Eddie Shu-yin Chan
Tadashi Matsuda
Editors

Endourology Progress

Technique, Technology and Training

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Editors
Eddie Shu-yin Chan
Department of Surgery
The Chinese University of Hong Kong
Hong Kong

Tadashi Matsuda
Department of Urology and Andrology
Kansai Medical University
Hirakata, Osaka
Japan

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Foreword 1

Urology has the most innovative advances among the surgical specialties. Recent technology started with shockwave lithotripsy in 1979 followed by percutaneous lithotripsy in the 1980s. Lithotripters were installed worldwide and have revolutionized the treatment of stones from incisions to "no scars." The last decade has seen an accelerated technological journey including laparoscopic instruments, robotic equipment, and endoscopes with video cameras that can be made so small as to get retrograde access to the kidney, which was only imaginable in the movies of the 1970s.

With these advances it is a constant learning and upgrading process for urologists to keep pace with new techniques. Among the many endoscopes and types of lasers we have to find out which is the most effective, appropriate, and safe for our patients. We adopt some and discard those that are not effective. It is almost impossible for a single urologist to go into all the new equipment. We need to attend meetings, talk to the experienced, and then adopt which is the best for our patients bounded by the availability of resources in our health care systems.

This book is unique because it is Asian and represents the diverse cultures and the progress made in countries with health care systems of different priorities. Illustrations are clear and readers get to pick up the procedures step-by-step such as in robotic surgery. Tips and tricks are helpful. Further dedicated structured training is important to ensure we are able to handle the new technology. Further experience should be obtained by assisting the masters at work.

Eddie Chan and Tadashi Matsuda, the editors of ***Endourology Progress: Technique, Technology and Training***, should be congratulated for this innovative book. This book is a comprehensive introduction for residents and trained urologists to pick up some new knowledge and techniques.

It is my wish that this book will enable all urologists to offer our patients the most effective treatment in the era of modern endourological technology.

January 2019

Man Kay Li
Mt Elizabeth Novena Hospital
Singapore
Singapore

Foreword 2

It is a privilege to write a Foreword for this outstanding book entitled *Endourology Progress: Technique, Technology and Training* which is focused on all aspects of minimally invasive urology. The book is unique in its East Asian origins and with over 100 contributors, all of whom are from East Asian countries.

The opening chapter by Drs. Matsuda and Naito, which archives the history and development of endourology in East Asia, is a wonderful chronicle of the overall impact this urologic community has had towards progress in the field. The mission of the East Asian Society of Endourology is articulated "to study all questions related to endourology, to stimulate international cooperation in the field of urology and to encourage the development, evaluation and application of all aspects of minimally invasive therapy of urological disease across the East Asia region." There may be no better tangible example of the success in achieving this aspiration than the superb text *Endourology Progress: Technique, Technology and Training*.

The book is both comprehensive in its scope and current in all aspects of endourology, laparoscopy, robotics, and image-guided therapies in urology. Books can often lag in a field that is progressing as rapidly as endourology, but this comprehensive text manages to be completely up to date. This includes detailed descriptions of leading edge interventions in areas as diverse as pediatrics, transplantation, BPH, and MRI-guided diagnostics. The tables, illustrations, and figures in the book are excellent and the chapters are all very well referenced. As an academic urologist with a subspecialty interest in endourology I fully expect to be referring to this book, both for patient care questions and for purposes related to teaching students, residents, and fellows. Practicing urologists, trainees, and investigators with an interest in urologic technology and innovation will all find this to be a very practical and useful text.

I have had the privilege of visiting almost all of the countries classified as being in East Asia and in the case of some countries have visited on numerous occasions. This has often included the experience of operating side by side with the local urologic surgeons, many of whom have become good friends. It is my impression that many of the innovations and technical advances in endourology and minimally invasive approaches are emanating from the major centers in East Asian countries. In addition, I have witnessed the great value placed on training in this world region and the chapters in *Endourology Progress* focused on various aspects of training are among the best I have come across.

The editors, Drs. Eddie Chan and Tadashi Matsuda, along with all of the contributing chapter authors are to be congratulated for the production of this tremendous text. *Endourology Progress: Technique, Technology and Training* is an excellent contribution to existing resources in the rapidly changing field of endourology.

John Denstedt
Division of Urology, Schulich School of Medicine and Dentistry,
Western University, London, ON, Canada

American Urological Association,
Linthicum, MD, USA

Introduction

This book represents the work and development of endourology in Asia and the contribution of East Asian Society of Endourology. The horizons of endourologic surgery are expanding. Application of robot-assisted technique is one of the many examples of how new technologies change the surgical practice. Urologists from Asian countries encountered a lot of challenges due to high patient load, different diseases preference, limited access to new technologies, diversity in languages, and surgical practice. Innovative techniques have been developed in order to adapt the unique working environment. This book is intended to familiarize the modern urologists with the common endourology, laparoscopic and robotic urologic procedures, and the development of technology, techniques, and training in Asian countries.

On behalf of the East Asian Society of Endourology, recognized Asian experts in the field of endourology have contributed to share their experiences and opinions. It consisted of latest update and advancement of surgical techniques and technology in minimally invasive surgery. The development of endoscopic, laparoscopic, and robotic urological operations is reviewed. A whole session dedicated to training in endourology is included. Detailed descriptions of perioperative preparation, step-by-step surgical procedures, and tips/tricks will be emphasized in the corresponding chapters, supplemented by photographs and illustrations. The textbook will be divided into three specific sessions. The first session covers the important areas of endourology training and the development of endourology in different Asian countries. In the second session, techniques on various urologic surgeries are discussed. The third session is dedicated to the advances of new technologies in endourology. This book is most suitable for urology residents and young fellows who are keen to start their endourological training. It also provides up-to-date information on current topics of endourology for practicing urologists and experienced endourologists in Asian and other countries.

This book is contributed by more than 100 leading experts and their young fellows from China, Japan, Korea, the Philippines, Taiwan, and Hong Kong.

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Part I

Endourology Training

1

Introduction of East Asian Society of Endourology and Development of Endourology in East Asia

Tadashi Matsuda and Seiji Naito

Abstract

The East Asian Society of Endourology (EASE) was established in 2003 to promote advances in minimally invasive urological surgery in East Asia, to educate young endourologists of the member territories and to cultivate and cement friendship among endourologists from member territories including Japan, Korea, Taiwan, China, and Hong Kong. The Philippines subsequently became a member in 2007 and the annual meeting of EASE has been held in one of these territories on a rotational basis. This book was planned and published as one of the activities of EASE. Thanks to innovations in endoscopic technology and surgical technique, together with the activities of the relevant associations and societies in the EASE territories, a variety of endourological, laparoscopic and robotic procedures have been widely disseminated to minimize invasiveness and enhance effectiveness of urological treatments.

Keywords

East Asia · Endourology · Laparoscopy

1.1 Introduction to the East Asian Society of Endourology (EASE)

1.1.1 History of EASE

The Yamanouchi International Symposium was held in conjunction with the Japanese Society of Endourology and ESWL annual congress from 2001. Here, endourologists from East Asian territories gathered to discuss recent advances in endourology in East Asia. On November 19th, 2003 in Fukuoka, Japan, the leaders of endourology from Japan, Korea, China, Taiwan, and Hong Kong met and decided to establish EASE as the progression of this symposium. The following doctors gathered as the representatives of endourologists from each country/region:

- Japan: Dr. Eiji Higashihara, Kyorin University, Dr. Shiro Baba, Kitasato University, Drs. Shinichi Oshima and Yoshinari Ono, Nagoya University
- Korea: Dr. Tchun Yong Lee, Hanyang University, and Dr. Tae-Kon Hwang, the Catholic University of Korea
- China: Dr. Li-Qun Zhou, Peking University
- Taiwan: Dr. Jun Chen, National Taiwan University
- Hong Kong: Dr. Shu-Keung Li

The first EASE annual congress was held on November 19th, 2004 in Okayama under the presidency of Dr. Eiji Higashihara, Kyorin University, Japan, in conjunction with the 18th Congress of the Japanese Society of Endourology and ESWL.

At the Board of Directors (BOD) meeting of EASE held on December 13th, 2007 in Hong Kong, it was decided that the Philippines would join EASE and that the Annual Congress of 2009 would be held in Manila.

1.1.2 Activities of EASE

According to the by-laws, the mission of EASE is to study all questions relating to endourology, to stimulate international co-operation in the field of urology and to encourage the development, evaluation and application of all aspects of minimally invasive therapies of urological disease across the East-Asian region.

The annual congress of EASE has been held every year since 2004, to enable through international co-operation in education and research, all EASE territories to achieve the highest quality of urological patient care (Table 1.1).

