Computer-assisted reproductive surgery: why it matters to reproductive endocrinology and infertility subspecialists

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Trained fertility specialists possess a unique clinical perspective and an extensive medical and technological armamentarium to overcome reproductive dysfunction: it is their privilege and ethical duty to lead the field of reproductive surgery. However, modern reproductive surgery can no longer exist outside of the realm of advanced laparoscopy. This has been a major hurdle to the thriving of surgery within our subspecialty, owing to the time and effort required to achieve and maintain proficiency in the antiergonomic environment of conventional laparoscopy. Computer-assisted surgery minimizes aptitudinal restrictions to the adoption of advanced laparoscopy. As such, it promotes strategy over technique and may hold the key to the continued success of high-specialty reproductive surgery. (Fertil Steril® 2014;102:911–21. ©2014 by American Society for Reproductive Medicine.)

Key Words: Laparoscopy, robotic surgery, computer-assisted surgery, reproductive surgery, infertility, fibroids, endometriosis, tubal reanastomosis

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REDEFINING REPRODUCTIVE SURGERY IN THE AGE OF COMPUTER-ASSISTED LAPAROSCOPY

Reproductive surgery in gynecology can be defined as loosely or as restrictively as one chooses. In its broadest conception, any conservative surgery performed on the reproductive organs of women who have not completed their childbearing constitutes reproductive surgery. In more specific terms, when we refer to reproductive surgery, we think of surgery that is specifically planned to improve spontaneous or assisted fecundity or to minimize the impact of any pathology on a present or future reproductive endeavor. In this sense, reproductive surgery is but one component of a programmatic approach to the care of infertile patients. The target of reproductive surgery is not the immediate pathology at hand (such as leiomyoma, tubal disease, or endometriosis) but the ultimate attainment of a healthy maternity. The role of surgery in this context is overall minimalistic and carefully targeted: a deep knowledge of reproductive endocrinology and infertility is fundamental to plan and execute effective reproductive surgery. Indeed, it can be argued that a trained infertility subspecialist can better tailor the timing and extent of medical, surgical, and assisted reproductive technology (ART) interventions to each patient's unique reproductive endeavor. If one accepts this argument, it is hard to pretend that the current state of affairs of reproductive surgery, both in our country and globally, is optimal and sustainable. Indeed, in spite of heartfelt appeals from leaders in our field to promote the role of high-specialty reproductive surgeons in modern fertility care (1, 2), the development of advanced laparoscopy has changed the parameters by which the quality of reproductive surgery is defined, and a culture of disconnected care has rapidly developed. It is currently the norm for delicate reproductive surgery operations to be referred by fertility specialists to general gynecology (or even gynecologic oncology) practices, so that they can be performed laparoscopically. While the intention

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of deferring management to a technical expert may be noble, the final outcome may not be consistently to the patient's advantage. For example, a nulligravida in advanced maternal age, with borderline ovarian reserve, a radiological diagnosis of bilateral endometriomas, hydrosalpinges, and a sizable subserosal myoma (an overall common clinical scenario) may undergo different procedures to address her pathology depending on the type of practitioner in charge of her care. Laparoscopic excision of hydrosalpinges, stripping of endometriomas, and myomectomy would be reasonable procedures, yet they may be the wrong long-term choice in a case like this. The surgical strategy should not be the eradication of pelvic pathology but the preservation of ovarian follicles and a rapid enrollment in an assisted reproduction cycle. The latter plan will resonate as the obvious choice to any fertility expert, yet it is our experience that IVF clinics around the world are crowded with women who have lost their last oocyte cohorts to overzealous scalpels.

