggest that downsizing abdominal ports allows equal or better surgical results compared with standard laparoscopic procedures (Quattrone, Cicione et al. 2015) (Ghezzi, Cromi et al. 2008) (Mamazza, Schlachta et al. 2001). In addition, the use of small-diameter laparoscopes and instruments is feasible with low carbon dioxide pressures (Bogani, Uccella et al. 2014) thereby reducing possible complications related to pneumoperitoneum.

Obesity may represent a challenge to minilaparoscopic instruments because intraperitoneal access could be more demanding and low insufflation pressures can be insufficient to lift the weight of the abdomen and provide a good view. However, these potential technical problems did not alter our ability to safely and effectively perform minilaparoscopic sacrocolpopexy. We observed that minilaparoscopic instruments were very efficient in suturing, vessels and nerves identification, allowing precise hemostasis and nerve preservation. We can assume that the adequacy of sacrocolpopexy is mainly determined by the expertise of the surgeon rather than by the caliber of the instruments used. Indeed, we decided to adopt a minilaparoscopic approach to sacrocolpopexy only after overcoming our learning curve with conventional laparoscopy. Under this view, our findings must be interpreted cautiously since generalization of these results in less experienced hands is far from guaranteed.

Finally, costs of minilaparoscopic instruments overlaps conventional ones, although its expected shorter durability. The smaller incisions cuts and miniature tools involved in minilaparoscopy may provide somewhat better cosmetic results and shorter hospital stays that should be balanced at the end.

The POSAS was developed recently and found to be a useful subjective evaluation tool for burns scars and it is an appropriate subjective tool for the evaluation of linear scars (van de Kar, Corion et al. 2005).

Some study limitations should be acknowledged like the sample size and the absence of randomization. The experience with this technique is very small, and follows up limited. Despite these restraints, to the best of our knowledge, this represented the first study that compares minilaparoscopic versus laparoscopic sacrocolpopexy using validated assessment tools (i.e., POSAS, Visual Analogue Pain Score) and our results indicate that ML approach might offer a better surgical scar from the patient's and observer's point of view. Thus, further studies are necessary in this field.

We also carried out minilaparoscopic subtotal hysterectomy and sacrocervicopexy to resolve isolated pelvic central compartment uterine prolapse, with posterior cul-de-sac specimen extraction **(Chapter 7)**. We assessed the reduction of prolapse-related symptoms, operative and postoperative complications, and patient satisfaction. The operation was performed effectively with no intraoperative or postoperative complication in all cases. At the patients' fourth week postoperative visits, no prolapse in any compartment was identified. There were no operative complications related to colpotomy incision and no cases of postoperative vaginal cellulitis or pelvic infection were reported. Patients reported only minimal pain on the day after the surgery and were overall very satisfied especially with the cosmetic results. No new onsets of urinary symptoms following the procedure were found.

It has been referred that the ideal indication for minilaparoscopic surgeries are the procedures that do not require specimen extraction, or the ones in which the specimen to be removed from the abdominal cavity fits the 10-mm trocar used for the laparoscope introduction (Dubeux, Carrerette et al. 2016). However, in gynecology, to remove large specimens from inside the abdominal cavity, we can make a culdotomy (opening of the posterior vaginal cul de sac) performing a natural orifice specimen extraction (NOSE) **(Chapter 7)**. Then, minilaparoscopy has an additional beneficial role in the gynecological field.

In our human studies, all the genital prolapse cases approached by minilaparoscopy revealed very positive anatomic and functional outcomes. No case of de novo pelvic organ dysfunction such as incomplete voiding, defecatory dysfunction, pain, and sensory problems has been reported after surgery.

In a very short future, the new ultra-high definition (UHD) cameras will succeed in surgery therefore more precise and delicate instruments must follow this better image resolution. We are firmly convicted that these minilaparoscopic instruments will have a solid role in this next video cameras generation. It will be possible to join a more accurate picture to a more precise tool. As described recently, laparoscopic sacrocolpopexy should be a nerve-sparing technique (Sarlos, Aigmueller et al. 2015). This more precise combined approach will help, even more, in nerves preservation and other anatomical delicate structures identification.

By reproducing the principles of standard laparoscopy, and with predictable improvements of 3 mm instruments and higher definition cameras, we predict that MLSC can be regarded as an excellent option to pelvic organ prolapse correction.