T. Matsuda (✉)
Department of Urology and Andrology,
Kansai Medical University, Osaka, Japan
e-mail: matsudat@takii.kmu.ac.jp

S. Naito
Hara-Sanshin Hospital, Fukuoka, Japan

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Table 1.1 Annual Congress of East Asian Society of Endourology

	Year	City	Country/region	President
1st	2004	Okayama	Japan	Eiji Higashihara
2nd	2005	Jeju Island	Korea	Tae Kon Hwang
3rd	2006	Taipei	Taiwan	Jun Chen
4th	2007	Hong Kong	Hong Kong	Shu-Keung Li
5th	2008	Shanghai	China	Liqun Zhou
6th	2009	Manila	Philippine	Joel P. Aldana
7th	2010	Seoul	Korea	Hyeon Hoe Kim
8th	2011	Kyoto	Japan	Seiji Naito
9th	2012	Taipei	Taiwan	Allen Chiu
10th	2013	Hefei	China	Yinghao Sun
11th	2014	Hong Kong	Hong Kong	Berry Fung
12th	2015	Manila	Philippine	Joel P. Aldana
13th	2016	Osaka	Japan	Toshiro Terachi
14th	2017	Hong Kong	Hong Kong	Eddie Chan

Table 1.2 Global-scale Congress of Endourology held in EASE countries/region

Year	Name of congress	Country	President
1989	Seventh World Congress of Endourology and SWL	Kyoto, Japan	Osamu Yoshida
1991	Third World Congress on Videourology	Hakone, Japan	Hiroshi Tazaki
1995	Seventh World Congress on Videourology	Taipei, Taiwan	Luke S. Chang
2003	15th World Congress on Videourology	Busan, Korea	Hwang Choi, Jin Han Yoon, Gyung Tak Sung
2008	26th World Congress of Endourology and SWL	Shanghai, China	Yinghao Sun
2011	29th World Congress of Endourology and SWL	Kyoto, Japan	Tadashi Matsuda
2012	23rd World Congress on Videourology	Hong Kong	Sidney KH Yip
2014	32th World Congress of Endourology and SWL	Taipei, Taiwan	Allen Chiu

EASE published the proceedings of the annual congress as its official journal named Recent Advances of Endourology from 2005 to 2012. As the progression from Recent Advances of Endourology, EASE has published this textbook of endourology, Endourology Progress—Technique, Technology and Training.

Since the establishment of EASE, the World Congress of Endourology and the World Congress of Videourology has been held in EASE territories as shown in Table 1.2 thanks to the support of the other EASE members. EASE has had close communication with the Urological Association of Asia and the Asian Society of Endourology, and some EASE congresses have been held in conjunction with these bodies.

1.1.3 Future of EASE

Since its establishment in 2004, EASE has played important roles in promoting advances in minimally invasive urology in East Asia, educating young endourologists of the member territories and cultivating and cementing friendship among endourologists in the region. The activities of EASE have become well-known throughout the global endourology community. At the 2016 BOD meeting in Osaka, the BOD members agreed that EASE would continue holding annual congresses in the 2020s and pursue new and diverse activities such as the publishing of this textbook.

1.2 Development of Endourology in East Asia

1.2.1 Endourological Societies of East Asian Countries

Endourologists in East Asian countries meet at their respective national endourological society or endourological branch or subgroup of their respective national urological association. The year of establishment and the number of members of each national endourological society are shown in Table 1.3. These societies and subgroups have played a major role in the development and dissemination of minimally invasive endourological procedures in each country together with their respective national urological associations.

1.2.2 Advancement of Endourology in East Asia

Due to the development of endourological instruments such as the Stern-McCarthy resectoscope in 1931, electrohydraulic lithotripter in 1950, endoscopes equipped with rod lens and fiber-optic light cable system around 1960, and ultrasonic lithotripter in 1973, a variety of endourological procedures including TURP, TUL and PCNL have

Table 1.3 Endourological societies of EASE territories

Country	Name of the society/group	Establishment year	No. of members
China	The Endourological Branch of Chinese Urological association	1993	
Hong Kong	Hong Kong Endourological Society	2006	252
Japan	Japanese Society of Endourology	1987	3969
Korea	Korean Endourological Society	1992	750
Philippine	Philippine Endourological Society	2009	41
Taiwan	Taiwan Urological Association	1978[a]	938[a]

[a] Data on the Urological Association, not the Endourological Group

Table 1.4 Year of start of endourological procedures in EASE territories

Country	TURP	PCNL	TUL	SWL	Lap. nephrectomy	Lap. prostatectomy
China	1980	1985	1986	1984	1992	2000
Hong Kong		1984		1985	1996	2002
Japan	1960s	1982	1984	1984	1991	1999
Korea	1977	1984	1984	1987	1996	2002
Philippine	1969	1985	2004	1996	2001	2004
Taiwan		1984	1984	1985	1992	

been developed and used around the world (Miki and Aizawa 2009; Higashihara 2012). The year of introduction of these procedures in East Asian territories is shown in Table 1.4.

As for the endoscopic surgery for benign prostate hypertrophy, enucleation of prostate hypertrophy was first performed by Hiraoka and Akimoto (1989) in Japan using a mechanical instrument, which was the precursor of the Holnium laser or bipolar electronic enucleation of the prostate.

A flexible ureteroscope was first developed by Takayasu and Aso in 1971 in collaboration with Olympus in Japan (Takayasu et al. 1971) and the world's first TUL was performed by Pretz-Castro in 1980 using a Storz rigid ureteroscope (Pérez-Castro Ellendt and Martínez-Piñeiro 1982). Rigid ureteroscopes were launched by Storz, Wolf and Olympus in 1980, 1982 and 1984 respectively. Flexible ureteroscopes were launched by Storz in 1976 and by Olympus in 1986. Shock wave lithotripsy (SWL), first developed by Chaussy et al. in 1980 (Higashihara 2012; Chaussy et al. 1982), spread rapidly in East Asian countries. The current number of SWL machines is 911, 726, 12 and 50 in Japan, Korea, Hong Kong and the Philippines, respectively. Furthermore, in Korea and Hong Kong, the number of SWL procedures performed annually was more than 175,000 and 1300, respectively.

Thanks to improvements in endoscopes or SWL machines and in surgical technique, the treatment strategy for urolithiasis has dramatically shifted from open surgery to endoscopic and shock wave treatments in East Asian countries. The transition of treatment modalities for urolithiasis in Japan during the past 40 years is shown in Fig. 1.1 according to the nation-wide surveys performed every 5–10 years since 1965 (Terai and Yoshida 2001; Yasui et al. 2008). The number of PCNL and TUL in Korea are increasing as shown in Fig. 1.2a, b, respectively.

1.2.3 Development of Laparoscopic Surgery in East Asia

The first urologic laparoscopic surgery in East Asian countries as a disease treatment was a laparoscopic varicocelectomy in 1990 (Matsuda et al. 1992). The world's first laparoscopic adrenalectomy was performed in February of

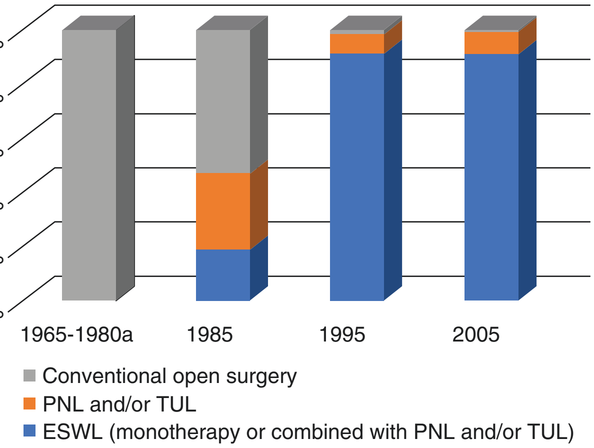

Fig. 1.1 The transition of treatment modalities for urolithiasis in Japan during the past 40 years according to the nation-wide surveys performed every 5–10 years since 1965 (Terai and Yoshida 2001; Yasui et al. 2008)

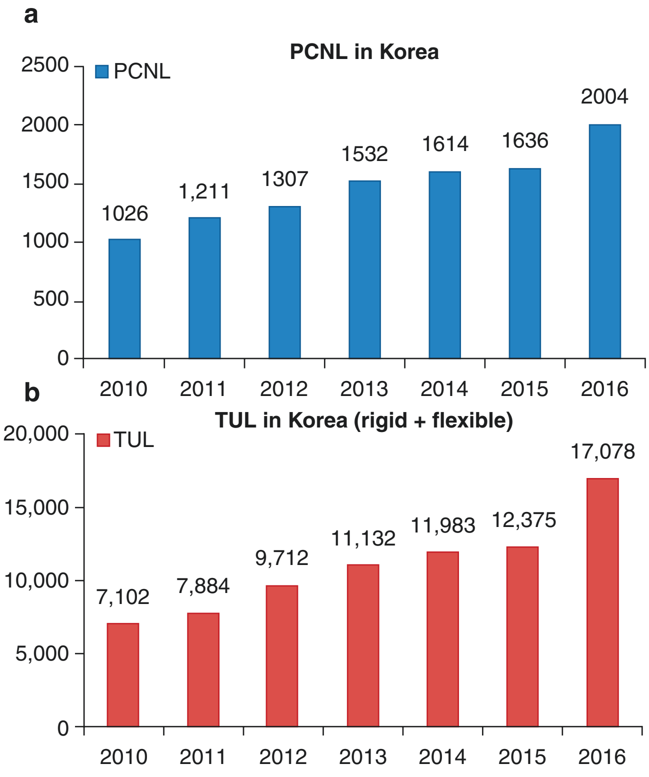

Fig. 1.2 The number of PCNL and TUL in Korea since 2010. (**a**) PCNL, (**b**) TUL

