New Technologies in Urology

Prokar Dasgupta • John Fitzpatrick
Roger Kirby • Inderbir S. Gill (Eds.)

New Technologies in Urology

Springer

Prof. Prokar Dasgupta
Medical Research Council (MRC) Centre
for Transplantation
King's College London
Department of Urology
Guy's Hospital, London SE1 9RT
United Kingdom
prokarurol@gmail.com

Prof. Dr. John Fitzpatrick
University College Dublin
Mater Misericordiae Hospital
Department of Surgery
47 Eccles Street
Dublin 7
Ireland
jfitzpatrick@mater.ie

Prof. Roger Kirby
Prostate Centre
32 Wimpole Street
London
United Kingdom W1G 8GT
Rogerkirby@theprostatecentre.com

Prof. Inderbir S. Gill
1441 Eastlake Ave, Suite
7416 Los Angeles CA 90089
Keck School of Medicine
USA
gillindy@gmail.com

ISBN: 978-1-84882-177-4 e-ISBN: 978-1-84882-178-1
DOI: 10.1007/978-1-84882-178-1
Springer Dordrecht Heidelberg London New York

Library of Congress Control Number: 2009938955

Printed on acid-free paper.

Springer is part of Springer Science+Business Media (www.springer.com)

Dedicated to our families and friends

Preface

Technology seems to be an integral part of modern living. Urologists have over the years embraced new technological advances for patient benefit. On some occasions, however, the initial enthusiasm in something new has failed to endure rigorous scientific scrutiny. Thus, while being technological leaders, we urologists know better than most other surgical specialties that what is new is not necessarily good.

This textbook is aimed at urologists and surgeons at all levels and has contributions from international experts. The topics vary from robotics to lasers to single port laparoscopy. The comprehensive chapters should be of equal interest to uro-oncologists and those involved in treating benign urological diseases. While the contents are meant to bring the reader up to date with technological advances, the authors have attempted to balance their enthusiasm with basic science, translational research, and clinical outcomes. It will be obvious that some of the subjects mentioned here, such as nanotechnology, are still evolving, and it will be a while before they undergo clinical trials that establish their position in clinical medicine.

We hope you enjoy reading this book as much as we have enjoyed creating it.

London, UK — Prof. Prokar Dasgupta
Dublin, Ireland — Prof. John Fitzpatrick
London, UK — Prof. Roger Kirby
CA, USA — Prof. Inderbir S. Gill

Acknowledgements

The editors thank all authors for their time and valuable contributions.

We are also grateful to our developmental editors Joni Fraser and Barbara Lopez-Lucio.

Prokar Dasgupta acknowledges support from the UK Department of Health via the National Institute for Health Research (NIHR) comprehensive Biomedical Research Centre award to Guy's & St Thomas' NHS Foundation Trust in partnership with King's College London and King's College Hospital NHS Foundation Trust.

Contents

Contributors

Hashim U. Ahmed, MRCS (Ed), BM BCh (Oxon), BA (Hons) Division of Surgery and Interventional Sciences, University College London, London, UK

David M. Albala, MD Department of Urology, Duke University Medical Center, Durham, NC, USA

Kaspar Althoefer, PhD, Dip.-Ing. Department of Mechanical Engineering, King's College London, London, UK

Monish Aron, MD Department of Urology, Cleveland Clinic, Cleveland, OH, USA

Manit Arya, MBBS, BSc, MD, FRCS (Urol) Division of Surgery and Interventional Sciences, University College London, London, UK

Mohamed A. Attala, MD Smith Institute for Urology, New Hyde Park, NY, USA

Arie S. Belldegrun, MD Department of Urology, David Geffen School of Medicine, University of California Los Angeles, Los Angeles, CA, USA

James William Brewin, B Med Sci, BMBS, MRCS Department of Urology, Kings College Hospital, London, UK

Gareth J. Bydawell, MBChB, FRCR Department of Radiology, St. George's Hospital, London, UK

Jeffrey A. Cadeddu, MD Department of Urology, University of Texas Southwestern Medical Center, Dallas, TX, USA

Arthur Caire, MD Department of Urology, Duke University Medical Center, Durham, NC, USA

David Canes, MD Institute of Urology, Lahey Clinic, Burlington, MA, USA

Benjamin J. Challacombe, BSc, MS, FRCS (Urol) The Urology Centre, Guy's and St. Thomas' NHS Foundation Trust, London, UK

Department of Urology, Royal Melbourne Hospital, Melbourne, Australia

Shahin T. Chandrasoma, MD Department of Urology, University of Southern California, Los Angeles, CA, USA

Rafael Ferreira Coelho, MD Department of Urology, Florida Hospital Celebration Health, Celebration, FL, USA

Jose R. Colombo, MD Division of Urology, University of Sao Paulo, Sao Paulo, Brazil

Anthony J. Costello, MD, FRACS, MBBS Department of Urology, Royal Melbourne Hospital, Melbourne, Australia

Geoff Coughlin, MD, FRACS Department of Urology, Global Robotics Institute, Florida Hospital Celebration Health, Celebration, FL, USA

David W. Cranston, MBChB, DPhil, FRCS Nuffield Department of Surgery, University of Oxford, Oxford, UK

Ranan DasGupta, MBBChir, MA, MD, MRCS, FRCS (Urol) Department of Urology, Guy's Hospital, London, UK

Prokar Dasgupta, MSc (Urol), MD, DLS, FRCS, FRCS (Urol), FEBU The Urology Centre, Guy's Hospital, London, UK

King's Health Partners Academic Health Sciences Centre, London, UK

John Hugh Davis, BSc, MBBS, FRCS (Ed), FRCS (Urol) Department of Urology, Royal Surrey County Hospital, Guildford, UK

Roger E. De Filippo, MD Division of Urology, Childrens Hospital Los Angeles, Los Angeles, CA, USA

Jean J.M.C.H. de la Rosette, MD, PhD Department of Urology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands

