Textbook of Gynecologic Robotic Surgery

Alaa El-Ghobashy
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Editors
Alaa El-Ghobashy
Department of Gynaecological Oncology
Royal Wolverhampton Hospitals NHS Trust
Wolverhampton, West Midlands
UK

Thomas Ind
Department of Gynaecological Oncology
Royal Marsden and St George's Hospitals
London
UK

Jan Persson
Department of Obstetrics and Gynecology
Skane University Hospital
Lund
Sweden

Javier F. Magrina
Department of Gynecological Oncology
Mayo Clinic
Phoenix, Arizona
USA

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I would like to thank my parents, wife (Abeer), and children (Maiar, Mirna, Amy) for their support and care throughout the journey of this textbook.

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Javier Magrina

Preface

Surgical practice has undergone significant evolution over the past few decades from open access through to laparoscopy approach to most recently robotic techniques. Since the first description of robotic hysterectomy in 2005, the technique has gained popularity and its indications have broadened. Therefore, it was timely to offer a comprehensive review of the present status of robotic surgery in gynecology using the *Da Vinci* system.

This book is not only a compilation of the knowledge and experiences of the world renowned robotic surgeons, but it has also incorporated the recent advances and updates in gynecological surgery.

The textbook is aimed at practicing gynecologists, urogynecologists, and gynecological oncologists and is designed to provide a detailed guide to common robotic gynecologic procedures for the purpose of helping novice surgeons in their transition to robotic surgery and seasoned robotic surgeons to refine their surgical technique and expand their repertoire of robotic procedures.

The descriptive, step-by-step, text is complemented by figures, intraoperative photographs, and videos detailing the nuances of each procedure. Emphasis is placed on the operative setup, instrument and equipment needs, and surgical techniques for both the primary surgeon and the operative assistant.

This edition will provide unique insights into robotic gynecologic surgery and reduce the learning curve of accomplishing these increasingly popular procedures.

We would like to express our deepest thanks and gratitude to all the contributors, who so graciously have given their time and effort, and without whom this book would not have been born. There are many more people who have made this book possible specially Springer who supported this project since its inception. To all, thank you for the advice and help and for making this book a reality.

Alaa El-Ghobashy
Javier Magrina

Contents

Contributors

Arnold P. Advincula, M.D., F.A.C.O.G., F.A.C.S. Division of Gynecologic Specialty Surgery, Department of OB/GYN, Columbia University Medical Center/New York-Presbyterian Hospital, New York, NY, USA

Shashank Agarwal Department of Anaesthesia, The Royal Wolverhampton Hospital, Wolverhampton, UK

Sarfraz Ahmad, Ph.D. Florida Hospital Gynecologic Oncology, Florida Hospital Cancer Institute and Global Robotics Institute, Orlando, FL, USA

Marc Barahona, M.D. University Hospital of Bellvitge (IDIBELL), University of Barcelona, Barcelona, Spain

Rasiah Bharathan, M.Sc., M.R.C.S., M.R.C.O.G. Department of Gynaecological Oncology, Royal Surrey County Hospital, Surrey, UK

Lucie Bresson Department of Gynecologic Oncology, Cancer Center Oscar Lambret, Lille Cedex, France

Peter W. Cooke Department of Urology, The Royal Wolverhampton NHS Trust, Wolverhampton, UK

Nita A. Desai, M.D. Division of Gynecologic Surgery, St. Joseph's Hospital and Medical Center, Phoenix, AZ, USA

Alaa El-Ghobashy, M.D., M.R.C.O.G. Department of Gynaecological Oncology, The Royal Wolverhampton Hospitals NHS Trust, West Midlands, UK

Becca Falik, M.D. Center for Special Minimally Invasive and Robotic Surgery, Palo Alto, CA, USA

Stanford University Medical Center, Stanford, CA, USA

Ashley L. Gubbels, M.D. Division of Gynecologic Surgery, St. Joseph's Hospital and Medical Center, Phoenix, AZ, USA

Mete Gungor Faculty of Medicine, Department of Obstetrics and Gynecology, Acıbadem Mehmet Ali Aydınlar University, Istanbul, Turkey

Sarika Gupta, M.D. Florida Hospital Gynecologic Oncology, Florida Hospital Cancer Institute and Global Robotics Institute, Orlando, FL, USA

Matt Hewitt Department of Robotic Surgery, Cork University Maternity Hospital, Cork, Ireland

Michael Hibner, M.D. Division of Gynecologic Surgery, St. Joseph's Hospital and Medical Center, Phoenix, AZ, USA