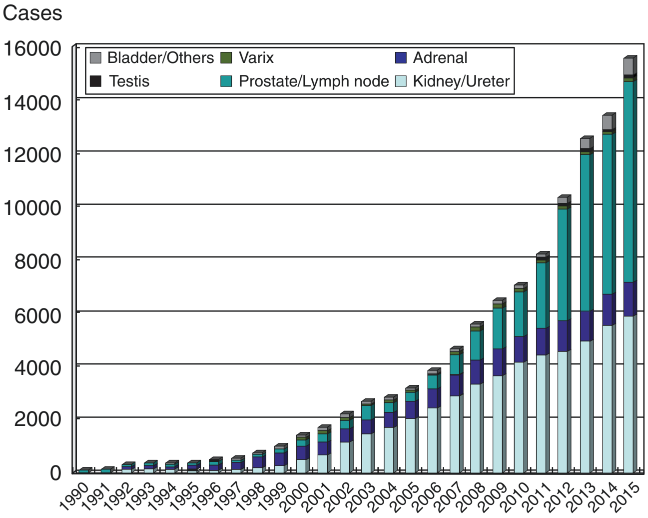

Fig. 1.3 The number of urologic laparoscopic surgeries in Japan since 1990

1992 by Japanese doctors (Go et al. 1993). The year of introduction of laparoscopic nephrectomy and prostatectomy is shown in Table 1.4. Since then, a variety of urologic laparoscopic surgeries have been introduced in these countries and the number of surgeries in Japan is still increasing as shown in Fig. 1.3, according to the nation-wide survey of urologic laparoscopic surgeries (The Japanese Society of Endoscopic Surgery 2016).

1.2.4 Introduction of Robotic Assisted Surgery in East Asia

The surgical robot, da Vinci was first introduced to East Asia in 2003 in Japan and has since been used in East Asian countries as shown in Table 1.5. Now in 2016, the number of da Vinci S, Si or Xi across the EASE region together with the number of urological robotic operations in 2016 are shown in Table 1.5.

Table 1.5 Introduction of surgical robot da Vinci in EASE territories

Country/ region	Year of the first case	No. of machines[a]	No. of urologic operations in 2016
China	2007	50	8000
Hong Kong	2006	10	600
Korea	2006	60	5000
Japan	2003	250	16,000
Philippine	2005	3	100
Taiwan	2005	30	2000

[a] At the end of 2016

Acknowledgements Drs. Yinghao Sun, Eddie Chan, Hon Ming Wong, Koon Ho Rha, Young Eun Yoon, Joel Aldana, Takahiro Yasui, Saint Shiou-Sheng Chen, produced the data on endourology of East Asian territories.

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Training of Endourology in Asia

2

Kai Zhang, Tao Han, and Gang Zhu

Abstract

For over hundred years, the training for surgeon was the accumulation of personal experience following the model of “see one, do one, teach one”. Even when this worked, such training lacked standardization because of different cases and teachers’ experience. This is clearly suboptimal from a safety viewpoint. More importantly, modern clinical ethics sits poorly with surgeons practicing new techniques on patients without any attempt at learning the skills on simulators. Patients are also increasingly reluctant to be the “guinea pigs” for inexperienced surgeons. Asia has a vast territory and a large population, the development of endourology varies greatly among different countries and regions. Systematic training and standardization of technique is in pressing need in Asia, especially in developing countries. In the last couple of decades, numbers of new animal and mechanical models and simulators have been developed and validated. Based on the currently available data, endourological training could help surgeons to gain experience and improve skills outside the operating room in a short time. Efforts should be made to identify the best aspects of every model and procedure-specific simulation courses should be developed and validated. Conclusive data on the training effect and feedback on real clinical environment is also needed in Asia.

Keywords

Endourology · Training · Training model

K. Zhang · G. Zhu (✉)
Department of Urology, Beijing United Family Hospital,
Beijing, China

T. Han
Department of Urology, Ningxia People’s Hospital,
Ningxia, China

2.1 Training Models of Endourology

Animal and mechanical models are most commonly used for endourology training worldwide, with the advantages of cost-effective, easy accessibility and high reliability. A large number of models have been developed to train medical students, residents and young urologists with limited experience in transurethral resection (TUR) surgery, ureteroscopy, percutaneous nephrolithotripsy (PCNL), laparoscopy and robotic surgery (Ganpule et al. 2015; Chandrasekera et al. 2006; Zhang et al. 2008; Soria et al. 2015; Celia and Zeccolini 2011). Some models could simulate the whole procedures with high fidelity and some could only simulate basic tasks or be used for specific steps but with low cost and good reusability.

A model was designed with an *in vitro* porcine heart tissue model for laser prostatectomy endoscopic technique training in China (Zhang et al. 2009). In the evaluation study, ten junior surgeons without experience of benign prostatic hyperplasia (BPH) laser prostatectomy were assessed for ability and speed over a period of time with two technique evaluation points: resection and vaporization. A 26F irrigating laser resectoscope was used to perform laser resection and vaporization on left ventricle chordae tendineae (Figs. 2.1 and 2.2). Before the first and the second training stage, the trainees were trained in theory and techniques. Feasibility, technique and both resection and vaporization speed were analyzed. There was significant improvement in terms of resection time, vaporization time and the total manipulation time ($P < 0.01$) in the second stage compared with those of the first stage. In this model, the space of the left ventricle in porcine heart was highly similar to the space of prostatic urethra during the laser BPH treatment and it was very suitable for this particular training. This model showed that porcine heart is a simple, cheap and reproducible model for learning the basic skills of laser prostatectomy using laser before working on patients.

Pig is also widely used for laparoscopic training, mostly simulating the whole procedure such as laparoscopic nephrectomy, partial nephrectomy and pyeloplasty (Chiu

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et al. 1992; Barret et al. 2001; Yang et al. 2010; Gettman et al. 2002) (Fig. 2.3). The morphometric and anatomic of porcine kidney are greatly similar to human kidney (Sampaio et al. 1998) (Fig. 2.4).

Early in 1993, laparoscopic nephrectomy was performed in 15 male live pigs in Taiwan by Chiu et al. (1992). The average operation time was 200 min. The complications included renal vein tear in one case, mild subcutaneous emphysema in two cases.

In India, the crop and esophagus of a chicken were used to simulate the renal pelvis and ureter for laparoscopic pyeloplasty training (Ramachandran et al. 2008). This model was cheap, easily available and could provide a realistic feel to the tissue and anatomy of human. To assess the effectiveness of this model, three residents was chosen to complete laparoscopic pyeloplasty for four times in a period of 1 month. The operation time and quality of anastomosis were compared among the four attempts. For all the three trainees, the operation time showed remarkable reduction and the quality of anastomosis improved significantly from the first to the fourth attempt, suggesting a favorable trend in terms of learning curve.

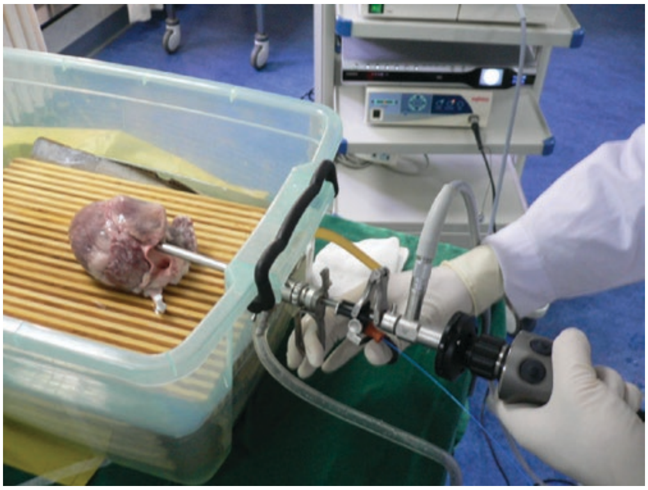
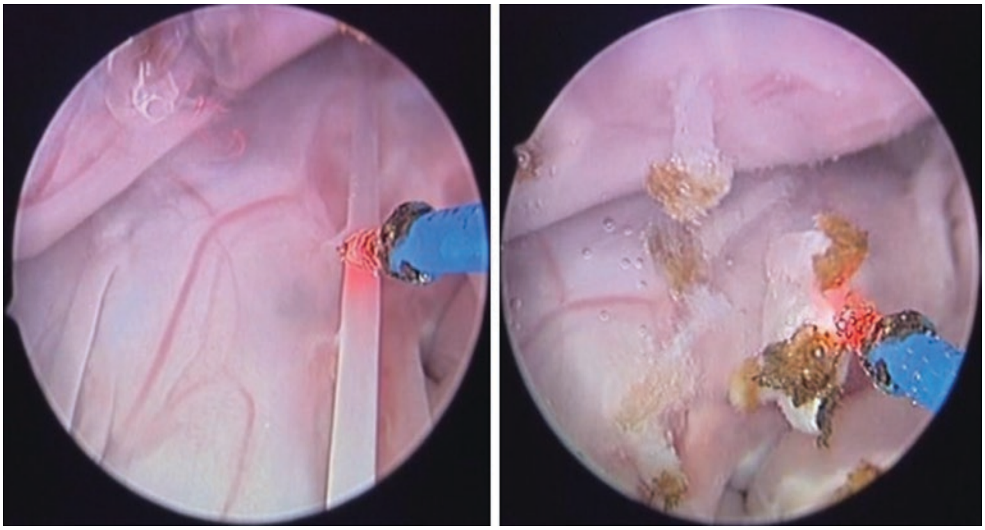


