SECOND EDITION

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Operative Obstetrics & Gynecology

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2 Future of Gynecological Surgery: Next Five Decades

Sulbha Arora, Gautam N Allahbadia

"Technology breeds more technology"

—**Alvin Tofler** in *Future Strock*

INTRODUCTION

Prior to 1980, traditional gynecological surgery remained unchanged for over 60 years. Following the introduction of the laparoscope in the late 1960s, its use was restricted to diagnostic and sterilization procedures. In the 1970s, Kurt Semm from Kiel pioneered operative laparoscopy. The 1980s saw the introduction of the carbon dioxide (CO_2) laparoscopic laser. In 1988, Harry Reich performed the world's first laparoscopic hysterectomy, which subsequently broadened the appeal of this approach. By the early 1990s, the availability of surgical technological aids such as quality cameras, disposable ports, staples and electrosurgery had facilitated the progression of laparoscopic surgery into mainstream gynecology.

The marvels of electronic and information technology have strengthened the biochemical and molecular power of diagnosis and the surgical and medical management of gynecology, transforming the very practice of medical science into a reality that could barely be envisaged 2 decades ago. We now enter the age of robotics, telesurgery and therapeutic cloning. This dynamic process of progress continues to deliver practitioners with information, ideas and tools that spell answers to some of the most pressing dilemmas in clinical management today.

FUTURE DEVELOPMENTS

The major areas of gynecological surgery today are:

- Obstetrics—antenatal, intrapartum and postpartum maternal, and fetal surgeries
- Fertility enhancing surgeries and assisted reproduction
- Oncosurgery
- Gynecologic urosurgery
- Pelvic floor and retroperitoneal surgery
- Uterine surgery: transcervical and transperitoneal.

The major developments in future, likely to impact surgical techniques, are:

- Evolution of anesthetic agents—minimal postoperative recovery time
- Advanced real-time imaging systems
- Newer generation of minimally invasive operating instruments with higher degree of automation (robotics)
- Advanced drug delivery systems for more targeted therapy
- Stem cell therapy for reconstructive therapy
- High resolution and high magnification optical imaging
- Real-time histopathology, on table in situ histology
- Immunomodulative therapy for transplants
- Newer hemostatic and tissue ablation techniques
- Telemedicine.

Apart from these, lifestyle and environmental factors are likely to play a role in determining the course of gynecological surgery in the coming 5 decades. These include:

- Increase in lifespan
- Changing lifestyles and social concepts of childbearing
- Late marriages and delayed conceptions
- Lower family sizes and evolving human relationships
- Emergent viral agents
- Environmental toxins.

TECHNOLOGICAL ADVANCES

Ongoing usage of nanotechnology and integration of computers in all of the fields in surgery are leaving future imprint.

VIRTUAL REALITY SIMULATORS AND ROBOTS

Advances in computer graphics, robotics and virtual reality (VR) technology have opened up new possibilities in medicine. Robots fit readily into the infrastructure of today's hospitals (Fig. 1). Users of this technology, the new generation of computer literate physicians and patients, recognize their potentials and benefits.

In developed countries, more elderly people require hospital care and fewer working-aged people are able to provide it. One solution is automation in health care. Advances in telecommunications now routinely allow surgeons to view operations taking place in distant hospitals using videoconference techniques. Adding a robot assistant to this setup allows a distant surgeon to participate directly in the procedure, controlling the robot in exactly the same way as if they were in the same room.

Fig. 1: Robot as in da Vinci system

Virtual Reality Training Systems

Virtual reality based surgical simulation systems will become even more realistic in the future. They will be integrated into multimedia teaching and training environments and all surgical disciplines will be covered.