Robert W. Holloway, M.D. Florida Hospital Gynecologic Oncology, Florida Hospital Cancer Institute and Global Robotics Institute, Orlando, FL, USA

San Soo Hoo Department of Gynaecological Oncology, The Royal Wolverhampton Hospitals NHS Trust, West Midlands, UK

Delphine Hudry Department of Gynecologic Oncology, Cancer Center Oscar Lambret, Lille Cedex, France

Elizabeth Y. Kang Center of Hope, University of Nevada School of Medicine, Reno, NV, USA

John T. Kidwell Department of Surgery, Mayo Clinic College of Medicine, Phoenix, AZ, USA

Sami Gokhan Kilic, M.D., F.A.C.O.G., F.A.C.S. Division of Minimally Invasive Gynecology and Research, Department of Obstetrics and Gynecology, The University of Texas Medical Branch, Galveston, TX, USA

Rainer Kimmig Department of Gynaecology and Obstetrics, West German Cancer Center, University Hospital Essen, Essen, Germany

M. Faruk Kose Faculty of Medicine, Department of Obstetrics and Gynecology, Acıbadem Mehmet Ali Aydınlar University, Istanbul, Turkey

Mertihan Kurdoglu, M.D. Division of Minimally Invasive Gynecology and Research, Department of Obstetrics and Gynecology, The University of Texas Medical Branch, Galveston, TX, USA

Sandra Madeuke Laveaux, M.D. Division of Gynecologic Specialty Surgery, Department of OB/GYN, Columbia University Medical Center/New York-Presbyterian Hospital, New York, NY, USA

Eric Leblanc Department of Gynecologic Oncology, Cancer Center Oscar Lambret, Lille Cedex, France

Mario M. Leitao Jr, M.D. Memorial Sloan Kettering Cancer Center, New York, NY, USA

Anjie Li, M.D. Center for Special Minimally Invasive and Robotic Surgery, Palo Alto, CA, USA

Stanford University Medical Center, Stanford, CA, USA

Peter C. Lim, M.D., F.A.C.O.G., F.A.C.S. Center of Hope, University of Nevada School of Medicine, Reno, NV, USA

Celine Lönnerfors, M.D., Ph.D. Department of Obstetrics and Gynecology, Skane University Hospital and Lund University, Lund, Sweden

Javier F. Magrina, M.D. Department of Medical and Surgical Gynecology, Mayo Clinic, Phoenix, AZ, USA

Paul M. Magtibay, M.D. Department of Medical and Surgical Gynecology, Mayo Clinic, Phoenix, AZ, USA

Paul M. Magtibay III, M.S. Department of Administration, Mayo Clinic, Phoenix, AZ, USA

Nitin Mishra, M.D. Department of Surgery, Mayo Clinic College of Medicine, Phoenix, AZ, USA

Esther Moss, M.R.C.O.G., M.Sc., Ph.D. Department of Gynaecological Oncology, University Hospitals of Leicester, Leicester, UK

Damian Murphy Department of Gynaecological Oncology, The Royal Wolverhampton Hospitals NHS Trust, West Midlands, UK

M. Murat Naki Faculty of Medicine, Department of Obstetrics and Gynecology, Acıbadem Mehmet Ali Aydınlar University, Istanbul, Turkey

Fabrice Narducci Department of Gynecologic Oncology, Cancer Center Oscar Lambret, Lille Cedex, France

Camran Nezhat, M.D., F.A.C.S., F.A.C.O.G. Center for Special Minimally Invasive and Robotic Surgery, Palo Alto, CA, USA

Stanford University Medical Center, Stanford, CA, USA

University of California San Francisco Medical Center, San Francisco, CA, USA

Marielle Nobbenhuis, M.D., Ph.D. Department of Gynaecological Oncology, The Royal Marsden NHS Foundation Trust, London, UK

B.A. O'Reilly Department of Robotic Surgery, Cork University Maternity Hospital, Cork, Ireland

O.E. O'Sullivan Department of Robotic Surgery, Cork University Maternity Hospital, Cork, Ireland

Jan Persson, M.D., Ph.D. Department of Obstetrics and Gynecology, Skane University Hospital and Lund University, Lund, Sweden

M. Jesus Pla, M.D., Ph.D. University Hospital of Bellvitge (IDIBELL), University of Barcelona, Barcelona, Spain

Jordi Ponce, M.D., Ph.D. University Hospital of Bellvitge (IDIBELL), University of Barcelona, Barcelona, Spain

Athula Ratnayake Department of Anaesthesia, The Royal Wolverhampton Hospital, Wolverhampton, UK