Fig. 2.1 Instruments and porcine heart model

Fig. 2.2 Space of the left ventricle in porcine heart



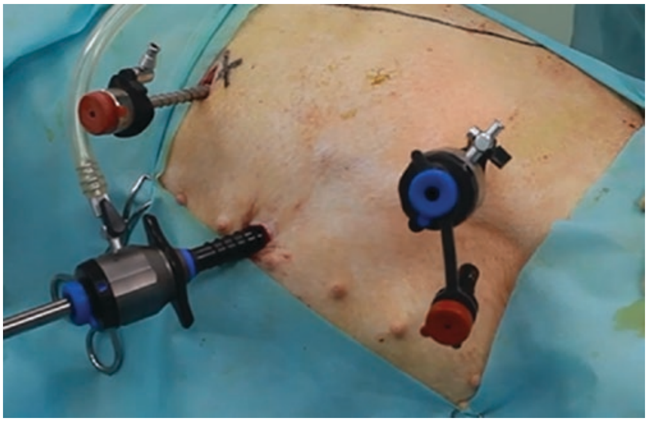


Fig. 2.3 Live porcine model for laparoscopic training

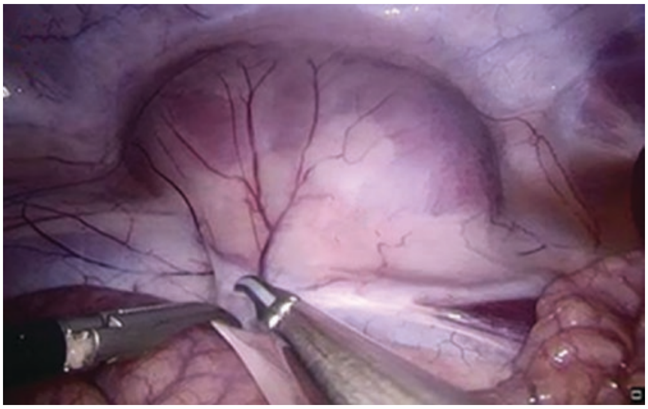


Fig. 2.4 Live porcine kidney

In addition to transurethral and laparoscopic procedures, a number of models were created for training of ureteroscopy and PCNL (Soria et al. 2015; Mishra et al. 2013; Bele and Kelc 2016; Sinha and Krishnamoorthy 2015; Strohmaier and Giese 2009). A biologic bench model using a porcine kidney was reported to simulate intrarenal procedures in China (Zhang et al. 2008). The porcine kidney was wrapped with subcutaneous tissue and muscle in a thick skin flap. The whole model was fixed to a wooden board with nails and the radiologic contrast medium or normal saline could be injected into the kidney through ureteral catheter. Stones were placed inside the kidney through a small incision on the renal pelvis in advance. A total of 42 urologists with limited experience of endourology surgery attended this training, performing percutaneous renal surgery training under ultrasound guidance. At the end of training, 60.6% trainees could finish the whole procedure successfully and 85.7% trainees regarded this model for percutaneous renal surgery training "very helpful" or "helpful".

In general, animal and mechanical models are easily built and cost-effective, could provide realistic and reproducible practice for most endourology surgery. However, the validity varies among various models and standard evaluation system is still lacking.

2.2 Virtual Reality Training of Endourology

Virtual reality (AR) is defined as "Inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference" (Hamacher et al. 2016). The first VR simulator emerged in 1909 and was used for the training of aircraft pilots (Hamacher et al. 2016). Nowadays, an increasing number of validated VR simulators are widely used for endourology training (Aydin et al. 2016a; Phe et al. 2017; da Cruz et al. 2016; Noureldin et al. 2016; Tjiam et al. 2014).

In 1999, a VR simulator for transurethral resection of the prostate (TURP) procedures was first reported (Ballaro et al. 1999; Gomes et al. 1999). Software was developed to generate the images of urethral and prostate with using a magnetic sensor input device attached to a dummy resectoscope, which could help trainees be familiar with the TURP technique.

Zhu et al. (2013) investigated the utility of VR simulators in training of TURP in China. The TURPSim system was used and 38 trainees were randomly selected to take part in the training (Figs. 2.5 and 2.6). The global rate scale, rate of capsule resection, amount of blood loss, external sphincter injury was compared between the baseline and post-training levels. It showed that all the parameters improved remarkably after training and most trainees were satisfied with the TURP simulator. It is noteworthy that all the other parameters, except for the global rate scale can be objectively and accurately evaluated with this VR model.

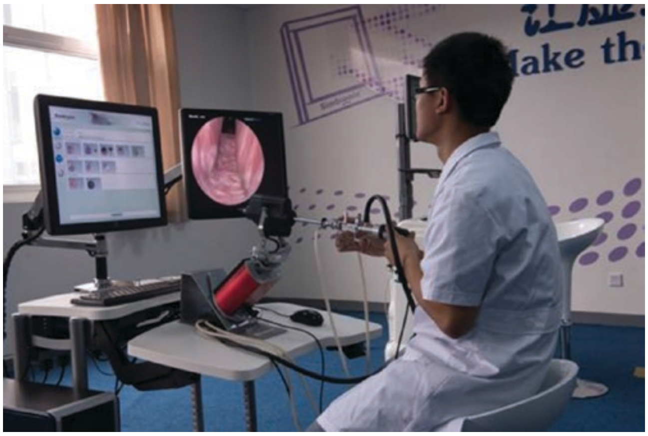


Fig. 2.5 TURPSim training system

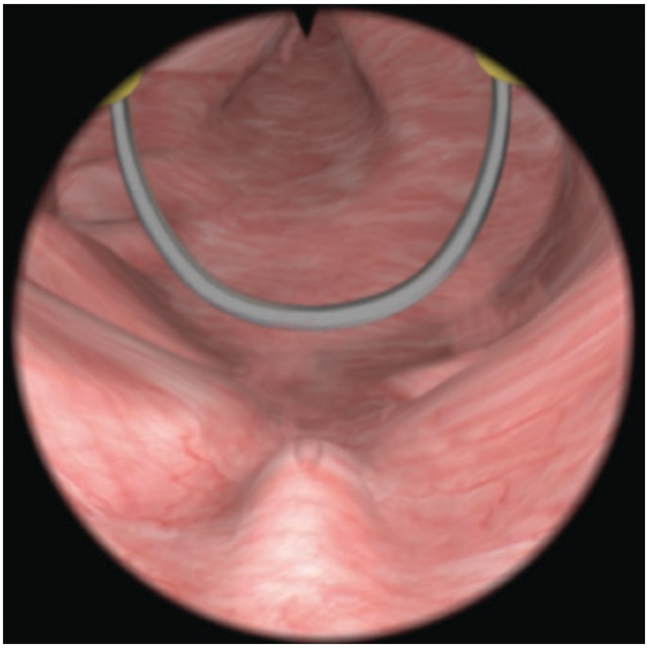


Fig. 2.6 Virtual TURP surgery

In accordance with rapid and wide adoption of robot-assisted laparoscopic surgery in the last decade, robotic VR simulators emerged and were increasingly applied worldwide. At present there are five VR simulators: the Surgical Education Platform (SEP; SimSurgery, Oslo, Norway), the Robotic Surgical System (RoSS; Simulated Surgical Systems, San Jose, CA, USA), the dV-Trainer (Mimic, Seattle, WA, USA), the da Vinci Skills Simulator (dVSS; Intuitive Surgical), and the recently introduced RobotiX Mentor (3D Systems, Simbionix Products, Cleveland, OH, USA) (Moglia et al. 2016).

In Korea, the dVSS system was used to train 50 medical school students to perform 12 exercises with the aim to determine whether a robotic VR training enabled inexperienced trainees to complete a hands-on operation (Song and Ko 2016). The program was conducted in two parts. Firstly, 43 students received VR training for basic skills and advanced suture. Then a real robotic surgical system was applied to perform urethrovesical anastomosis on a hands-on model which was created using the proximal end of rectal tubes. In analysis, the console time of hands-on training was significantly associated with the total time and attempt of VR training, suggesting robotic VR training system could help beginners to acquire and improve robotic surgery skills.

In India, Mishra et al. compared the validation between a live porcine model and a VR simulation model for percutaneous renal access training (Mishra et al. 2010). In this study, a live anesthetized pig with a pre-placed ureteric catheter and a high-fidelity simulator (PERC Mentor, Simbionix; Lod, Israel) were used. A total of 24 urologists with experience of more than 50 cases of PCNL firstly performed percutaneous renal access with a real-time C-arm in the porcine model, then operated the same procedure on the simulator. In comparison, there was no statistical significant difference in overall usefulness. The simulator model came with a high price but was safer and easier to set up than live porcine model. However, the live porcine model was more realistic than the high-fidelity simulator model.

Cai et al. reported the value of VR simulator in the skill acquisition of flexible ureteroscopy (Cai et al. 2013). URO Mentor (Simbionix) VR model was used in this study. Thirty urologists took part in the study and received 1-h basic training for the instruments and the whole procedures, then followed by an assessment with task of seven programs. After another 4-h practice on the simulator, the participants performed the same task. It showed that most parameters including total procedure time, progressing time from the orifice to stone, time of stone translocation, fragmentation time, laser operate proficiency scale, total laser energy, maximal size of residual stone fragments, number of trauma from the scopes and tools and damage to the scope improved remarkably on the second assessment. This study illustrated that VR simulator could aid the trainees to enhance their flexible ureteroscopy skills in a short time.