Mihir M. Desai, MD Stevan Streem Center for Endourology, Cleveland Clinic Foundation, Cleveland, OH, USA

Oussama Elhage, MRCS Department of Urology, Guy's Hospital, London, UK

Mark Emberton, BSc, MBBS, MD, FRCS, FRCS (Urol) Interventional Oncology and Urological Surgery, University College London, London, UK

Michael Ferrandino, MD Department of Urology, Duke University Medical Center, Durham, NC, USA

John Fitzpatrick, MCh, FRCSI, FCS (Urol), SA FRCS (Glas), FRCS Mater Misericordiae University Hospital, Dublin, Ireland

Troy Gianduzzo, MBBS, FRCS (Urol) The Wesley Medical Centre, Auchenflower, Queensland, Australia

Inderbir S. Gill, MD, MCh Department of Urology, Keck School of Medicine, University of Southern California Los Angeles, Los Angeles, CA, USA

Peter J. Gilling, FRACS Department of Urology, Tauranga Hospital, Tauranga, New Zealand

Justin J. Gould, MD Institute of Urology, Lahey Clinic, Burlington, MA, USA

Stavros Gravas, MD, PhD Department of Urology, University Hospital of Larissa, Larissa, Greece

David M. Hartke, MD Department of Urology, Case Western Reserve University School of Medicine, Case Medical Center, Cleveland, OH, USA

Makoto Hashizume, MD, PhD Department of Advanced Medical Initiatives, Kyushu University, Fukuoka City, Japan

Nicholas Hegarty, MB, PhD, FRCS (Urol) Department of Urology, Guy's Hospital, London, UK

Alastair Henderson, MBBS, PhD, FRCS (Urol) Department of Urology, Royal Surrey County Hospital, Guildford, UK

Department of Urology, Guy's Hospital, London, UK

Brian H. Irwin, MD Division of Urology, University of Vermont College of Medicine, Burlington, VT, USA

Mohamed Ismail, MBChB, MRCS, PhD Department of Urology, Homerton University Hospital, London, UK

Jihad H. Kaouk, MD Section of Robotic Urologic Surgery, Glickman Urological and Kidney Institute, Cleveland Clinic, Cleveland, OH, USA

Louis R. Kavoussi, MD Smith Institute for Urology, New Hyde Park, NY, USA

Patrick A. Kenney, MD Institute of Urology, Lahey Clinic, Burlington, MA, USA

Roger S. Kirby, MA, MD, FRCS (Urol), FEBU The Prostate Centre, London, UK

Jeffrey C. La Rochelle, MD Department of Urology, University of California Los Angeles, Los Angeles, CA, USA

Tom A. Leslie, BSc, MBChB, Dphil, MRCSEd Nuffield Department of Surgery, University of Oxford, Oxford, UK

Charalampos Mamoulakis, MD, PhD, MSci, FEBU Department of Urology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands

Magnus J. Mansard, MS Department of Surgical Gastroenterology, Asian Institute of Gastroenterology, Hyderabad, India

Tsuneharu Miki, MD, PhD Department of Urology, Kyoto Prefectural University of Medicine, Kyoto, Japan

Caroline Moore, BSc, MBBS, MD, MRCS Division of Surgery and Interventional Sciences, University College London, London, UK

Declan G. Murphy, MB, FRCS (Urol) The Urology Center, Guy's and St. Thomas' NHS Foundation Trust, London, UK

Azad Najmaldin, MB, ChB, MS, FRCS (Ed), FRCS (Eng) St. James's University Hospital, Leeds, UK

Masahiko Nakamoto, PhD Department of Radiology, Graduate School of Medicine, Osaka University, Suita, Japan

Timothy G. Nedas, MBBS, MRCS, MSc (Urol) Department of Urology, Eastbourne District General Hospital, Eastbourne, UK

Shu Pan, BS Smith Institute for Urology, New Hyde Park, NY, USA

Sijo J. Parekattil, MD Department of Urology, University of Florida, Gainesville, FL, USA

Uday Patel, MB, ChB, FRCR, MRCP Department of Radiology, St. George's Hospital, London, UK

Vipul R. Patel, MD Global Robotics Institute and Urologic Oncology Program, Florida Hospital Celebration Health, Celebration, FL, USA

Thomas J. Polascik, MD Department of Surgery/Urology, Duke University, Durham, NC, USA

Lee E. Ponsky, MD Department of Urology, Center for Urologic Oncology & Minimally Invasive Therapies, Cleveland, OH, USA

University Hospitals Case Medical Center, Case Western Reserve University, Cleveland, OH, USA

Frédéric Pouliot, MD, PhD, FRCSC Department of Urology, David Geffen School of Medicine, University of California Los Angeles, Los Angeles, CA, USA

Guduru V. Rao, MS, MAMS Department of Surgical Gastroenterology, Asian Institute of Gastroenterology, Hyderabad, India

Pradeep P. Rao, MB, DNB (Surg), FRCSEd, DNB (Urol) Department of Urology, Mamata Hospital, Mumbai, India

Duvvuru N. Reddy, MD, DM, DSc, FAMS, FRCP Department of Gastroenterology, Asian Institute of Gastroenterology, Hyderabad, India

Peter Rimington, FCS (Urol) Department of Urology, East Sussex Hospitals, Eastbourne, East Sussex, UK

Jorge Rioja Zuazu, MD, PhD Department of Urology, AMC University Hospital, Amsterdam, The Netherlands

Yoshinobu Sato, PhD Department of Radiology, Graduate School of Medicine, Osaka University, Suita, Japan

Mohammad Shamim Khan, OBE, FRCS (Urol), FEBU Department of Urology, Guy's Hospital, London, UK

King's Health Partners Academic Health Sciences Centre, London, UK

Philippa L. Skippage, MBChB, MRCP, FRCR Department of Radiology, St. George's Hospital, London, UK