Kanagasabai Sahadevan City Hospitals Sunderland NHS Trust, Sunderland, UK

Brooke A. Schlappe, M.D. Memorial Sloan Kettering Cancer Center, New York, NY, USA

John H. Shepherd Department of Gynaecological Oncology, The Royal Marsden NHS Foundation Trust, London, UK

Ozguc Takmaz Faculty of Medicine, Department of Obstetrics and Gynecology, Acıbadem Mehmet Ali Aydınlar University, Istanbul, Turkey

Sarvpreet Ubee Department of Urology, The Royal Wolverhampton NHS Trust, Wolverhampton, UK

Bekir Serdar Unlu, M.D. Division of Minimally Invasive Gynecology and Research, Department of Obstetrics and Gynecology, The University of Texas Medical Branch, Galveston, TX, USA

René H.M. Verheijen Formerly University Medical Center Utrecht, Utrecht, Netherlands

Megan Wasson, D.O. Mayo Clinic, Phoenix, AZ, USA

Sorana White Department of Anaesthesia, The Royal Wolverhampton Hospital, Wolverhampton, UK

Anna E. Wright Department of Urology, The Royal Wolverhampton NHS Trust, Wolverhampton, UK

Johnny Yi, M.D. Mayo Clinic, Scottsdale, AZ, USA

Vanna Zanagnolo, M.D. Department of Gynecologic Oncology, European Institute of Oncology, Milan, Italy

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1 The Development of Robotic Surgery: Evolution or Revolution?

John H. Shepherd and Marielle Nobbenhuis

A Historical Perspective

The history of mechanical automatons can be traced back to the ancient world with the development of the earliest mechanical machinery. During the fourth century BC, the Greek mathematician Archytas designed a mechanical bird, 'the pigeon' driven by steam. In 320 BC Aristotle postulated that automatons would replace human slavery. He quoted Greek mythology in which Hephaestus, the Greek god of craftsmen, created three-legged tables that could action under their own power.

In the twelfth century Al-Jazari, a Muslim inventor designed automated machines that could play music and carry out simple duties. Villard de Honnecourt in the thirteenth century created similar machines. At the end of that century, Robert of Artouis designed and built a number of humanoid and animal robots displayed in his castle at Hesdin. It was some time later in 1495 that Leonardo da Vinci made several drawings of a mechanical knight in armour which was able to move its limbs and head (Fig. 1.1) [1].

This was based on his anatomical sketches and research described in the 'Vitruvian Man'. There is no record as to whether the robot was in fact built. The following century Johannes Müller designed and built an automated eagle made of iron that did fly. Descartes, in his 'Discourse on the Method', 1657, postulated that automatons could be made by man but did not predict that one day they would be able to respond to human instruction [2].

A flurry of developments occurred in the early 1700s with mechanical toys created that could play music, fly, draw and even move as puppets. The most imaginative of these was 'the Digesting Duck' of Jacques de Vaucanson which had wings that flapped as well as a 'digestive system' which could swallow grain and defecate from a hidden storage chamber. Later that century in Japan, Hisashige Tanaka developed a number of complex mechanical toys that were able to fire arrows from a bow, serve Japanese tea and paint.

During the late nineteenth century, remotely controlled machinery was developed, mainly for usage during wartime as radio-controlled torpedoes and rockets.

Deep-sea robots followed in time (Fig. 1.2) as did the first remote-controlled robot to land and move on the surface of the moon followed in 1970.

The word robot is attributed to Joseph Kapak, derived from the Czech word 'robota' meaning service, in his 1921 play, 'Universal Robots'. The film industry subsequently developed human machines as the forerunners of science fiction. A humanoid robot was exhibited in London at an exhibition of Model Engineers in 1928 designed by WH Richards with an aluminium body containing 11 electromagnets and a battery powered motor. This robot could move its hands and head by remote control. In 1939 Electro, a humanoid robot was exhibited at the world fair. The aluminium outer skin contained a motorised skeleton; it could respond to voice commands, smoke cigarettes, blow up balloons and move its head and arms.

The term robotics was coined by Asimov in his short story 'Runaround 1942' [3]. In this he described 'three rules of robotics' in which he postulated that (1) a robot should not injure a human being or through interaction allow one to come to harm; (2) a robot must obey all orders given to it from humans, except where such orders would contradict the previous Law; and (3) a robot must protect its own existence, except when to do so would contradict the previous two Laws. These rules remain a reasonable ethical framework upon which robot development may be applied to surgical care. Subsequently, in 1949 complex behavioural autonomous robots were created at the Burden Neurological Institute in Bristol by William Walter. He used analogue electronics to stimulate brain processes, whilst Alan Turing and John Von Neumann developed digital computation [4, 5]. Artificial intelligence was a short step away.