Generally, the high-fidelity VR simulators usually seem a very high price. However, the running cost is very low once the models are installed. It can be easily set up, only a space and an electricity supply needed. Of the available VR simulators, some have held high level of evidence and recommendation, such as the UroSim and TURPsim for TUR surgery, the URO Mentor and PERC Mentor for urolithiasis, and the dv-Trainer for robotic surgery (Aydin et al. 2016b).

2.3 Evaluation of Training Effect

The main objective of endourology training is to shorten the time needed for clinical training and provide the residents or urologists with the possibility to gain experience and improve skills outside the operating room. However, the role of training in certification and credentialing of real surgery is still under investigation. There is limited data regarding whether training could affect actual performance in a hands-on setting.

In Japan, Fujimura et al. developed a mentoring system to balance training new surgeons while controlling medical quality (Fujimura et al. 2016). Novice surgeons with experience of radical retropubic prostatectomy and laparoscopic renal and adrenal surgery participated in the study (only one surgeon had experience of laparoscopic radical prostatectomy). They first underwent intensive dry and animal training and then observed 47 cases of robot-assisted radical prostatectomy performed by an experienced surgeon (Menon M, Henry Ford Hospital, Detroit, Michigan, USA). Moreover, in the first five cases of real operation, the new surgeons were supervised by a proctor who had enormous experience in laparoscopic and robot-assisted radical prostatectomy.

In the step-by-step procedures, time limits and blood loss was measured and ten checkpoints were set up during every operation in the mentoring program. The cut-off point was set at 70% of the time and blood loss limit. Once the time or blood loss limit was exceeded, a mentor would take over the operation or another new surgeon would replace the surgeon and finished the step. In this setting, the surgical quality and patient's safety could be controlled to the maximum extent.

In this study, a total of 242 patients underwent robot-assisted radical prostatectomy, with the median operative time 237 min and median perioperative blood loss 300 ml. 88% of new surgeons could finish the whole procedure after an average of 10.7 cases. There was no perioperative mortality and no conversion to open prostatectomy. Seven patients (2.8%) suffered from postoperative hemorrhage and one patient underwent emergent hemostatic surgery because of active bleeding of left epigastric artery. It is interesting to note that there was no statistically difference between the results of a mentor and those of new surgeons with a mentor in terms of median operative time, console time, blood loss, incidence of blood transfusion and duration of catheterization. One must admit that the majority of studies on endourology training merely compare the results between the baseline and post-training period on models or simulators. However, the ultimate goal of training is to improve the doctor's performance on real patients. This Japanese study provides us some enlightenment on how to investigate the effect of training in real clinic environment on the premise of ensuring medical quality and safety. Regrettably, there are too few data on this subject in Asia, even worldwide.

2.4 Training Organization in Asia

There are a lot of endourology training courses supported by local urology societies in Asian countries or Areas in the purpose of improving Asian urologist's endoscopic skills and techniques.

Asian Urological Surgery Training & Education Group (AUSTEG) was founded in Hong Kong, with the aim to enhance professional competencies to advance the standard of urological surgery in Asia through a comprehensive training platform for experience skill exchange, and hence, cultivate next generations in Asia. The members are all urological experts with a high reputation from China, Japan, Korea, Malaysia, Thailand and some other Asian countries and regions. There are extensive curriculums including laparoscopic upper tract surgery, endourology and stone management, lower tract surgery and urology nursing workshop (Figs. 2.7 and 2.8).

East Asian Society of Endourology (EASE) regularly has the pre-congress training program. Such as the EASE 2014 & The Sixth Hong Kong Congress of Endourology: The Next Generation in Endourology: Training, Technique and Technology.

Chinese Urology Association (CUA) has organized many training courses and provided support to local training centers in China. Usually the training centers were organized by each province and run by a local teaching hospital. There were regular courses, which have contributed to the development of Chinese Urology. There were also some collaborated international courses, such as the Endourology Society Global Education Initiative Skills Courses in Endourolgy, Laparoscopy and Robotics held in Chengdu, China, in March 2016.

In Korea, Yonsei University College of Medicine Department of Urology provided 1-year training program under the guidance of a urological surgeon. During the fellowship, the fellow will be exposed to different techniques and latest available instruments in endourologic, laparoscopic and robotic surgery.

In India, ceMAST organizes courses like two-day Upper Tract Endourology Course covering usage of semirigid ureteroscopes, flexible ureteroscopes, nephroscopes, etc.

Fig. 2.8 AUSTEG model training for ureteroscopy

Fig. 2.7 AUSTEG trainers and trainees

Japanese Urological Association and Japanese Society of Endourology have established a urologic laparoscopic skills qualification system called the Endoscopic Surgical Skill Qualification (ESSQ) System in 2004 to assess the techniques and skills of applicants in performing lap nephrectomy or adrenalectomy.

The Chinese University of Hong Kong (CUHK) Jockey Club Minimally Invasive Surgery Skills Centre (MISSC) has collaborations with the International Training Centre of Intuitive Surgical®. Intuitive Surgical® issues certifications for all courses in robotic assisted laparoscopic surgery conducted at the MISSC. CUHK MISSC runs courses covering the important clinical aspects of robotics as used in a wide variety of specialties, including urology. A similar International Training Centre of Intuitive Surgical® has just recently been established in Shanghai Changhai Hospital.

It is worth mentioning that, even with different organizers, all the courses combining academic lecture, model-based training and practice, case discussion, providing remarkable promotion not only on surgical skill, but also on professionalism of our future medical care providers to better serve our patients.

Remark Permission is obtained to show the human images in this article according to local regulation.

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3 Laparoscopic Training Using Cadavers

Thomas Y. Hsueh

Abstract

Surgical education is the fundamentals of medicine and warrants experience transfer from generations to generation to achieve a better disease management. Laparoscopic procedure requires a steep learning curve compared to conventional open procedures due to two-dimensional vision, lack of tactile sensation and limited working space. The training curriculum in laparoscopic procedures includes not only didactic lectures but also hand-on surgical training lab. The application of computerized simulators, tissue analogue simulators and cadavers is proved to be efficient for surgical skills training in laparoscopy. The training in nontechnical surgical skills is found to have positive impact on surgical training, especially in interpersonal communication and team work during emergency scenarios in the operating room. This chapter will discuss the concept on surgical training, training curriculum design, the application of simulators in laparoscopic training and nontechnical training in laparoscopic surgery.

Keywords

Laparoscopy · Surgical training · Simulator

3.1 Introduction

Laparoscopic surgery was first introduced into urology in early 1990s. The advancement of technology, miniature of instruments and duplication of open surgical procedures are key elements for the revolution of minimal invasive surgery in the past 30 years. Robotic surgery, one of the revolutionary change of laparoscopic procedures, redefines the horizon of minimal invasive surgery and serves as the procedure of choice in complex urological surgical procedures. However, the evolvement of surgical training of laparoscopic procedures does not establish well as the development of laparoscopic procedures. Most urologists learned laparoscopic procedures just like the scenario about 40 years ago, as what we learned from our mentors. At that time, we learned the surgical procedures from our patients and from textbooks. In fact, the traditional training in surgery could be defined in the phrase, "see one, do one, teach one," as what surgeons learned for many decades (Halsted 1904). However, with the awareness of patient safety, financial constraints and medical legal issues in health care organizations, the training model used for many decades requires a fundamental renewal for urologists nowadays.

The advancement of computer science in the past 40 years and the widespread application of internet have changed people life in all aspects of our society. The use of smartphone, instant online communication and online video learning provide more chances for urologists to learn new surgical concepts. In international academic meetings, live demonstration of complex laparoscopic procedures via video streaming technology and real time communication with international experts deliver more opportunities for urologists in both step-by-step surgical illustrations and troubleshooting scenario in learning complex laparoscopic procedures. However, most complex laparoscopic procedures are associated with steeper learning curves compared to conventional open procedures. The restricted vision, lack of tactile perception, difficulty in handling endoscopic instruments and limited working space are main reasons for urologists to learn laparoscopic surgery. With the growing realization that most procedural learning curves do not require patients for skill acquisition, the implementation of training models in laparoscopic education has gained more and more attention in the past 20 years. Besides, the training program is more important than training models (Traxer et al. 2001). This chapter will focus on the discussion about

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T. Y. Hsueh (✉)
Division of Urology, Department of Surgery, Taipei City Hospital Renal Branch, Taipei, Taiwan

Department of Urology, School of Medicine, National Yang-Ming University, Taipei, Taiwan

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training program for laparoscopic procedures and the validity of training models, so as to provide a panoramic view of current status of laparoscopic education.

3.2 Evaluation of a Training Curriculum

Surgical education is the long-standing responsibility for physicians as the clinical experience transferred for generations to generations so as to treat diseases in a better way. Continuous medical education is not only important for a surgeon to be competent in his specialty, but also provide a chance for patients to receive better medical treatment. In order to keep clinical competence, a well-designed training curriculum is required in all aspects of clinical practice, which would be more important in surgical field. Although the curriculum might change a lot as the alongside with the progression of computer science, the measuring tools remain constant in the past several decades. The validity test is the essential part to evaluate a training curriculum and will be discussed in the following parts.