Naomi Smith, MA (Hons), MBBS, MRCS Department of Urology, Guy's and St. Thomas' NHS Foundation Trust, London, UK

Robert J. Stein, MD Department of Urology, Cleveland Clinic Foundation, Cleveland, OH, USA

Dan Stoianovici, PhD Department of Urology, Johns Hospital University, Baltimore, MD, USA

Li-Ming Su, MD Department of Urology, University of Florida, Gainesville, FL, USA

Kay Thomas, MBBS, MD, FRCS (Urol) Department of Urology, Guy's and St. Thomas' NHS Foundation Trust, London, UK

Chad R. Tracy, MD Department of Urology, University of Texas Southwestern Medical Center, Dallas, TX, USA

Sheaumei Tsai, MD Institute of Urology, Lahey Clinic, Burlington, MD, USA

Vassilios Tzortzis, MD Department of Urology, University Hospital of Larissa, Larissa, Greece

Osamu Ukimura, MD, PhD Department of Urology, Kyoto Prefectural University of Medicine, Kyoto, Japan

Wesley M. White, MD Section of Laparoscopic and Robotic Urologic Surgery, Glickman Urological and Kidney Institute, Cleveland Clinic, Cleveland, OH, USA

Hessel Wijkstra, MSc, PhD Department of Urology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands

Liam C. Wilson, FRACS Department of Urology, Tauranga Hospital, Tauranga, New Zealand

Lawrence L. Yeung, MD Department of Urology, University of Florida, Gainesville, FL, USA

Part I

Robots

Prokar Dasgupta and Roger Kirby

1 Robotic-Assisted Laparoscopic Radical Prostatectomy

Rafael Ferreira Coelho, Geoff Coughlin, and Vipul R. Patel

Introduction to Robotics

History of Robotics

The word "robot" was originally coined by Karel Capek in his play, Rossum's universal robots, in 1921.[1] It is derived from the Czechoslovakian term robota, meaning forced work. His original vision dealt with a world in which robots help humans with everyday tasks but eventually turn on their masters and attempt world domination. The first truly robotic flexible arm, known as the Programmable Universal Manipulation Arm (PUMA), was developed in 1978, by Victor Scheinman, and quickly became the industry standard. The first surgical application of this technology was in 1985 when the PUMA 560 was used to orientate a needle for a radiologically guided brain biopsy.[2] Soon after, robots were utilized in other surgeries including the PROBOT, to perform transurethral resection of the prostate, and the ROBODOC, for use in hip replacements.[3–6]

The contemporary generation of surgical robots consists of "master–slave" systems made by Intuitive Surgical Inc. (Sunnyvale, CA). These systems resulted from research initially conducted by the Stanford Research Institute, the National Aeronautics and Space Agency (NASA), and the Department of Defense. The concept of surgeons being able to perform surgery from a remote location with use of such a master–slave system would be optimal for use in space travel for astronauts and to remove specialist surgeons from the battlefield.[7]

The da Vinci® Robotic System

The da Vinci is an advanced master–slave robotic system. The basic principle involves control of three or four robotic arms by a surgeon sitting at a remote console. The system has three components: (a) a surgeon console, (b) a surgical robot with three or four arms, and (c) an endoscopic stack (Fig. 1.1). The console contains the master tool manipulators, the visual supply, and foot pedals for camera and tool manipulation. The surgeon's hands are inserted in the free-moving finger controls (masters). These controls convert

Fig. 1.1 The da Vinci S surgical system. The three components are shown: the surgeons console, the 4-armed surgical robot, and the endoscopic stack. Courtesy Intuitive Surgical, CA

P. Dasgupta et al. (eds.), *New Technologies in Urology,*
DOI: 10.1007/978-1-84882-178-1_1, © Springer-Verlag London Limited 2010

the movements of the surgeon's fingertips and wrist into electrical signals. These signals are translated to computer commands that direct the robot to replicate the movements with the robotic instruments in the operative field. The console is connected to the video and surgical component of the robot via cables. The patient-side surgical robot has an arm to control the camera and two or three arms to hold the operating instruments. These instruments are articulated at the wrist and have seven degrees of freedom and two degrees of axial rotation. This master–slave robotic system overcomes many of the limitations of conventional laparoscopy. It provides the surgeon with 3D 10× magnified vision, wristed instrumentation, tremor filtration, and motion scaling. The system produces an *immersive telerobotic environment* ideally suited for surgical precision and reconstructive applications.

Evolution of Minimally Invasive Laparoscopic Prostatectomy

Data from the Surveillance, Epidemiology, and End Results (SEER) registry indicate that the incidence of prostate cancer in men under 50 years of age has risen over the past 10 years, with an annual increase of 9.5%.[8] Prostate cancer accounts today for nearly 33% of all newly diagnosed cancers in men.[9] For patients with prostate confined disease, a number of treatment alternatives are now available. However, radical prostatectomy (RP) remains the gold standard for long-term cure.[10] Since its first description in 1905 by Young, RP procedure has been associated with significant perioperative morbidity, including excessive blood loss, urinary incontinence, and impotency.[11] In the late 1970s and early 1980s, several detailed anatomic studies provided important insights into the periprostatic anatomy, especially that of the dorsal venous complex,[12] neurovascular bundle,[13] and striated urethral sphincter.[14] These observations allowed the development of an anatomic approach to radical prostatectomy with significant reduction in operative morbidity.

With the increasing use of screening for prostate cancer detection, younger and healthier men are presently being diagnosed with the condition. These patients desire treatments that not only provide good oncological and functional outcomes but also treatments that can also be performed in a minimally invasive nature with short hospitalization times and minimal convalescence. In an effort to further decrease the morbidity of open radical prostatectomy, a minimally invasive surgical approach was first described by Schuessler and colleagues in 1997.[15] These authors performed the first successful laparoscopic radical prostatectomy (LRP). With their initial experience, the authors noted the challenging nature of the operation with long operative times and hospital stays. The operation was advanced in the late 1990s, as European surgeons tackled the difficult learning curve and reported feasibility with results comparable with the open surgical approach.[16–18] Despite this, the technical demands of the surgery and the protracted learning curve has prevented the widespread adoption of LRP by most urologic surgeons.