To provide the virtual environment, a realistic three-dimensional (3D) representation of the anatomic sites is derived from two dimensional (2D) medical image data using imaging algorithms and visualization techniques (Fig. 2). Thus the surgeon is able to perform endoscopic procedures at the virtual sites (Fig. 3). By means of realistic user interface, the gynecologist is able to grasp, cut, coagulate, introduce new instruments, suture, apply clips, initiate bleeding coagulation, achieve hemostasis and retract the intestines, all in a realistic simulation scenario. A capability score can also be drawn up for each trainee for evaluation of still untrained.

Robotic-assisted Laparoscopic Surgery

There are different types of robotic camera holding systems. Automated endoscopic system for optimal positioning (AESOP), available with hand, foot or voice control, received the robot of the year award 2000 in medical application. A surgeon can direct the articulated metal arm by voice control. The laparoscope can be moved in any of six directions—possible only with dexterity of hand. The da Vinci is another surgical system whereby it is possible to perform complex surgical procedures through 1 cm ports in a sitting position, with a so called surgical immersion technology, with the look and feel of an open surgery (Figs 4 and 5). The eyes and hands of the surgeon are completely immersed in the patient. With the da Vinci

Fig. 2: Virtual surgery

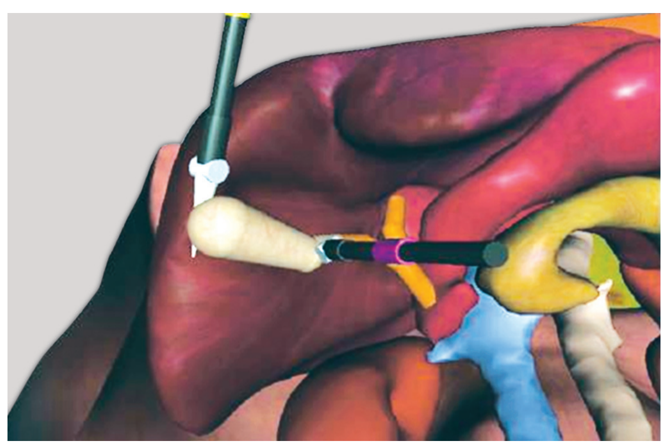


Fig. 3: Virtual laparoscopic surgery from a haptic bench

Fig. 4: da Vinci surgical system

Fig. 5: da Vinci in use

surgical system, the future of surgery is at our fingertips. However, the system is very expensive and not yet in widespread use.

Intelligent Operating Rooms

In the Hermes intelligent operating room (OR1), as a road map to networked voice-controlled devices, data management and surgeon control is unified in one system (Fig. 6). The camera is controlled by an AESOP.

The second example of an intelligent OR is the OR1 from Karl Storz, which realizes the integration and central steering of different operation room components. This allows central control of all OR components, processing, capturing and mailing of all patient data for data exchange between clinics, doctors and health care staff. Radiological and histological data can also be called upon.

Following benefits of both these ORs are at hand: improved ergonomics, better data management, more efficient personnel utilization and optimized surgeon control.