3.2.1 Face Validity

Face validity refers to the measurement of a test in all aspects (Guion 1980; Holden 2010). It also means the transparency and relevance to test participants. In a simple word, face validity means how a test really "looks like" as evaluated by all faculties of a training curriculum.

3.2.2 Content Validity

Content validity is also known as logical validity, which refers to a measure on all aspects of the test (Lawshe 1975). It also needs to use a designed scale to evaluate the effectiveness of a test and a statistical test might be needed for further analysis. Content validity is most often used in academic and vocational testing and it might refer to the curriculum evaluation in clinical education.

3.2.3 Construct Validity

Construct validity is one of the three types of validity evidence, along with the content validity and criterion validity in traditional validity theory. It refers to the identification of appropriateness made on the basis of observations or measurements for a test. In 1955, Cronbach and Meehl reported that construct validity could be evaluated in the following three aspects, including the articulation of a set of theoretical concepts and their interactions, to develop ways to measure the hypothetical constructs for a theory and empirically testing the hypothesized relations. Construct validity is very important in social science, psychology and language studies and are one of the important measurements for a training curriculum of laparoscopy nowadays.

3.3 Training Curriculum

The training curriculum using cadaveric/animal models, high/low fidelity simulators and virtual reality simulators provide the possibility of getting knowledge-based behavior (Satava 2001). However, the course aiming to train new laparoscopic surgical procedures should focus on both technical and non-technical skills in handing various clinical scenarios. There are several issues needed to be addressed, such as length of the program, content of didactic courses, hand-on training materials and homogeneity of trainees (Vaziri 2013). It is reported that participants that are trained for more than 1 day interactive program might be more competent. In order to decrease the perioperative complication rate in laparoscopic procedures, the implementation of surgical volume after the training program is essential. Hence, an optimal course should include not only didactic lectures and interactive simulator training program, but also improve the performance of trainee (Kneebone 2003). The aim of the training course should focus on the decrease of possible complications and increase dexterity during laparoscopic procedures. In 1998, a guideline from society of American gastrointestinal endoscopic surgeons (SAGES) suggested the following rules for courses design in laparoscopic/robotic surgery. The principles were: (1) The objectives and the assessment methodology should be clearly illustrated, (2) the faculties should be qualified, (3) a fundamental knowledge, skills and clinical experiences should be identified in participants, (4) the facilities should be adequate. In 2006, Corica et al. reported the training experience of mini-residency program for laparoscopic procedures with more than 2-year follow-up period. A 5-day training program was conducted, including didactic lecture, hand-on training in dry lab and animal models and observation of live surgery in the operating room. The authors concluded that 5-day mini-residency program could encourage trainees to perform more complex laparoscopic procedures in their daily practice. The course coordinator needs to identify the requirement of trainees and tries to design a tailor-made content for all participants. The content of didactic lecture is another concern for a training course and should include fundamental knowledge of laparoscopic surgery, step-by-step laparoscopic surgical procedures and possible landmark identification during surgery, complications of laparoscopic surgery and future perspectives or current status of laparoscopic surgery. For participants who have certain level in laparoscopic procedures, the trouble-shooting lecture might be more helpful so as to provide experience sharing scenario in the course. Finally, the satisfaction survey of the training course is essential for course coordinators. It can provide not only the evaluation of the training course, but also provide suggestions for course refinement. To sum up, there is no perfect training curriculum, but a training curriculum can be refined to become perfect.

3.4 Training Models

There were several training models focused on laparoscopic surgical procedures. With the advancement of computer science and virtual reality, the application of computerized model has gained widespread acceptance in recent years. Besides, there were several validated models used for radical/partial nephrectomy, pyeloplasty, ureteral reimplantation, and urethrovesical anastomosis using analogue materials. The animal model was still the most common selection to simulate clinical scenario although fresh frozen cadaveric model might provide better experience in endoscopic dissection. The simulated training models will be discussed in the following section.

3.4.1 Computerized Simulators

As the development of imitative technology, application of augmented reality in real life and the widespread deployment of high definition video system, the use of virtual reality in educational training has gained popularity since early 2000s (Laguna et al. 2002). The computer-based design of a simulator mainly focused on the reproducibility of three-dimensional environment, tissue texture and the creation of force-feedback mechanisms. Besides, the possible smoke generation and tissue elasticity alongside the bleeding phenomenon during endoscopic dissection and vessel ligation is another consideration to be implemented in a computer-based simulator. In 2012, Matsuda et al. reported the experience in virtual reality simulator and compared to the videotape assessment from real laparoscopic procedures. They concluded that the basic skill training in virtual reality simulators might demonstrate the construct and concurrent validity to evaluate preclinical laparoscopic skills.

3.4.2 Analogue Training Model

3.4.2.1 Partial/Radical Nephrectomy

There were several studies describing the application of training models in simulated training of partial nephrectomy. In 2010, the Procedicus MIST nephrectomy VR simulator was reported to have face, content and construct B validity (Brewin et al. 2010). Lee et al. (2012a) reported the partial nephrectomy model mimicking renal hilar injury, which demonstrated face, content and construct B validity. In 2012, Hung et al. reported another model using porcine kidney and styroform ball to mimic renal tumor requiring laparoscopic/robotic partial nephrectomy while face, content and construct B validity could be demonstrated in this study. In 2013, De Win et al. reported the animal model of porcine kidney, which found to have content and construct A validity. With the advancement in augmented reality, the computerized model was designed. In 2015, Hung et al. reported the application of dV-Trainer in robotic partial nephrectomy training and face, content and construct B validity was found in this training model. All four reported studies gained a level of evidence 2b.

3.4.2.2 Pyeloplasty

There were two studies evaluating the application of pyeloplasty model. In 2013, Jiang et al. reported the use of chicken crop model to simulate clinical scenario of laparoscopic pyeloplasty which demonstrated construct B validity between experts, specialists and junior residents. In 2014, Poniatowski et al. reported the pyeloplasty simulator model by using a low-cost, high-fidelity tissue analogue. It was reported to have face, content and construct B validity (Poniatowski et al. 2014). Those two studies gained a level of evidence 2b.

3.4.2.3 Ureteral Reimplantation

In 2013, Tunitsky et al. reported the use of hydrogel to simulate laparoscopic/robotic ureteral reimplantation. The model demonstrated to have face, content and construct B validity and gained a level of evidence 2b.

3.4.2.4 Vesicourethral Anastomosis

There were several studies evaluating the training models of vesicourethral anastomosis. In 2006, Laguna et al. reported the chicken model to mimicking vesicourethral anastomosis and found to have construct B validity in this study with a level 2c evidence. In 2012, Sabbagh et al. reported the latex UV model to simulate vesicourethral anastomosis, which demonstrated face and predictive validity and a level 2a evidence was identified. In 2014, Kang et al. reported the use of tube3/dV-Trainer to simulated vesicourethral anastomosis. Face, content and construct B validity was found in this study while a level 2b evidence was identified. In 2015, Chowriappa et al. reported the use of augmented reality to simulate vesicourethral anastomosis in HoST/RoSS model. Face and concurrent validity were found in this study and a level 1b evidence was noted.

3.4.3 Animal Model

The use of animal to simulate real surgical scenario was a longstanding choice for surgical training, not only in conventional open surgery, but also in laparoscopic surgical procedures (Alemozaffar et al. 2014). The most commonly used animal is porcine model while canine or calf model was sporadically reported. The interactive training program can be divided to upper urinary tract and lower urinary tract. The trainees will be divided into several groups and about 2–3 trainees per group is the usual setting. Each group will be assigned to perform 2–3 procedures in about 4 h. Partial/radical nephrectomy, pyeloplasty and ureteroureterostomy are the usual procedures for upper urinary tract while ureteroneocystostomy, enterocystoplasty and radical cystectomy are usually conducted for lower urinary tract.

3.4.4 Cadaveric Model

The use of cadaveric model for surgical training may provide an ideal environment to realize real human anatomy and to simulate manipulations in laparoscopic surgery. It also serves as the transition to evaluate the surgical competence of trainees from simulation-based training model to real laparoscopic surgeries. In 2008, Giger et al. reported the experience using Thiel cadavers in laparoscopic training. They reported a high satisfaction scores were identified for the course and all participants were willing to recommend the course to their colleagues. In 2012, Sharma and Horgan reported the comparison between fresh frozen cadavers and high-fidelity simulators for laparoscopic training. They found that fresh frozen cadaver was perceived as a better tool for laparoscopic training. In 2016, Imakuma et al. reported the application of fresh frozen cadavers for laparoscopic training without pneumoperitoneum. They concluded that the use of fresh frozen cadavers could provide a promising model for laparoscopic training. However, the use of cadavers might raise several ethic and financial issues which limit the widespread use of cadaveric model.

3.4.5 Non-technical Skill Training

The nontechnical skill training was first reported in England, which refers to the evaluation of situation awareness, communication, teamwork and decision making and leadership. Lee et al. (2012b) reported the experience in high-fidelity simulation-based training for laparoscopic complication management. They concluded that the nontechnical training might improve the interdisciplinary communication skills.