The recent introduction of advanced robotic devices such as the da Vinci Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA) has simplified complex laparoscopic procedures and added new hopes of reducing operative times and the learning curve for a minimally invasive approach to radical prostatectomy.[19] Robotically assisted laparoscopic radical prostatectomy (RALP) offers the additional advantages of 10× magnified three-dimensional visualization, motion scaling with tremor filtration, improved surgical ergonomics and miniature wristed, articulating instruments with 7-degrees of freedom. The surgeon can dissect with improved operative precision and robotic technology greatly simplifies the reconstructive element of the procedure. The first robotic prostatectomy was performed in 2000 by Binder and Kramer in Germany.[20] Subsequently, the procedure has undergone significant innovation and improvement. Menon, Guillonneau, and Vallancien refined the technique at Henry Ford Hospital later in the same year and its growth has been exponential since then.[21]

Robotic-Assisted Laparoscopic Radical Prostatectomy (RALP)

Indications

The indications for RALP are identical to that for open surgery. Patients with clinical stage T2 or less prostate cancer with no evidence of metastasis, either clinically or radiographically, are candidates for RALP. Absolute contraindications include uncorrectable bleeding diatheses, increased intracranial pressure, or the inability to undergo general anesthesia due to severe cardiopulmonary compromise.

Some predictable situations provide a technical challenge to the entire robotic operative team. Though these scenarios certainly are not contraindications, they should be avoided by inexperienced teams during their initial experience with the procedure. These scenarios include patients with: prior major abdominal or pelvic surgery, morbid obesity, large prostate size, prior TURP, presence of a median lobe, prior pelvic irradiation, neoadjuvant hormonal therapy, or a history of prostatitis. As the experience of the robotic team increases, these challenging scenarios can be approached with more skill and confidence.

Table 1.1 Criteria for selection of ideal initial patients

Prostate size: 60 g
BMI < 30
No previous prostatic or abdominal surgery
Erectile dysfunction
Low-risk disease: PSA < 10 ng/mL, Gleason score <7, cT1 or T2a
No androgen ablation therapy or history of prostatitis

The ideal criteria for patient selection during the initial learning curve for RALP are shown in Table 1.1. From an oncological and functional viewpoint, patients with low-risk disease and erectile dysfunction are ideal. These characteristics reduce the risk of positive surgical margins and nerve sparing is a less important operative consideration. From a technical standpoint, patients with a BMI < 30, no prior abdominal surgery, prostate size < 60 g with no prior TURP, no median lobe, no prior androgen ablation, and no history of prostatitis is desirable. By eliminating these predictable challenges, the technical aspect of the operation is simplified. As experience is gained, these factors become less important considerations. This stepladder approach allows the surgeon to continually develop skills to deal with even the most challenging patients.

RALP and the "Learning Curve"

As robotic technology is introduced to surgery, there is a time period where surgeons develop the knowledge and skills required to utilize the technology with efficiency. This time is generally referred to as the learning curve and can be reduced by factors such as standardization of the surgical procedure, specialized resident or fellowship training, or case proctorship/mentorship. Initial reports on the learning curve for RALP suggested that approximately 20 cases were required for the surgeon to acquire basic proficiency at the procedure.[22–24] With increasing experience and standardization of the operation, it has become evident that far greater experience is required for the surgeon to be confident and provide good patient outcomes.[25]

Outcomes of RALP

Intraoperative Outcomes

Berryhill et al[26] reviewed the outcomes of radical prostatectomy via robotic, laparoscopic, and open approaches. Twenty-two robotic prostatectomy series were identified with pertinent reported outcomes. Many institutions were represented, including studies from Institute Mutualiste Montsouris (Paris, France), Goethe University of Frankfurt (Germany), Vattikuti Urology Institute (Detroit, Michigan), and University of California-Irvine. They found a mean operative time of 164 min (varying from 55 min to 13 h) for RALP. The mean EBL was 152 mL (range of means, 50–570 mL). The intraoperative and postoperative RALP transfusion rates were generally minimal, with a mean of 2.9% of cases requiring blood. This was compared favorably with LRP and open RP where mean EBL was 406 and 697 mL, respectively. The LRP studies reported a mean of 8.3% of cases requiring transfusion, while the open RP articles reported an even higher mean transfusion rate of 24%.

We reviewed our perioperative outcomes for fifteen hundred consecutive RALPs performed by a single surgeon (VRP).[27] Operative times fell with increasing experience of both the surgeon and team. While some of our initial cases were between 4 and 6 h, our operative times have averaged 105 min over the last 300 cases. Mean EBL was 111 mL (50–500) with no patient requiring intraoperative transfusion and 0.4% of patients receiving postoperative transfusion. Two rectal injuries occurred during the initial 25 cases that were recognized intraoperatively and repaired with no sequelae.

The comparative results for operative time and blood loss from some different robotic series are presented in Table 1.2.

Postoperative Complications

The same current review by Berryhill and colleagues reported a mean overall postoperative complication rate for RALP of 6.6%.[26] This is consistent with our findings where 63 of our first 1,500 patients (4.3%) suffered a perioperative complication.[27] As our experience progresses, we have observed a decreased trend in complications from 9.3% in the first 300 to 2.6% in the last 300 cases. In addition, more than half of the radiologically detected anastomotic leaks occurred during the first 300 patients. Though complications such as anastomotic leaks and rectal injury disappeared relatively early in our learning curve, occasional complications such as MI, DVT/PE, and postoperative bleed continue to occur sporadically at a low rate.

Oncological Outcomes

Given that the first RALP was performed in 2000, data regarding long-term cancer-specific survival will not be matured for some time. Likewise, evidence for biochemical recurrence free survival is also sparse. At present, positive surgical margin rates are being used as a surrogate marker to assess the oncological efficacy of RALP.