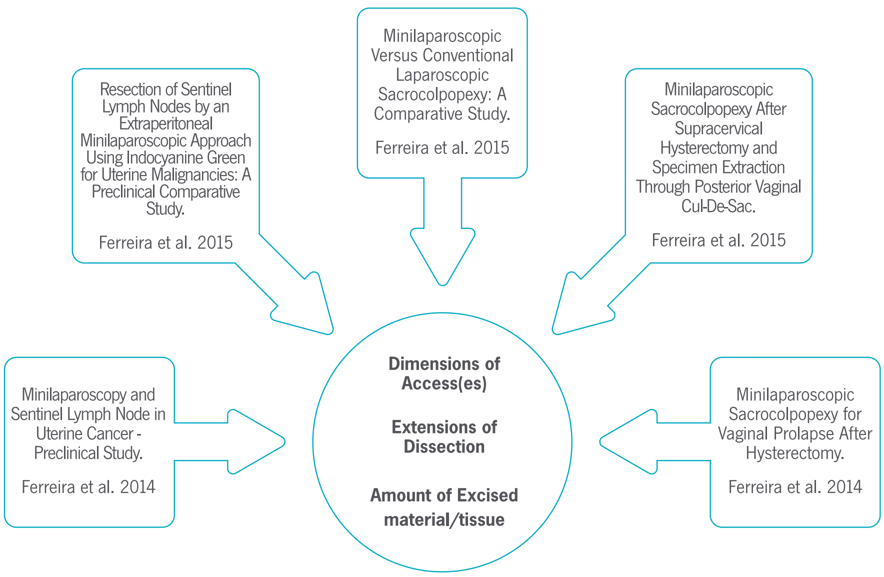

Figure 2 – Diagram showing the converging of our studies towards our aim of minimizing the aggressiveness of endoscopic surgery in some pioneering gynecological procedures.

The main advances offered by the use of minilaparoscopic instruments are the reduction of abdominal wall trauma and intraoperative injury. Therefore, coming back to the beginning of our discussion, we have offered a small contribution for the aggressiveness reduction of endoscopic surgery in some pioneering gynecological procedures (Figure 2). We tested positively the use of a smaller surgical access that may cause less stress and trauma to the patient. Using the SLN concept, an image-guided surgery approach and finer instruments we have reduced the amount of removed tissue and we may have improved the quality of surgical dissection preserving small structures like the nerves and the lymphatics. SLNs mapping seems to have the potential to improve the stage of the disease with lower morbidity, consequently offering several benefits for both patients and the health-care system (Benedetti Panici, Basile et al. 2008). If surgeons are able to identify structures more easily with help of NIR fluorescence imaging, operating and anesthesia time may be reduced, which simultaneously may reduce costs and associated risks (Handgraaf, Verbeek et al. 2014). In prolapse correction surgery, we also confirmed that the use of smaller instruments diminishes the surgical access related trauma and offers the ability to perform more precise dissection. The anatomical and functional results were very positive, as well as the recovery time **(Chapter 5, 6, 7)**.

Most of the patients complaining of genital prolapse have an advanced age and other concomitant morbidities, so our treatment approach must be even less traumatic in order to avoid any additional damage to their health reserve. Being less aggressive we can treat patients better and safer, even if they have a fragile extra-disease health.

Our final goal should be to treat the disease avoiding collateral damage. In a short future, thanks to the minilaparoscopic smaller instruments, image guided-surgery and our previous described innovative techniques we may offer superior outcomes to our patients. This less invasive surgical treatment also may significantly increase the number of procedures that can be performed in an ambulatory regime.