3.5 Conclusion

With the advancement of optic technology, energy-based endoscopic equipment and computer science, the implementation of laparoscopic surgeries into surgeon's daily practice is essential nowadays. The introduction of laparoscopic training into continuous medical education could provide a solution to maintain clinical competency and to learn new endoscopic procedures in a safe environment. In the near future, laparoscopic simulation using computerized virtual reality model, animal model and cadaveric model might serve as the step-by-step learning protocol to deliver a new surgical technique from the experimental test into a practical procedure.

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Simulation Training of Laparoscopy

4

Kazuhide Makiyama

Abstract

Simulators are often used as educational tools for training surgeons in laparoscopic procedures. Some surgical simulators have been proven to shorten clinical learning curves, and it was demonstrated that techniques learnt by using a simulator can be brought into the operation room. Laparoscopic surgical simulators can be classified into box and virtual reality type. Box-type simulators are cheaper and have a superior array of surgical tools. By using box trainers, trainees are able to use and become familiar with real surgical tools. Box trainers are perfectly suited for learning suturing and knot tying. Virtual reality simulators are generally more expensive than box trainers. The main advantage of virtual reality simulators is that every movement of the forceps is recordable in virtual space. Thus, the recorded data can be analyzed, and trainees' skills can be assessed objectively. Patient-specific simulators represent a new technological advancement. They provide patient-specific training, in which patients' three-dimensional imaging data are used to create virtual reality simulations.

It is necessary to evaluate the usefulness and adequacy of laparoscopic simulators. There are several ways to validate laparoscopic simulators, including both subjective and objective methods. Subjective simulator evaluations assess face and content validity, whereas quantitative evaluations examine construct, concurrent, and predictive validity.

Keywords

Simulator · Laparoscopy · Training

4.1 Introduction

Surgical techniques have advanced in the past three decades. In the urological field, the majority of major surgical procedures that were performed using open methods have been replaced by laparoscopic and robotic techniques. Now, in high-volume centers, open surgery is only conducted in limited and complicated cases, for example, those involving bulky tumors or tumors affecting the major vessels, etc. When open surgery is performed by a trainee surgeon, a trainer will be in front of the trainee, both the trainer and trainee share the operative field and the trainer can freely manipulate and control the operation easily. On the other hand, in laparoscopic surgery the surgeon is basically alone, and scopists and assistants are supposed to concentrate on their own roles. When trainers want to manipulate and control such surgery, they have to remove the trainee from the surgeon's position. So, it is more difficult to teach surgery to trainees without sacrificing surgical "smoothness" in laparoscopic procedures. Thus, laparoscopic procedures are considered to be difficult to learn and teach. For this reason, trainees have to be well educated outside of the operative room before they perform laparoscopic surgery for the first time. In addition, surgeons are supposed to acquire most of the knowledge and skills required for a particular surgical procedure by themselves. Training outside of the operation room can shift the learning curve from inside to outside of the operation room and minimize the clinical learning curve. Simulations offer the opportunity for surgeons to improve their technical skills in a structured, low-pressure environment outside of the operation room without putting patient safety at risk (Gava 2004).

Surgical simulators are one of the tools used for training outside of the operation room. The need for surgical simulators has increased with the rise of surgical technology and so the market for them has expanded. Some surgical simulators have been proven to shorten clinical learning curves. In fact, it was demonstrated that techniques obtained from simulators can be brought into the operation room. In this chapter, we review laparoscopic surgical simulators.

K. Makiyama (✉)
Department of Urology, Yokohama City University Graduate School of Medicine, Yokohama, Kanagawa, Japan
e-mail: makiya@yokohama-cu.ac.jp

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4.2 The Use of Simulators Laparoscopic Surgery Training

Training for laparoscopic surgery requires the trainee to acquire both knowledge and skills. At present, knowledge can be obtained from academic conferences, academic websites, textbooks, and videos. On the other hand, skill training is performed using simulators, animals, or cadavers. Although training using animals or cadavers is useful, it is expensive, and trainees have few chances to participate in such training. Conversely, simulator training can be performed repeatedly from day to day and is useful for skill acquisition. In the past two decades, the laparoscopic simulator market has expanded. As simulators are not affected by ethical or hygiene issues, it is expected that the need for surgical simulators will increase. By using laparoscopic surgical simulators, surgeons can train for laparoscopic surgery outside of the operating room. If simulators are appropriately incorporated into surgical training, they are considered to be a time-saving, cost-effective, and safe method of training (Le et al. 2007). In addition, some surgeons and urologists recognize simulators as important tools for laparoscopic surgical training (Le et al. 2007; Korndorffer Jr et al. 2006; Fried et al. 1999), and several randomized trials have reported that the use of virtual reality (VR) surgical simulators can improve performance in the operating room (Aggarwal et al. 2007; Grantcharov et al. 2004; Haque and Srinivasan 2006; Palter and Grantcharov 2014).

In the United States, FLS (Fundamentals of Laparoscopic Surgery) certification is required for American Board of Surgery Certification. The FLS process consists of hands-on manual skill practice and training via a box-type simulator. It was reported that undergoing FLS laparoscopic surgery training to proficiency levels can improve trainee performance (Sroka et al. 2010).

4.3 Classification of Laparoscopic Surgical Simulators

Table 4.1 shows a surgical simulator classification. As indicated in the table, part-task trainers are designed to train surgeons in the handling of tools during surgery. Box trainers are part-task trainers. Task trainers use virtual human bodies created by VR technology to train surgeons in surgical procedures and hand-eye coordination. VR-type simulators are task trainers. Mission rehearsal simulators are mainly used to determine the risks of surgery in advance via preoperative surgical training with a patient-specific model and to improve the surgeon's skills to minimize risks during the actual operation. Patient-specific simulators are mission rehearsal simulators. In general, the technical difficulty and cost of a system increase from classifications (1) to (3).

4.4 Box-Type Simulators (Box Trainer)

Box trainers are superior to other types of simulator in terms of their cost and surgical tools. Box trainers are relatively cheap. In box trainers, trainees are able to use and become familiar with real surgical tools. Box trainers are perfectly suited to basic training, e.g., learning suturing and knot tying. Although some VR simulators have suturing and knot-tying applications, box trainers seem to be the best type of simulator for training that requires fine manipulation and tactile sensation, especially for knot tying. Repeated training with a trainer could provide maximal benefits for trainees in terms of allowing them to acquire adequate suturing and knot-tying skills. Through such repetitive training, trainees obtain hand-eye coordination (Fig. 4.1).

Although box trainers are commercially available from a lot of companies, they can be "scratch built"(Aslam et al. 2016), which can be a cost-effective way of acquiring laparoscopic

Fig. 4.1 Training using a box trainer

Table 4.1 Classification of laparoscopic surgical simulators

Classification	Typical example	Applications	Surgical tools	Basic training	Procedure-specific training	Patient-specific training
(1) Part-task trainers	Box trainers	Mechanical	Real	Possible	Possible with a good model	Impossible
(2) Task trainers	Common VR simulators	Virtual reality	Virtual	Possible	Possible	Impossible
(3) Mission rehearsal	Patient-specific simulators	Virtual reality	Virtual	Possible	Possible	Possible

skills. Low-cost alternatives are needed to allow trainees to practice and develop their laparoscopic skills outside of the workplace (Li and George 2017). A portable bookbinder-sized box trainer that is used in combination with a smartphone has been developed (http://www.g-mark.org/award/describe/42712), and a box trainer that incorporates an iPad has been reported to be effective (Ruparel et al. 2014). As described above, trainees can create homemade box trainers by themselves, which can be beneficial in terms of cost and space.

Another important issue for box trainers is image quality. Recently, in response to surgeons' requests, it has become possible to obtain high-quality laparoscopic images. However, many box trainers still only produce low-quality images. Thus, it will be necessary to improve the image quality of box trainers in order to facilitate high-quality training. Achurra et al. (2017) reported that box trainer image quality is an important issue.

You can place any material in a box trainer and freely practice whatever skills you want. Traditionally, chicken meat and mandarin oranges are used for dissection training. Bimanual coordination skill can be obtained by trimming chicken skin from poultry or finding and dissecting nerves or blood vessels from poultry. In addition, trainees peel skin from mandarin oranges using laparoscopic forceps. During such skin-peeling training, rough dissection will cause the orange to rupture, leading to the release of juice. Therefore, trainees try to carefully dissect such oranges so that they do not release the juice. Sponge and rubber goods of moderate size and hardness can be used for suturing training. Thus, appropriate training can be conducted using everyday items. It is important to have an aim during training. Training for certain procedures or situations can also be conducted using ordinary goods. For example, Fig. 4.2 shows a vesicourethral anastomosis model composed of sponge, chicken, and rubber tubing. The sponge mimics the pelvic floor, anterior rectal wall, and deep dorsal complex; the chicken represents the bladder; and the rubber tube mimics the urethra.

Recently, with the rise of three-dimensional printers and advances in material engineering, three-dimensional training models have been developed, including models of the kidneys, stomach, lungs, liver, colon, and blood vessels, etc. By using such three-dimensional organ models in a box trainer, trainees can participate in more realistic training involving real surgical tools. Figure 4.3 shows examples of three-dimensional kidney models that are used for partial nephrectomy training. They can be cut and sutured freely. These three-dimensional organ models can be used to reduce and replace animal training. In addition, they might bridge the gap between real surgery and VR simulators.