Table 1.2 RALP outcomes

Study (reference)	*N*	Age (year)	OR Time (minutes)	Mean EBL (mL)	Positive margin rate (%)			Continence outcomes		Potency outcomes			
					pT2	pT3	Overall	Time of assessment (months)	Continence rate (%)	Time of assessment (months)	BNS % intercourse	UNS % intercourse	Percentage of intercourse
Ahlering et al[28]	45	61.4 (46–71)	209 (150–600)	145 (25–350)	14.8	62.5	35.5	3	81	<12	33	0	33
Bentas et al[29]	40	61.3 (45–72)	500 (246–780)	570 (100–2,500)	8	67	30	3	84	12	–	–	21.1
Tewari et al[30]	200	59.9 (42–76)	160 (71–315)	153 (25–750)	–	–	6	6	96	<12	50	–	50
Wolfram et al[31]	81	62.9 (43–78)	250 (150–390)	300 (100–1,500)	12.7	42	22	–	–	–	–	–	–
Ahlering et al[32]	200	62.9 (43–78)	–	108 (25–400)	6.5	32	20.4	3	77	–	–	–	–
Ahlering et al[33]	109	56.1	–	92 (25–250)	–	–	13	–	–	<12	24.4	14.3	–
Chien et al[34]	56	58.9	356 (240–480)	356 (25–1,200)	–	–	10.7	–	–	12	35.7	40	40
Joseph et al[35]	50	59.6–1.6	202–38	206–63	–	–	12	3	90	<12	–	–	46
Menon et al[36]	1,142	60.2 (39–80)	154 (71–387)	142 (10–750)	–	–	13	12	95	12	97	74	–
Patel et al[37]	500	63.2	130 (51–330)	50 (10–300)	2.5	13.8	9.4	6	95	12	–	–	78
Tewari et al[38]	700	62.1			–	–	5,2	6	97	12	87	–	87
Badani et al[39]	2,766		154 (71–387)	142 (10–1,350)	13	35	12.3			12	79.2	–	79.2
Patel et al[27]	1,500	60.7	105	111	4	34	9.3	–	–	–	–	–	–

When stratified by pathological stage, positive margin rates following RALP range from 2.5 to 22% for pT2 and 13.5 to 67% for pT3 disease.[27–29,32,37,39] Only two prospective, nonrandomized comparative studies have compared robotic and open radical prostatectomy. They showed higher positive surgical margin rates in patients who had undergone open RP when compared with those treated with RALP.[30,39]

The overall positive margin rate for our first 1,500 cases was 9.3%.[27] When stratified for pathological stage, positive surgical margin rates were 4% for pT2, 34% for pT3, and 40% for pT4. The median Gleason score was 6 (range 5–10) and Gleason grade of 4, 5, 6, 7, 8, 9, and 10 was found in 0.69, 2.78, 62.36, 26.68, 5.18, 2.16, and 0.15% of prostate specimens. Pathologic stage was T2a, T2b, T2c, T3a, T3b, and T4 in 15, 3.07, 60.23, 13.76, 5.69, and 1.46%, respectively.

In Henry Ford's series of 2,766 patients, the positive margin rate for pT2 tumors declined from 7% in the first 200 cases to 4% in the last 200.[39] The pT3 positive margin rate for the overall cohort was 35%, and the overall positive margin rate was 13%.

The oncological results based on positive surgical margins for RALP are very encouraging. The centers experienced at this procedure are reporting results as good as the best published series for open RP (Table 1.2).

Functional Outcomes: Erectile Dysfunction

Mature data on erectile function after nerve-sparing RALP is presently limited. As more series mature in the near future, this information will be more abundant. Robotic-assisted surgery has the potential to improve nerve-sparing techniques during radical prostatectomy. Magnified stereoscopic vision, the relatively bloodless field provided by pneumoperitoneum, and the wristed instrumentation allow the surgeon to operate in a very precise manner during this intricate portion of the dissection. We find the benefits of robotic technology to be essential when performing our nerve preservation technique of "early retrograde release of the neurovascular bundles." Utilizing this approach for bilateral nerve sparing on 98 consecutive patients with a preoperative SHIM score ≥21, 87.7% were potent at 12 months follow-up with or without the use of oral PD5 inhibitors. Using the same technique on 48 men with mild erectile dysfunction preoperatively (SHIM 17–20), 73% of men were potent 12 months postoperatively.[40]

The available 12-months follow-up data suggest that between 20 and 97% of patients regain potency after nerve-sparing RALP.[26,29,36] Comparing postoperative potency rates between different centers and different techniques is quite difficult. Varying definitions of "potent" combined with several methods of data collection introduce the potential for significant variations in outcomes.

Menon and colleagues at the Vattikuti Institute in Detroit, recently reported potency results for their technique of lateral prostatic fascia-sparing (Veil of Aphrodite) RALP.[39] Erectile function was measured with the SHIM questionnaire. Complete follow-up erectile function data were available for 910 patients. Preoperative SHIM scores were >17 in 721 of 910 patients. Of these, 79.2% reported successful sexual intercourse postoperatively (defined as a SHIM score of at least 2 on the second question of the SHIM questionnaire: "When you had erections with sexual stimulation, how often were your erections hard enough for penetration?"). Phosphodiesterase-5 inhibitors (PDE5) were used in 44.2% of patients.

With regard to surgical technique, Ahlering et al demonstrated in a prospective, nonrandomized, comparative study that the adoption of a cautery-free technique for preservation of the neurovascular bundles produced a significantly higher potency rate 3 months postoperatively than the then standard bipolar cautery technique.[33] Erectile function was assessed through self-administered questionnaires and defined as erections sufficient for vaginal penetration with or without PDE-5 inhibitors. After 3 months of follow-up, 43% of men in the cautery-free group were potent when compared with 8.3% of the control group. At present, leading centers control the prostatic pedicle and perform nerve sparing without the use of any cautery.

