MONOGRÁFICO: FORMACIÓN QUIRÚRGICA Y ACADÉMICA EN UROLOGÍA

ARTÍCULO ORIGINAL

Arch. Esp. Urol. 2018; 71 (1): 97-107

TRAINING IN UROLOGICAL ROBOTIC SURGERY. FUTURE PERSPECTIVES

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Summary.- *As robotics are becoming more integrated into the medical field, robotic training is becoming more crucial in order to overcome the lack of experienced robotic surgeons. However, there are several obstacles facing the development of robotic training programs like the high cost of training and the increased operative time during the initial period of the learning curve, which, in turn increase the operative cost. Robotic-assisted laparoscopic prostatectomy is the most commonly performed robotic surgery. Moreover, robotic surgery is becoming more popular among urologic oncologists and pediatric urologists. The need for a standardized and validated robotic training curriculum was growing along with the increased number of urologic centers and institutes adopting the robotic technology. Robotic training includes proctorship, mentorship or fellowship, telementoring, simulators and video training. In this chapter, we are going to discuss the different training methods, how to evaluate robotic skills, the available robotic training curriculum, and the future perspectives.*

Keywords: *Robotic Training. Urology. Simulators. Telementoring. Curriculum.*

Resumen.- *A medida que la robótica va integrándose más en el campo de la medicina, el entrenamiento en robótica se está volviendo más crucial para superar la falta de cirujanos robóticos experimentados. Sin embargo, hay varios obstáculos a los que se enfrenta el desarrollo de programas de formación en robótica, como el alto coste de la formación y el aumento del tiempo operatorio durante el periodo inicial de la curva de aprendizaje, lo cual incrementa el coste de la operación. La prostatectomía laparoscópica asistida por robot es la cirugía robótica realizada con mayor frecuencia. Además, la cirugía robótica se está volviendo más popular entre oncourólogos y urólogos pediátricos. La necesidad de un curriculum de formación en robótica estandarizado y validado fue creciendo con el aumento del número de centros urológicos e institutos que adoptaban la tecnología robótica. La formación en robótica incluye monitorización, tutorización o fellowships, teletutela, simuladores y video entrenamiento. En este capítulo vamos a discutir los diferentes métodos de aprendizaje, cómo evaluar las habilidades roboticas, el curriculum en robotica disponible y las perspectivas futuras.*

Palabras clave: *Formación en robótica. Urología. Simuladores. Teletutoría. Curriculum.*

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INTRODUCTION

There has been a striking increase in the use of robotic surgery in urology since 2001. Currently, it is used mainly in oncologic and pediatric urology (1). This evolving technology has even crowned itself as the gold standard for management of prostate cancer and currently robotic-assisted radical prostatectomy is the most commonly performed robotic procedure worldwide (2). It has also been used in other oncologic urological procedures like radical cystectomy and urinary diversion, radical and partial nephrectomies with comparable oncological results to open and laparoscopic surgeries, better cosmetic results, less estimated blood loss (EBL) and narcotic use (1,3). Furthermore, robotics gained great popularity among pediatric urologists in the management of pediatric pyeloplasty with comparative results to open and laparoscopic surgery (1).

WHY DO WE NEED ROBOTIC TRAINING?

Robotic revolution of surgery is being limited by multiple factors including; increased cost, low institutional support and funding, and shortage of trained and specialized robotic surgeons (3), so one of the major obstacles facing the surgical community is the limited numbers of well-trained minimally invasive urologists especially robotic surgeons and this problem is increasing in magnitude over time (3). Nevertheless, a recent randomized controlled trial has raised some concerns on the real benefit of robotics versus open surgeries, pointing out the role of surgical experience as one of the key factors to the outcome, rather than the surgical approach (4).

ROBOTIC TRAINING IN UROLOGY

The principal aim of any urology-training program is to produce well-trained surgeons with sufficient knowledge and skills so as not to affect patient safety and be a competent urology consultant (5). The need for a standardized and validated training curriculum was growing along with the increased number of centers and institutes adopting the robotic technology.

Obstacles and challenges facing robotic training

There are several obstacles and challenges facing robotic training including: the high cost of acquiring and maintaining the robot, cost involved in training, increased operative time during the initial period of the learning curve which will result in the increase of the operative cost, and the effect of the learning curve on the operative outcomes (3).

The learning curve of different robotic procedures

The surgical learning curve is somehow different without standardized accepted definition. Generally, it is a self-stated point at which the surgeon reaches comfort zone after a specific number of cases but this definition is subjective as it is completely dependent on the surgeons' perception and not on objective measures. Alternatively, it can be defined as the number of cases of specific procedure needed by a single surgeon to obtain acceptable operative time with reasonable outcomes (6).