In spite of the need for expert reproductive surgeons, fertility specialists at large are on the verge of relinquishing surgery altogether. This is somewhat shocking if one considers that surgery has traditionally been considered a defining aspect of our profession. Many factors have contributed to this epochal shift, and this article does not presume to offer a socioeconomic analysis of this phenomenon. Rather, it will focus on a single technical aspect that has contributed to the defection of infertility specialists from the surgical ranks, that is, that advanced conventional laparoscopy is hard to master. Indeed, surgeons who preferentially adopt laparotomy over minimally invasive surgery invoke technical difficulty and inadequate training as the main reasons for their choice of technique (3, 4). Most infertility specialists reject the unacceptable burden of adhesions that open surgery entails (5, 6), yet the majority of us struggle with the extreme ergonomic challenges of laparoscopy in our field. An uncompromised laparoscopic approach that replicates true open microsurgical technique may be virtually impossible for all but the most skilled surgeons. Infertility specialists who have chosen to remain true to their surgical principles have historically faced a dichotomous professional choice: either diverting a large part of their clinical time and resources to acquire and maintain laparoscopic skills or relinquishing their patients' surgical care to skilled laparoscopists, often outside of their area of expertise. I will endeavor to demonstrate that the advent of computer-assisted laparoscopy renders this ethical dilemma somewhat obsolete, thereby redefining and revitalizing reproductive surgery.

COMPUTER-ASSISTED LAPAROSCOPY VERSUS ROBOTIC SURGERY: WHAT IS IN A NAME?

In this manuscript I employ the terms "computer-assisted laparoscopy," "robotic surgery," and "robot-assisted surgery" interchangeably, even though the da Vinci Surgical System (Intuitive Surgical)—the only surgical platform of this kind for which peer-reviewed literature is available—is not a robot in the scientific sense of the term, but a telemanipulator (7). Further conceptual distinctions between autonomous robotics and telerobotics are beyond the scope of this article. Simply stated, computer-assisted laparoscopy combines the intuitive operative environment of open surgery with the minimal invasiveness of laparoscopy. It is somewhat telling that reproductive surgeons were the first gynecologists to appreciate the benefits of robot-assisted surgery, adopting the (now discontinued) Zeus platform to facilitate robot-assisted laparoscopic tubal reanastomosis as early as 1999 (8). That was several years before the United States Food and Drug Administration (FDA) approved the da Vinci Surgical System for gynecologic surgery in 2005. This platform and its subsequent upgrades (da Vinci S, Si, Xi, and the upcoming Sp) are the only robotic systems approved for clinical use in laparoscopic surgery in the United States. Still, the da Vinci Surgical System is just one of many robotic tools that are increasingly appearing in operating theaters around the world. Competing technology is in the advanced stages of development and is likely to become available soon. Available platforms for gynecologic robotic surgery consist of three basic elements: a surgeon's console, a patient-side cart, and a vision cart (which contains the central processing unit in more recent devices; Fig. 1). The surgeon console is a computer-aided physical interface that allows the remote control of specially designed surgical instruments through the patient-side cart. These instruments enter the abdomen through dedicated cannulas. The arms of the patient-side cart are connected to these cannulas (a step that is automated in the Xi platform). The surgeon controls the camera arm, with the attached 8.5-mm or 12-mm stereolaparoscope, and up to three additional arms, which can be loaded with interchangeable robotic instruments (a dedicated camera arm no longer exists in the new Xi platform, where camera and instrument arms are interchangeable). Most robotic instruments in this multiport setup feature fully articulated tips and therefore allow grip, insertion, rotation, and pitch and yaw at both the elbow and the wrist. As an alternative to this classic multiport configuration, two FDA-approved robotic devices were specifically built for single-incision laparoscopy. The da Vinci Single-Site technology was approved for gynecologic surgery by the FDA in 2013. It employs a single-site port that is secured within a 2.5-cm umbilical incision and allows placement of an 8.5-mm stereolaparoscope, two 5-mm semirigid instruments, and a 5- to 10-mm assistant port (Fig. 2). Wristed instruments for this system are scheduled for release in 2014, making this device more attractive to reproductive surgeons. Finally, the FDA has recently approved the first da Vinci single-port surgical system (da Vinci Sp). This long anticipated evolution of the multiport robotic system will be available for clinical use in 2015. It consists of four separate flexible devices (a stereoscopic camera plus three instruments) entering the body through a single 2.5-cm cannula (Fig. 3).

All of these surgical systems use computer technology to overcome the fulcrum effect caused by the passage of instruments through the fixed point of the anterior abdominal wall. The fulcrum effect makes laparoscopy counterintuitive, a flaw that is magnified by working in a bidimensional environment and that becomes particularly vexing in advanced