According to the nonrandomized, comparative study of Tewari and colleagues,[30] RALP could allow better and earlier potency recovery when compared with open RP. These authors reported a prospective comparison between 100 open RPs and 200 RALPs. They demonstrated a more rapid return of erections with RALP (50% at a mean follow-up of 180 days vs. 50% at a mean of 440 days after open RP) as well as a quicker return to intercourse with RALP (50% at 340 days vs. 50% at 700 days for open RP).

The potency rates in various RALP series are shown in Table 1.2.

Functional Outcomes: Urinary Incontinence

As for erectile function, direct comparisons for urinary continence between different prostatectomy series are difficult due to variations in definitions, data collection methods, and length of follow-up. Despite these difficulties, current literature suggests both a quicker return to urinary continence as well as slightly improved overall continence rate with RALP when compared with both open RP and LRP.

In our earlier series of 500 patients, we reported continence rates of 89, 95, and 97% at 3, 6, and 12 months postoperatively.[37] Continence was defined as the use of no absorbent pads. Twenty-seven percent of these patients were continent immediately after catheter removal. The improved visualization of robotics aids in preserving the urethral sphincter and functional urethral length during the apical dissection of RALP. We feel that these factors along with the addition of some key technical refinements (described subsequently) are of utmost importance to the early return of urinary continence for patients postoperatively.

Menon and colleagues evaluated the continence rates in 1,100 patients who had a minimum of 1 year of follow-up after RALP.[39] Continence was defined as "no pads or a single pad for security purposes only and failure to leak urine on provocative maneuvers." They reported a 93% continence rate at 12 months following lateral prostatic fascia-sparing RALP and 23.7% of these men reported having complete urinary control immediately at the time of catheter removal (0 pads). The median time to complete urinary control was 3 weeks (range, 0–120 weeks). When stratifying patients according to the year of surgery, they found that those patients operated on in 2001 and 2002 had a longer median time to continence (on average, 5 weeks), whereas no difference was demonstrated in those operated on in 2003–2005 (on average, <3 weeks). The authors concluded that the impact of experience and learning curve resulted in reproducibility of return to continence.

Tewari and coworkers recently reported continence rates for 182 patients treated with RALP and their technique of total reconstruction of the vesico-urethral junction.[38] Continence was defined as no pad usage or one small liner used for security purposes only. Postoperative continence rates of 38, 83, 91, and 97% were found at 1, 6, 12, and 24 weeks, respectively.

The continence rates in various RALP series are shown in Table 1.2.

Fig. 1.2 Early retrograde release of the neurovascular bundle. The interfascial plane is developed between the neurovascular bundle laterally and the prostatic fascia medially. The bundle is stabilized with the PK dissector in the left hand, while the prostate is swept medially off the bundle with the monopolar scissors. Reprinted from Coughlin et al[41] with permission from Springer

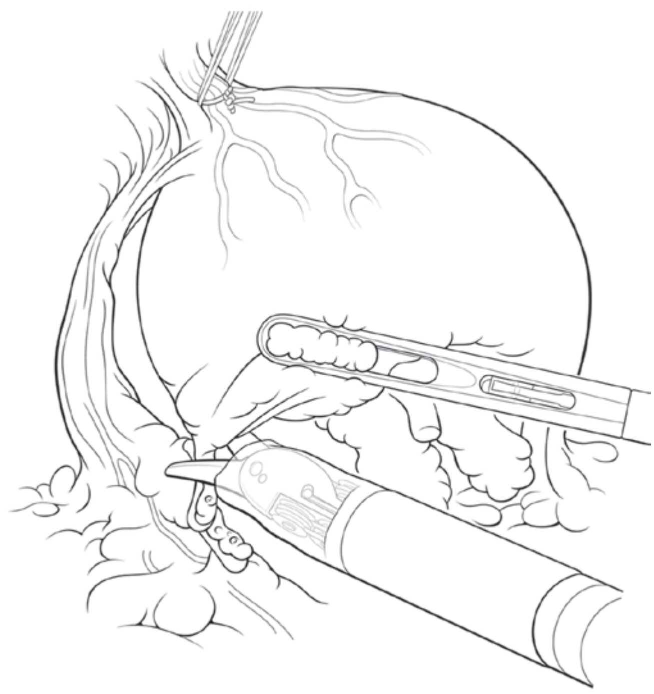

Fig. 1.3 Early retrograde release of the neurovascular bundle. The vascular pedicle is ligated with a hemolock clip. The clip is placed above the path of the neurovascular bundle. Releasing the bundle early and delineating its path avoids inadvertent damage to it at this point. Reprinted from Coughlin et al[41] with permission from Springer

Technical Refinements to Improve Early Postoperative Functional Outcomes

Our experience with RALP is now over 2,300 cases. Throughout this experience, we have continuously modified our technique in a quest to improve surgical outcomes. Here, we describe two of the refinements in our surgical technique, which we feel have had the greatest impact on the early functional outcomes following RALP.

Athermal Early Retrograde Release of the Neurovascular Bundle

Our approach to RALP is the traditional antegrade transperitoneal technique.[26] One significant refinement in our approach, however, has been to release the neurovascular bundles in a retrograde direction prior to control and division of the prostatic pedicles. This technique is a hybrid of both the traditional open and laparoscopic approaches to nerve sparing. After dividing the bladder neck and completing the posterior dissection, we incise the levator fascia along the length of the prostate. Using gentle blunt dissection, we develop the interfascial plane for nerve sparing and release the neurovascular bundle from the posterolateral surface of the prostate (Fig. 1.2). This approach allows us to clearly delineate the path of the neurovascular bundle prior to the placement of hemolock clips on the prostatic pedicles (Fig. 1.3). We are therefore able to avoid inadvertent injury to the cavernous nerves at this point of the dissection.