The first robotic arm was developed at the Rancho Los Amigos hospital in California and further modified at Stanford

J.H. Shepherd • M. Nobbenhuis (✉)
Department of Gynaecological Oncology, The Royal Marsden NHS Foundation Trust, London, UK
e-mail: alison@x-designs.co.uk

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Fig. 1.1 Model of Leonardo da Vinci's mechanical knight with inner workings, as displayed in Berlin. Photo by Erik Möller

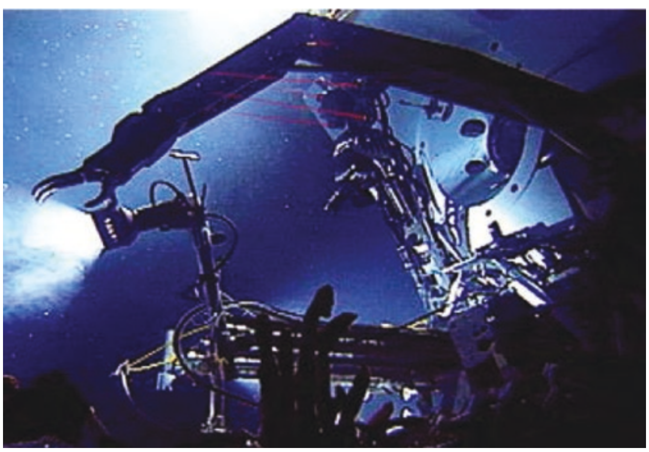

Fig. 1.2 Submersible, called 'Alvin', built for US Navy in 1964, operated by Woods Hale Oceanographic Institution

University in 1963. The following year the IBM system/360 was released and proved to be faster and more capable than previous machines. The Stanford Research Institute subsequently produced a mobile robot capable of reasoning with multiple sensory input in order to navigate. One of the first robotic applications came from the Stanford Artificial Intelligence Lab (SAIL) in 1969. They designed a robotic arm with six degrees of freedom all-electric mechanical manipulator exclusively for computer control. The Stanford Arm and SAIL helped to develop the knowledge base which has been applied in essentially all the industrial robots.

In the 1970s, the robots 'Freddy' and 'Freddy II' were built in the United Kingdom to assemble wooden blocks. The SCARA, Selective Compliance Assembly Robot Arm, created in 1978 was able to pick up parts and place them in various locations useful for assembly lines in factories. In 1986 Honda created a research programme capable of interacting successfully with humans.

It can be seen that with these exciting developments in technology, it was a short step to extending robotic usage into the operating theatre in order to aid and initiate already established laparoscopic and other instrumental techniques.

Surgical Developments

A major step forward in medicine was the invention by Dr. John Adler in 1994 of the CyberKnife, which was able to carry out stereotactic radiosurgery robotically for the treatment of the brain and subsequently other tumours [6]. With advances in microelectronics and computing robotic telecontrol technology with the use of robotic arms to assist in surgical procedures became a reality. Aesop (Computer Motion Inc., Goleta, California) utilised a voice-activated robotic arm. The same company developed Zeus, with remote control robotic arms. Intuitive Surgical Inc., Sunnyvale, California, produced the da Vinci robot controlled by a surgeon-operated console with foot and hand controls. Improvements in stereoscopic imaging gave a three-dimensional view far superior to previously available laparoscopic minimal access techniques although utilising similar optical equipment. Side carts with three and four robotic arms placed at the operating table side allowed further developments and an extension of numerous surgical techniques. In all surgical specialties, the use of fibre-optic technology has allowed diagnostic procedures to be extended to therapeutic and surgical procedures in a truly minimally invasive manner. Examples that can be given include: in urology, prostatectomy, cystectomy and nephrectomy; in colorectal surgery, anterior resection and hemicolectomy; in hepatobiliary and upper gastrointestinal surgery, liver resection, fundoplication and gastric banding, cholecystectomy, pancreatectomy and splenectomy; in cardiothoracic surgery, coronary artery bypass grafting and valve replacement; in otolaryngology, laryngectomy.