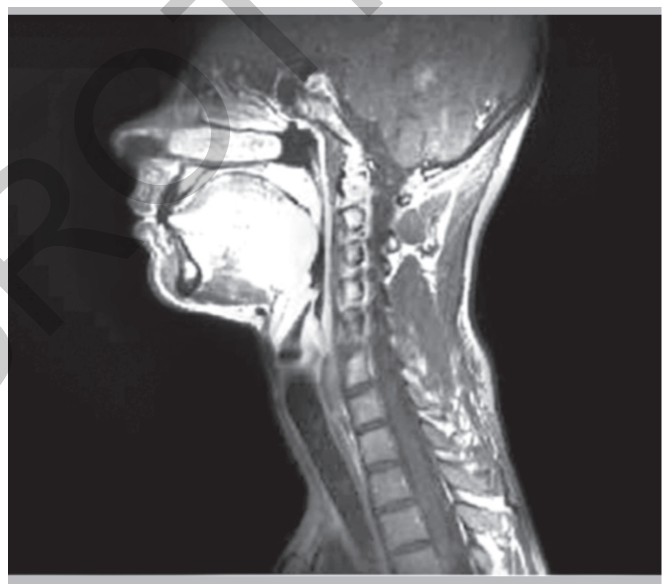


Fig. 6: Hermes

Newer Optics

A new imaging technology that uses directed laser or optical illumination, which is scanned at the distal end of the endoscope, has been introduced, especially for flexible endoscopes, which have limited image quality. In this technique, an alternative approach is used, called the pixel-array acquisition to scan a spot of light and detect each pixel sequentially by laser scanning or confocal microscopy. Thus, higher image quality may be obtained with this visualization technique when compared to similar diameter normal telescopes. Optical scanning technology may provide narrower telescopes with high quality images, and more space for operative instruments. Thus, thanks to such developments in the visual system, flexible telescopes may more widely be used in gynecological practice involving minimal access surgery.

Development of 3D endoscopic instruments has made clear view and perception of depth available. A specialized 3D telescope with a small, light-weight pair of glasses is required for visualization (Fig. 7). The images obtained from objects are processed by a control unit (digital image processing module, 3D scan converter, 3D video demultiplexer) and then they are displayed on the 3D monitor. The 3D vision with a perception of depth makes it easier to position instruments and structures in the area of the operation. Thus, diagnostic and operative endoscopy can be performed more easily (localization of the lesions, measurement of the size, suturing, etc.). The high-

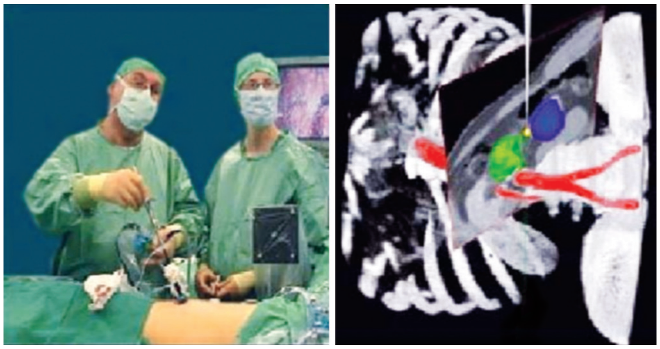
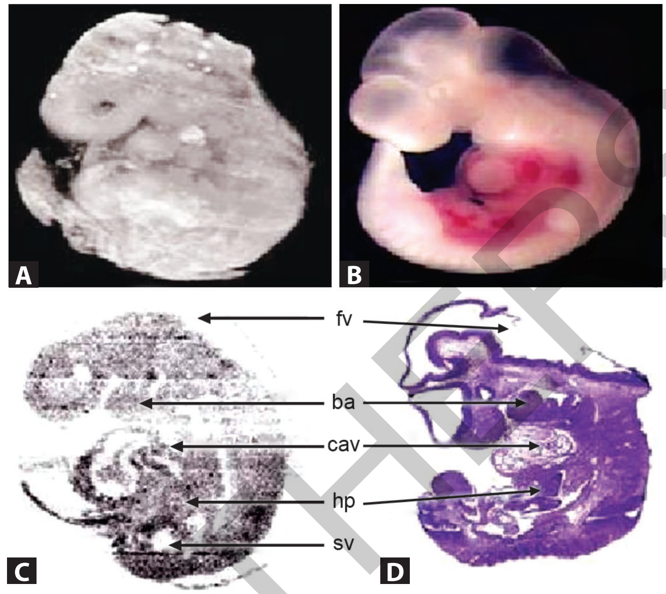


Fig. 7: 3D laparoscopic surgery in progress

resolution camera gives clearer image reproduction in 3D as well as 2D mode. Single axis image processing eliminates binocular contrasts and eyestrain. Polarized glasses allow more than one person to see three dimensionality. The learning curve in 3D endoscopy is shorter than its 2D counterpart because 3D modules can provide more actual and realistic views. The development of 3D technology in endoscopic applications will lead to widespread use of minimally invasive endoscopic surgeries in infertility evaluation. Increasing number of surgeons will be able to easily perform basic procedures without difficulty of orientation by means of 3D endoscopy.