Modified Posterior Reconstruction of the Rhabdosphincter

Temporary urinary incontinence after radical prostatectomy for prostate cancer remains a disadvantage of surgical treatment. Though long-term continence rates after radical prostatectomy are excellent, the time it takes to regain continence has a significant impact on the patient's quality of life in the initial postoperative period. Several technical modifications have been proposed to promote an earlier return of continence, including bladder-neck sparing, preservation of the puboprostatic ligaments, intussusception of the reconstructed bladder neck, and posterior reconstruction of the rhabdosphincter.[38]

Posterior reconstruction of the rhabdosphincter was initially described in 2001, by Rocco and colleagues, and consisted of a two-layered reconstruction with apposition of the free edge of Denovilliers' fascia and the posterior bladder with the posterior aspect of the rhabdosphincter and posterior median raphe.[42] The technique provides posterior support for the sphincteric mechanism and also draws the bladder caudally into a supported position, taking all tension of the vesicourethral anastomosis. The same authors reported significantly quicker times to recovery of urinary continence following open radical prostatectomy using this technique.[43]

The benefits of robotic technology are ideally suited for such precise suturing in the confines of the male pelvis. We adopted and modified this technique for use in RALP. The principles are consistent with the two-layer reconstruction originally described by Rocco with some minor technical modifications. The reconstruction is performed utilizing a continuous suture of two 3–0 monocryl sutures (RB1 needles) of different colors that are tied together with each individual length being 12 cm. The free edge of the remaining Denovilliers' fascia is identified following prostatectomy. This edge is approximated to the posterior aspect of the rhabdosphincter with a running suture using one arm of the continuous monocryl suture. Typically, four bites of Denovilliers' fascia and the rhabdosphincter/posterior median raphe are taken and the edges are approximated. The second layer of the reconstruction is then commenced with the other arm of the monocryl suture. This layer approximates the posterior bladder (2 cm posterosuperior to the bladder neck) to the initial reconstructed layer of posterior rhabdosphincter and Denovilliers' fascia. A continuous modified Van Velthoven vesicourethral anastomosis[44] is then performed with a running suture.

Our initial pilot study using this technique revealed a complete "early continence" rate (no pads) of 58% at 1 week postoperatively. If the definition of continent is broadened to also include mild urinary incontinence (0 or 1 pad per day), the rate was 72%.[45] Other authors have also demonstrated improvements in early postoperative continence rates following LRP and RALP utilizing a similar reconstruction.[46,47]

Conclusion

Since the first RALP was performed in 2000, the operation has undergone significant standardization and modification. The use of this operation has increased exponentially in the United States and a similar pattern is likely to be seen in other continents. Today, RALP offers men a minimally invasive approach to radical prostatectomy with good oncological and functional outcomes. Owing to refinements in technique, the majority of patients will experience a quick return to normal daily activities with minimal impact on their health-related quality of life.

References

1. Capek K. *Rossum's universal srobots* [Playfair N, Selver P, trans. Landes WA, ed]. New York: Doubleday; 1923
2. Kwoh YS, Hou J, Jonckheere EA, Hayati S. A robot with improved absolute positioning accuracy for CT guided stereotactic brain surgery. *IEEE Trans Biomed Eng*. 1988;35:153–160
3. Davies B. A review of robotics in surgery. *Proc Inst Mech Eng*. 2000;214:129–140
4. Davies BL, Hibberd RD, Coptcoat MJ, Wickman JEA. A surgeon robot prostatectomy – a laboratory evaluation. *J Med Eng Technol*. 1989;13:273–277
5. Bann S, Khan M, Hernandez J, et al Robotics in surgery. *J Am Coll Surg*. 2003;196:784–795
6. Bauer A, Borner M, Lahmer A. Clinical experience with a medical robotic system for total hip replacement. In: Nolte LP, Ganz R, eds. *Computer Assisted Orthopedic Surgery*. Bern, Switzerland: Hogrefe & Huber; 1999:128–133
7. Satava RM. Robotic surgery: from past to future – a personal journey. *Surg Clin North Am*. 2003;83:1–6
8. Surveillance, Epidemiology, and End Results (SEER) Program (www.seer.cancer.gov). *SEER*Stat Database: incidence – SEER 9 Regs Public-Use, Nov 2004 Sub (1973–2002)*. National Cancer Institute, DCCPS, Surveillance Research Program, Cancer Statistics Branch, released April 2005, based on the November 2004 submission
9. Meng MV, Elkin EP, et al Predictors of treatment after initial surveillance in men with prostate cancer: results from CaPSURE. *J Urol*. 2003;170(6 Pt 1):2279–2283