Unfortunately, there is no consensus about the optimal measures of the learning curve of any surgical procedure. Different variables were proposed as measures for the learning curve. The most common variable is the operative time; however, operative time as a single variable to evaluate the learning curve is not sufficient and not accurate to give an idea about the surgeon's level of experience. Other variables include oncological outcomes, functional outcomes, recurrence rates, hospital stay and complication rates (7). Many factors play an important role in determining the length of learning curve including surgeons experience and knowledge, the presence of a well-structured training and the complexity of the procedure (4,6).

Various authors tried to measure the learning curve of different urological robotic procedures. The learning curve for robotic-assisted radical prostatectomy (RARP) ranges from 8 to 150 cases based on the measured variable with an estimated average of 18 - 45 cases for an experienced open surgeons. The learning curve for other urologic procedure was not studied heavily. For example, the Radical Cystectomy Consortium stated that only 30 cases of robotic radical cystectomy were needed to reach the plateau for the operative time, lymph nodes count and positive surgical margins, while only 20-30 procedures are needed to reach the expert level in robotic partial nephrectomy (6). The introduction of robots in urology helped to shorten the learning curve of certain procedure, for example, the learning curve for laparoscopic radical prostatectomy is significantly longer than that of RARP (7).

Cost of Training

The operative cost of learning robotic-assisted prostatectomy is one of the limiting factors of robotic training especially among residents and young doctors, and it is directly related to the length of the learning curve and it ranges from $ 95,000 with the shortest learning curve to $ 1,365,000 with the longest learning curve (8).

Robotic training and operative outcomes

Another obstacle that faces the growing interest in robotic training is the effect of training on the operative outcomes. It may seem that the involvement of a fellow or a resident in robotic-assisted surgery will compromise the peri-operative and post-operative outcomes of the patients; however, this is not completely true. Several studies showed that trainee involvement in the different robotic urologic procedure (radical prostatectomy and partial nephrectomy) does not affect the oncological outcomes or the complication rates. Nonetheless, the operative time, estimated blood loss and the hospital stay are usually affected by the trainee involvement (9).

On the other hand, the implementation of robotic-assisted surgeries in many centers has negatively affected surgical training for trainees and fellows in these centers. This can be explained from two different points of views, the surgeons who believed that robotic training is difficult, time and money consuming, and may compromise the patient's safety, while the trainees believe that the limited working hours, fear of litigation and the financial limitations are the main reasons (2).

Time for training

Time is one of the important factors to consider when robotic training is considered. Over the past years, there has been a decrease in the time available for training of new surgeons and this can in turn be reflected on the patients' safety. Short training courses are often insufficient as surgeons are usually unable to implement the new skills (10). An intensive training program represents the ideal solution for this problem.

DIFFERENT METHODS OF ROBOTIC TRAINING

Teaching robotic surgery is completely different from teaching open or laparoscopic surgery. This is because during open or laparoscopic surgery, the supervising surgeon is neighboring the trainee and both of them have the same view of the operation field, besides his ability to take control over the trainee's maneuvers at any time during the procedure and this is not present in robotic training except in case of dual console robotic system (9).

As a result, an increasing interest in acquiring robotic skills before operating on patients and developing alternative models, tools and validated training programs, will facilitate the process of robotic skills learning without compromising the patients' safety.

a- Proctoring and preceptoring

Proctoring and preceptoring are two different terms with completely different meanings however, some authors and surgeons have used them interchangeably for supervised training. Proctoring is the process in which an experienced surgeon observes a trainee during the initial phase of the learning curve of certain procedure in order to evaluate the performance, knowledge, and skills of the trainee (8). A proctor is responsible for evaluating the trainee performance and reporting his comments to the department head and his reports may result in privileging the trainee or recommend more training while the proctor has no medico-legal responsibility for the patients' safety (11). On the other hand, the preceptor's main role is to act as a guide for the trainee and to help him acquire new skills and knowledge, and he reports his feedback directly to the trainee himself in order to improve the trainee's performance. Moreover, the preceptor is responsible for the patient's safety from the medico-legal point of view (11).

One of the challenges facing proctoring or preceptoring is arranging a program for an old consultant because some surgeons are uncomfortable with the idea of their skills being assessed and evaluated by others and will resist such programs (10). Another obstacle facing this kind of programs is the busy timetable for both expert surgeons and trainee with difficulty in providing time for proctoring especially if the proctor and the trainee are not working in the same place (10).

Moreover, the two-dimensional (2D) monitors are one of the drawbacks of proctorship as the proctor will not have the same view of the operative field as the operating trainee in the console. This problem was solved by the introduction of the dual console da Vinci robotic system which, allows the proctor to use three-dimensional (3D) pointers to guide and instruct the trainee (12). Three-dimensional (3D) ghost tools are cheaper alternatives to the dual console da Vinci robotic systems. These ghost tools consisted of 3D pointers, 3D cartoon hands and 3D instruments that rendered the proctor able to see and move in 3D with enriched interactions (12).