Ultrasound has already been integrated into endoscopy instruments and attempts are under way to integrate magnetic resonance imagining (MRI) technology into telescopes. It is obvious that optics and laser-based techniques will be integrated as well. Computer-assisted diagnostics for object identification in images will be applied to telescopes for the intelligent, automated segmentation, and recognition of pathology at the organ, tissue and cellular levels. Optical technique capable of identifying tissue components and pathology, as well as obtaining microstructural images is known as optical biopsy. Optical biopsy may eliminate several current problems encountered with endoscopy.

A new optical imaging technology called "optical coherence tomography" (OCT) may prove useful in providing more information on tissue morphology during endoscopic and laparoscopic procedures (Figs 8A to D). OCT is a laser-based optical imaging technology that is somewhat analogous to ultrasound B-mode imaging. It uses a technique called "flow coherence interferometry". The visualization of image subsurface morphology is the main potential benefit of OCT. However, a limitation of OCT is a penetration depth of only 2–3 mm. In contrast to ultrasound, tissue contact or an index-matching gel is not needed in order for images to be acquired, and scanning can be performed over large areas of tissues. For example,



Figs 8A to D: Optical coherence tomography of the murine embryo

endometriotic foci will be more easily recognized by OCT combined with laparoscopy.

Pain Mapping for Endometriosis

Smaller microlaparoscopes and microinstrumentation coupled with videolaparoscopy enables the patient to be an integral part of the operation and interact with the surgeon during the laparoscopy. So dawns the age of patient-assisted laparoscopy or laparoscopy under conscious sedation. Since, the patient was the only person in the OR who knew where the pain started and where it ended, it always seemed illogical to anesthetize the patient, leaving the surgeon to tell her where the pain was, based upon what he/she saw. Initial work on mapping of pain associated with the endometriotic lesions resulted in some thought provoking findings. The classic black lesions were found to be painful in only 11% of the patients when the lesion was touched. Similarly, white lesions were painful in 20% of the patient, red in 37% and clear lesions in 32%. These results added further reason as to why initial therapy gave such poor results. Surgeons would only "see" the black lesions and remove them, but these were the least painful lesions. What became apparent next was the fact that the pain extended 28 mm beyond the visible border of the lesion onto what looked like "normal" peritoneum. Therefore, if the surgeon only removed the lesion at its border, the microscopic disease in the previously identified normal looking peritoneum would remain and the symptoms would persist or recur.

CONCLUSION

Robotic surgical instruments give the surgeon new telesurgery opportunities such as image-guided positioning, image-augmented dexterity, sensor-guided positioning and dexterity and increased manual dexterity. As a hysteroscopic procedure, the robot-controlled endometrial resection in accordance with the exact measurement of the endometrium is certainly more optimal than manual uncontrolled resection. We are learning from the urologists who have been performing prostate resections by robots. Telescopes, rigid or flexible, are the main components of minimally invasive surgery. Technological advances in the last decade have produced thinner telescopes with good quality of vision so that many procedures, such as office hysteroscopy and laparoscopy, and hydrolaparoscopy, may be available to the patient in the absence of general anesthesia. However, new technology will provide us with better opportunities of vision of the operative field such as 3D endoscopy. Other promising technologies, such as incorporation of ultrasonography, MRI, laser-based technology or assisted OCT, will not only enhance better visualization of the surgical field but also discriminate the pathologic tissue from the normal one, enabling the surgeon to excise the pathologic tissue accurately. Pain mapping and photodiagnosis offer a new direction in the diagnosis of microscopic endometriosis. Better detection of the disease results in higher chances of success following treatment.

Progressive technological advances are going to revolutionize gynecological surgery for ease of surgery and comfort of place in the coming few decades.

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