10. Myers RP. Radical prostatectomy: making it a better operation in the new millennium. *Int J Urol*. 2001;8(7):S9–S14
11. Young HH. The early diagnosis and radical cure of carcinoma of the prostate. Being a study of 40 cases and presentation of a radical operation which was carried out in four cases. 1905 *J Urol*. 2002; 168(3):914–921
12. Reiner WB, Walsh PC. An anatomical approach to the surgical management of the dorsal vein and Santorini's plexus during radical retropubic surgery. *J Urol*. 1979;121:198–200
13. Walsh PC, Donker PJ. Impotence following radical prostatectomy: insight into etiology and prevention. *J Urol*. 1982;128:492–497
14. Oelrich TM. The urethral sphincter muscle in the male. *Am J Anat*. 1980;158:229–296
15. Schuessler WW, Schulam PG, Clayman RV, Kavoussi LR. Laparoscopic radical prostatectomy: Initial short-term experience. *Urology*. 1997;50:854–857
16. Guillonneau B, Vallancien G. Laparoscopic radical prostatectomy: the Montsouris experience. *J Urol*. 2000;163:418–422
17. Rassweiler J, Sentker L, Seemann O, et al Laparoscopic radical prostatectomy with the Heilbronn technique: an analysis of the first 180 cases. *J Urol*. 2001;166:2101–2108
18. Eden CG, Cahill D, Vass JA, et al Laparoscopic radical prostatectomy: the initial UK series. *BJU Int*. 2002;90:876–882
19. Menon M, Tewari A, Baize B, et al Prospective comparison of radical retropubic prostatectomy and robot-assisted anatomic prostatectomy: the Vattikuti Urology Institute experience. *Urology*. 2002; 60:864–868
20. Binder J, Kramer W. Robotically-assisted laparoscopic radical prostatectomy. *BJU Int*. 2001;87(4):408–410
21. Pasticier G, Rietbergen JBW, Guillonneau B, Fromont G, Menon M, Vallancien G. Robotically assisted laparoscopic radical prostatectomy: feasibility study in men. *Eur Urol*. 2001;40:70–74
22. Menon M, Shrivastava A, Tewari A, et al Laparoscopic and robot assisted radical prostatectomy: establishment of a structured program and preliminary analysis of outcomes. *J Urol*. 2002;168(3): 945–949
23. Ahlering TE, Skarecky D, Lee D, et al Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: Initial experience with laparoscopic radical prostatectomy. *J Urol*. 2003;170:1738–1741
24. Bhandari A, Peabody JO, et al Does surgical robot assist in safe learning of laparoscopic radical prostatectomy? AUA Abstract [presented 05/10/04]
25. Hugh JL, Thaly R, Shah K, Patel V. The advanced learning curve in robotic prostatectomy: a multi-institutional survey. AUA abstract [presented 05/20/07]
26. Berryhill R Jr, Jhaveri J, Yadav R, et al Robotic prostatectomy: a review of outcomes compared with laparoscopic and open approaches. *Urology*. 2008;72(1):15–23
27. Patel VR, Palmer KJ, Coughlin G, Samavedi S. Robotic-assisted laparoscopic radical prostatectomy: perioperative outcomes of 1500 cases. *J Endourol*. 2008;22(10):1–7
28. Ahlering TE, Skarecky D, Lee D, et al Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy. *J Urol*. 2003;170:1738–1741
29. Bentas W, Wolfram M, Jones J, et al Robotic technology and the translation of open radical prostatectomy to laparoscopy: the early Frankfurt experience with robotic radical prostatectomy and one year follow-up. *Eur Urol*. 2003;44:175–181
30. Tewari A, Srivasatava A, Menon M, et al A prospective comparison of radical retropubic and robot-assisted prostatectomy: experience in one institution. *BJU Int*. 2003;92:205–210
31. Wolfram M, Brautigam R, Engl T, et al Robotic-assisted laparoscopic radical prostatectomy: the Frankfurt technique. *World J Urol*. 2003;21:128–132
32. Ahlering TE, Woo D, Eichel L, Lee DI, Edwards R, Skarecky DW. Robot-assisted versus open radical prostatectomy: a comparison of one surgeon's outcomes. *Urology*. 2004;63:819–822
33. Ahlering TE, Eichel L, Skarecky D. Rapid communication: early potency outcomes with cautery-free neurovascular bundle preservation with robotic laparoscopic radical prostatectomy. *J Endourol*. 2005;19:715–718
34. Chien GW, Mikhail AA, Orvieto MA, et al Modified clipless antegrade nerve preservation in robotic-assisted laparoscopic radical prostatectomy with validated sexual function evaluation. *Urology*. 2005;66:419–423
35. Joseph JV, Vicente I, Madeb R, et al Robot-assisted vs pure laparoscopic radical prostatectomy: are there any differences? *BJU Int*. 2005;96:39–42
36. Menon M, Kaul S, Bhandari A, et al Potency following robotic radical prostatectomy: a questionnaire based analysis of outcomes after conventional nerve sparing and prostatic fascia sparing techniques. *J Urol*. 2005;174:2291–2296
37. Patel VR, Thaly R, Shah K. Robotic radical prostatectomy: outcomes of 500 cases. *BJU Int*. 2007;9(9):1109–1112
38. Tewari A, Jhaveri J, Rao S, et al Total reconstruction of vesicourethral junction. *BJU Int*. 2008;101:871–877
39. Badani KK, Kaul S, Menon M. Evolution of robotic radical prostatectomy assessment after 2766 procedures. *Cancer*. 2007;110(9): 1951–1958
40. Shah K, Palmer KJ, Coughlin G, Patel VR. Early retrograde release of the neurovascular bundle during robotic-assisted laparoscopic radical prostatectomy. *J Endourol*. 2007;21(suppl 1):27
41. Coughlin G, Dangle P, Palmer K, et al Athermal early retrograde release of the neurovascular bundle during nerve sparing robotic assisted laparoscopic radical prostatectomy. *J Robotic Surg*. 2009 Mar;3(1)
42. Rocco F, Gadda F, Acquati P, et al Personal research: reconstruction of the urethral striated sphincter. *Arch Ital Urol Androl*. 2001;73: 127–37
43. Rocco F, Carmignani L, Acquati P, et al Early continence recovery after open radical prostatectomy with restoration of the posterior aspect of the rhabdosphincter. *Eur Urol*. 2007;52:376–83
44. Van Velthoven RF, Ahlering TE, Peltier A, Skarecky DW, Clayman RV. Technique for laparoscopic running urethrovesical anastomosis: the single knot method. *Urology*. 2003;61(4):699–702
45. Coughlin G, Dangle P, Patil N, et al Modified posterior reconstruction of the rhabdosphincter: application to robotic assisted laparoscopic prostatectomy. *BJU Int* 2008 Nov;102(10):1482–5
46. Rocco B, Gregori A, Stener S, et al Posterior reconstruction of the rhabdosphincter allows a rapid recovery of continence after transperitoneal videolaparoscopic radical prostatectomy. *Eur Urol*. 2007;51:996–1003
47. Nguyen MM, Kamoi K, Stein RJ, et al Early continence outcomes of posterior musculofascial plate reconstruction during robotic and laparoscopic prostatectomy. *BJU Int*. 2008;101:1135–1139