Another recently developed technology is the suture evaluation system (https://www.kyotokagaku.com/products/detail01/m57.html). This system includes a personal computer, a camera, a suturing unit, and a suture pad with pressure sensors. It can evaluate a surgeon's skill, the procedure time, the force placed on a particular tissue, suture tension, stitch spacing, and stich equidistance (Ieiri et al. 2013). Although this product seems to be a bit expensive, an increase in demand might reduce the price, and it has the advantage of allowing objective assessments to be carried out.

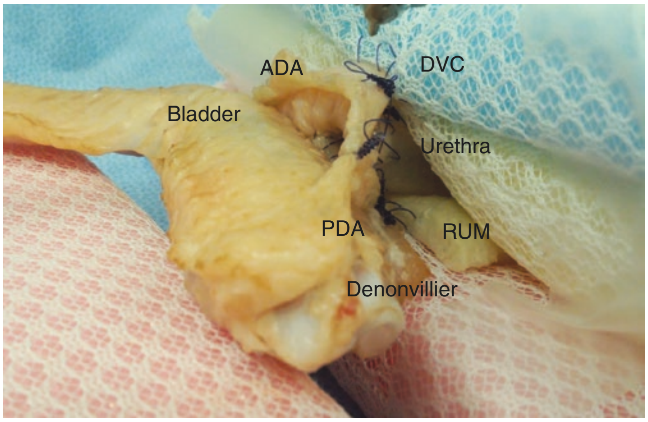

Fig. 4.2 A vesicourethral anastomosis model. In this model, chicken meat, sponge, and rubber tubing are used to mimic the bladder, Denonvilliers' fascia, deep dorsal vein complex (DVC), anterior detrusor apron (ADA), posterior detrusor apron (PDA), rectourethral muscle (RUM), and urethra

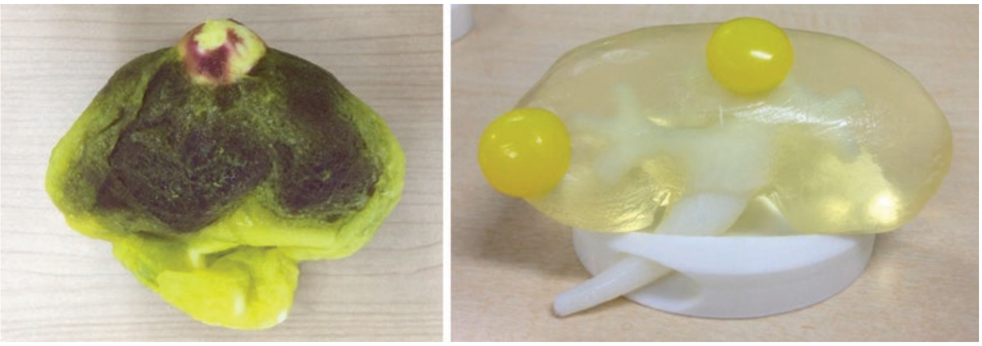

Fig. 4.3 Examples of three-dimensional kidney models used for practicing partial nephrectomy

4.5 Virtual Reality (VR) Simulators

Task trainers are training tools for specific tasks. In the laparoscopic field, VR simulators are used as task trainers. Figure 4.4 shows a VR simulator. VR simulators almost always include basic skill training software and procedure training software, and they are generally more expensive than box trainers. The main advantage of VR simulators is that every movement of the forceps or affected organs is recordable in virtual space. The recorded data can be analyzed, and trainees' skills can be assessed objectively (Fig. 4.5). Personal archival records might motivate trainees to continue training. Many pieces of surgical training software are commercially available, including software for general laparoscopic surgery and urological and gynecological laparoscopic procedures. Figure 4.6 shows a nephrectomy procedure performed on a simulator. Such simulators can be used to train surgeons in a particular procedure under various scenarios. During the procedure, trainees can experience the interaction between the forceps and the target organ; i.e., they can learn how to achieve good organ traction. They can also experience bleeding from blood vessels and learn how to achieve hemostasis. Some VR simulators have a haptic function, so the user can experience haptic feedback from the target organ. Many companies sell laparoscopic VR simulators, including the LAP Mentor (Simbionix Ltd., Airport City, Israel), LAPSIM (Surgical Science, Göteborg, Sweden), Simendo (Simendo B.V., Rotterdam, The Netherlands), LapVR (CAE Healthcare, FL, USA), and Lap-X (Medical X, Rotterdam, The Netherlands). Among these, the LAP Mentor and LapSim are available for nephrectomy training.

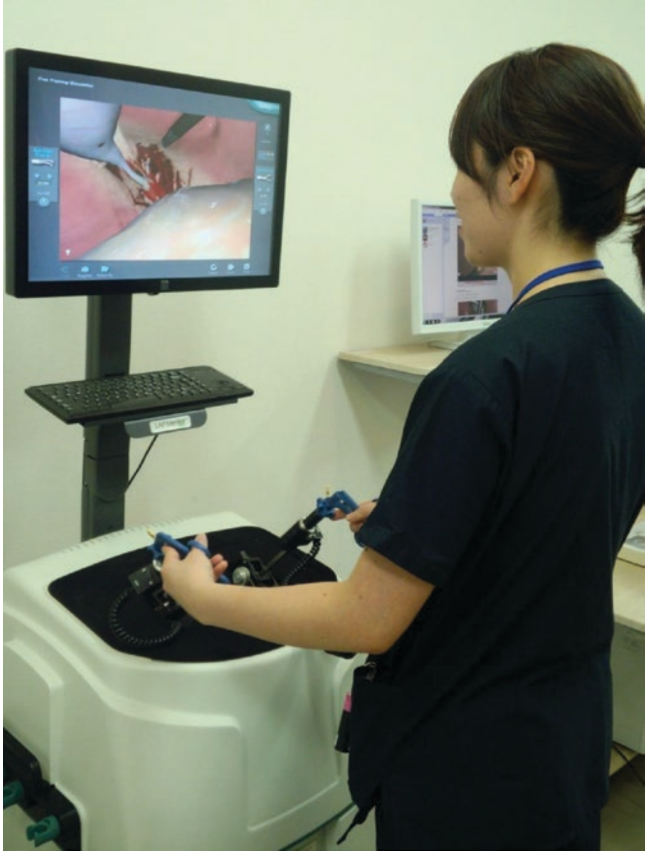

Fig. 4.4 A VR-based laparoscopic surgical simulator

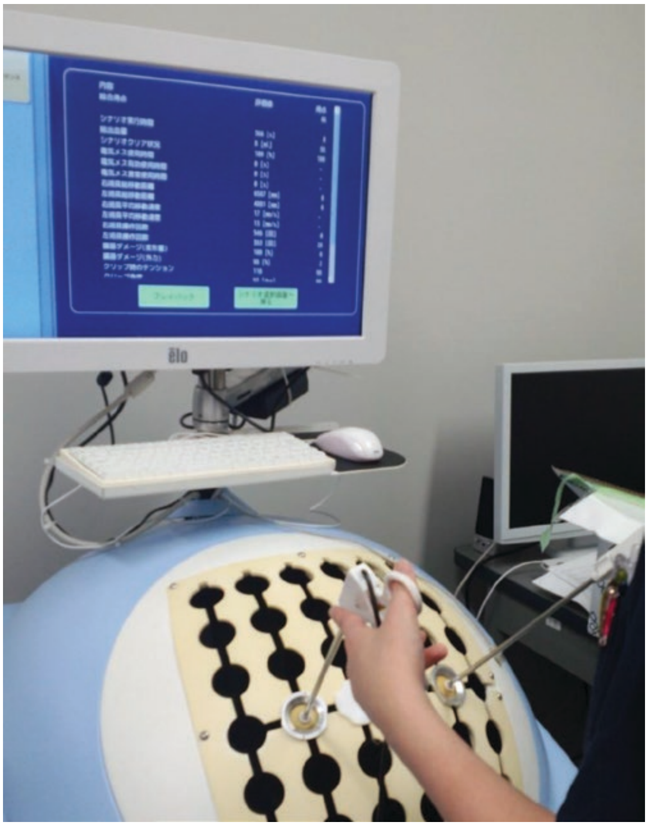

Fig. 4.5 A score is displayed after each VR simulator procedure

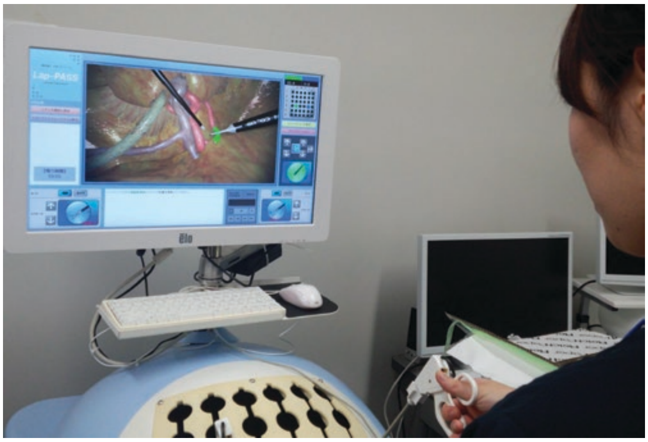

Fig. 4.6 A nephrectomy procedure performed on a simulator