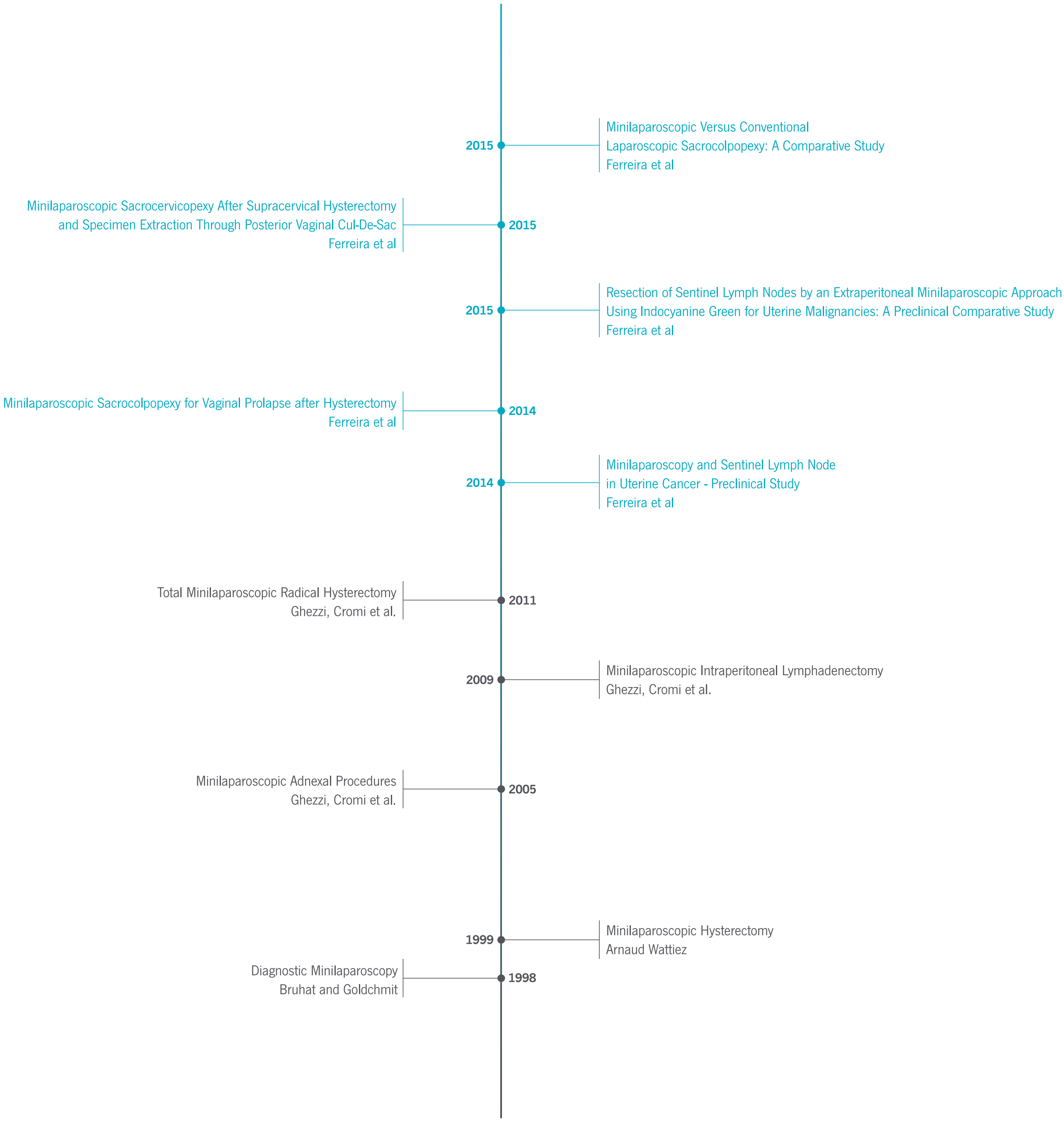

Figura 3. Evolution of Minilaparoscopic surgery in Gynecology

9
Future Directions

Supported by our promising results, two main research lines appears as natural consequences of this thesis: i. the performance of a minilaparoscopic approach to SLN and genital prolapse correction, need validation by other minimally invasive surgeons with experience in minilaparoscopy from high-volume centers. A large-scale multicenter study or a multicenter registry for prospective data collection is therefore warranted to assess this new less aggressive surgical approach. ii. in a very short future, the UHD image will be available in many operative rooms and the more detailed image-guided surgery picture, offered by the new UHD-cameras, will demand more precise instruments. With a better resolution image, it will be possible to identify even very small anatomic structures like nerves, minor vessels and lymphatics. Our impressions are that the minilaparoscopic instruments will have a decisive role on image-guided surgery, precision and enhanced-image combination but this will need additional tests.

10
Conclusions

With a current emphasis on diminishing the visibility of scars, on increasing the surgical precision and on decreasing the amount of dissection, minilaparoscopy has reemerged as an appealing option for surgeons.

Having in the mind the aims of the present dissertation, namely to add the advantage of minilaparoscopy to the benefit of the SLN concept in uterine malignancies and to carry out minilaparoscopic sacrocolpopexy and sacrocervicopexy (nerve sparing techniques) to correct genital prolapse, main achievements derived from this dissertation are listed below.

- We attested the feasibility of the minilaparoscopic surgical approach for identification, dissection, and excision of SLN, as well as for sealing the lymphatic vessels that supply the nodes. This procedure might be considered a potentially better alternative to reduce morbidity during staging procedures for gynecological malignancies;
- We confirmed the feasibility and reliability of extraperitoneal minilaparoscopic approach for identification, dissection, and excision of SLN using an NIR imaging system and ICG;
- We demonstrated a feasible method for performing supra-cervical hysterectomy and sacrocervicopexy using minilaparoscopic instruments with specimen removal through the posterior vaginal cul-de-sac;
- We confirmed that minilaparoscopy is a feasible and attractive approach for sacrocolpopexy as it enhances cosmetics, keeping the low morbidity associated with the classical laparoscopic approaches.

Our research work added an extra contribution to minimize the aggressiveness of laparoscopic surgery in gynecology (Figure 3). With a smaller access size, more precise surgical dissection and excising less tissue we save the patients to extra injury. Simultaneously, we followed the believe that image-guided surgery also adds an additional benefit for better outcomes. By this way we may offer an opportunity of treatment for patients whose health reserve has not previously allowed an efficient therapeutic approach. That's why we hope to continue this journey and we expect that other centers will follow this challenge of reducing even more the laparoscopic aggressiveness in gynecology.

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