Whilst it may seem impractical and difficult to find a role for robotic assistance or minimal access surgery in the practice of obstetrics, in the field of gynaecology the possibilities are clearly endless. The pelvis lends itself anatomically to performing laparoscopy, and therefore robotic assistance will be applicable as has been shown with multiple procedures, when appropriate. The uterus is an obvious organ for such an approach when surgical intervention is necessary. Thus hysterectomy may be aided by robotic assistance and minimal access techniques. Similarly approaches to the pelvic sidewalls and retroperitoneum when dealing with endometriosis can be greatly facilitated with robotic assistance as may sacrocolpopexy and myomectomy. Magnification gained by the optics at the console can be a great aid to the surgeon as can the obliteration of any tremor with delicate procedures.

Oncological Surgery

Similarly it has been shown that pelvic oncological procedures including pelvic node dissection and radical hysterectomy may be greatly facilitated by the use of robotic assistance. With more flexibility using rotating arms, newly developed robots are able to access the pelvis and then the mid and upper abdomen without the necessity to de-dock. Thus more extensive procedures including pelvic exenteration and reconstruction as well as on occasions ovarian cancer surgery may be performed. The indications for these procedures will depend upon the particular circumstances present will be discussed in other sections of this textbook.

Surgical Training

In the past surgical training has occurred in the operating theatre at the table side by observation, assisting and then carry out procedures under direct supervision (Figs. 1.3 and 1.4).

Whilst animal laboratories are not available in the United Kingdom, simulation of anatomical structures and pathology have now given way to computerised models in laboratories (Fig. 1.5).

Robotically assisted surgery may be ideally taught and learnt from such programmes and will have an increasing impact on the quality of training and therefore surgical practice. Just as airline pilots take refresher courses with tests in simulation chambers, so will the surgeons of the future be able to maintain their skills and test their ability. At the same

Fig. 1.3 St Bartholomews surgeons, London, in the 1900s. Archived photo from Medical Photography Department at St Bartholomews Hospital (from Professor John Shepherd's personal collection)

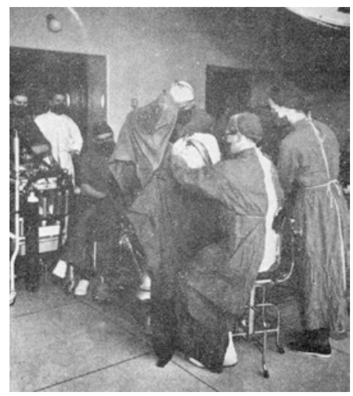

Fig. 1.4 St Bartholomews surgeons in the 1940s. Archived photo from Medical Photography Department at St Bartholomews Hospital (from Professor John Shepherd's personal collection)

Fig. 1.5 Set-up of robotic 'lab' at the Royal Marsden Hospital at time of introduction of robotic gynaecological programme in 2007 (With permission from Thomas Ind)

Fig. 1.6 Double console robotic surgery. The Royal Marsden Hospital (permission Press Office The Royal Marsden Hospital London)

time the surgeon's brain activity can be measured to assess fatigue and even stress levels. The impact on patient safety is quite clear. Newer models of robot equipment have dual controls which will allow tutoring and co-surgical techniques to be performed (Fig. 1.6).

Added Tools and Technology

With further developments in imaging especially using MRI, three-dimensional images may be superimposed into the optics at the console of the robot to enable tumours and other anatomical structures to be visualised prior to a surgical procedure being carried out. This will be especially useful in cancer surgery for identifying tumours as well as other anatomical features, such as with the development and incorporation of fluorescent imaging identifying sentinel lymph nodes (Fig. 1.7).

Similarly, with developments in immunocytochemistry and microscopy in histology, in vivo identification of pathology becomes a realistic possibility allowing intelligent knives to excise malignant tissue with greater dexterity than the surgeons' hand. With developments with haptic feedback, this will facilitate precision microsurgery. An alternative is the use of robotic endoscope holders providing an alternative to telesurgery systems by offering a third arm to the surgeon during an operation.

Fig. 1.7 Sentinel lymph node detection external iliac artery using indocyanine green and Firefly filter (archive MA Nobbenhuis)

The Future

The future is already here; we do not need to go back to it. Smaller robots with artificial intelligence are being developed with almost frightening possibilities for their use. Nanotechnology will supersede today's machinery. Research will continue at an accelerating pace, and the place of new techniques and technologies will need to be carefully evaluated in a critical way as they become available. This will be at an inevitable cost, but this must be offset by an improvement in efficiency and success of treatments available. A reduction of morbidity and inevitable sequelae of treatment must be shown to be achieved with a reduction in hospitalisation and time away from home and work. Advances in medical care need to be supported and encouraged but their correct place carefully assessed. To quote Martin Luther King "Nothing in all the world is more dangerous than sincere ignorance and conscientious stupidity". We just must accept anything is possible although not always practical.

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