Furthermore, another problem of proctorship is the absence of standardized certification for surgeons to become proctor or preceptor, according to the manufacturer of da Vinci robot a urologist requires to independently perform only 20 cases of robotic surgery to become a proctor and this is insufficient. Usually an experienced open surgeon in a suitable environment can usually perform independent robotic surgeries after five-proctored procedure (13).

b- Mentorship & Fellowships

Fellowship is considered one of the most structured and important forms of robotic training (13). Successful fellowship programs require dedicated and committed leaders to establish the framework for the program and to create an immersion learning experience for the trainees (14). Furthermore, mentors' training and accreditation are among the most important factors that affect the success of the fellowship programs (10). Other factors affecting the success of fellowship programs include the presence of financial support for the trainers, the hospital resources utilization and providing sufficient suitable time for the program (10).

The main aim of the fellowship is to produce a systematic method of teaching that is easily reproducible. Fellowships involve different methods of skills acquisition like simulators, animal models, cadaveric based models and may also involve observing robotic experts performing surgeries and having the ability to discuss what they have observed with their mentors or the robot experts (13,14). "Interactive hands-on-training" is one of the most powerful tools of transferring and teaching new skills to trainees and thus improving patient care and safety, and it is usually one of the main pillars of fellowship programs (14).

The main disadvantages of the fellowship programs are the geographic, financial and time burden on both the mentor and the trainee and one of the proposed solutions for this problem is the self-mentoring by partnered training (14). The presence of a well experienced and trained robotic team together with two surgeons working together (self-mentoring) during the initial phase of learning curve may be more effective in acquiring robotic skills than even proctorship (15).

Another form of mentorship and fellowship is the mini-fellowship (sometimes called miniresidency) which is preferred by most urologist as a method for learning robotic surgery as it only requires short period of time (usually few days) but the training is condensed and intensive (13,15).

c- Telementoring

Mentoring is usually done with the mentor and the trainee in the same room however, this is practically difficult if the mentor and the surgeon do not belong to the same institution (16). Telementoring can overcome this geographical limitation of mentoring by using technological advances to remotely mentor a surgical procedure through the transmission of video and/or audio data. In other words, telementoring is capable of bringing highly expert mentors to areas that lack this specialty (17).

Latency, which is the time required for the audiovisual information to travel from the source to the destination and it is considered the main obstacle facing the idea of telementoring. Usually, the range of accepted latency in telementoring is 500 - 600 ms (16).

As a result of these geographical and time limitation and the availability of few robotic surgery experts in correspondence with the increased demand of robotic training and surgeries, researchers invented a remote proctoring technology for *da Vinci* robotic system called *da Vinci* Connect™. This remote mentoring system allows mentors to observe trainee using their laptops while being able to give verbal instruction and seeing the trainee's same operative field (18).

d- Simulators

Simulators can be defined as a teaching and assessment platform that enables the trainee to perform a task or a procedure in an environment and conditions that replicates the real environment (19). The assumption that repeating a manual task improves its performance and that learning from failure results in error reduction are the main ideas behind the use of simulators in our life (8).

The main advantage of simulation in robotic training is that it works as a training platform for novice robotic surgeon allowing them to learn and practice robotic skills in a safe non-clinical environment without risking real patients. Furthermore, they can help trainees track the progress of their performance and skills. Moreover, they can be of a great value for expert robotic surgeons as it gives them the chance to re-adapt to the console immediately before cases (this is known as warm-up) (19).

Aydin A et. al. (20), classified simulator modalities into different categories including virtual reality simulators, augmented reality, bench top or synthetic models (either low fidelity or high fidelity), 3D printed models, animal tissue, living animal models, human cadavers (fresh frozen or thiel-embalmed), full immersion simulation and high fidelity operating room simulation. One of the important factors that need to be considered before using a simulator is the validation. Validity means the ability of a test to examine the competencies it is supposed to test (2). There are different types of validity including face validity, which determines if the test replicate the situation in real world or not, and content validity that determines if the designed test is really measuring what it is designed to measure. Other types of validity are, construct validity that determines the ability of the designed test to differentiate between different levels of experience and concurrent validity, which means that the designed test is comparable with the gold standard test designed to measure the same domain. Finally, the predictive validity means the ability of the test to predict the future performance of the trainee (2).

Virtual Reality (VR) simulators

Virtual Reality simulators use computer programs to create a virtual operative field that completely immerses the trainee in an experience very close to the real one. Virtual reality simulators have many advantages including: immediate evaluation and feedback of skill performance, re-usability and short set up time. On the other hand, they have some drawbacks like the cost, need for maintenance, the absence of real instruments and poor 3D vision. They can be best used for basic robotic skills acquisition (19-21).

Different types of virtual reality simulators are commercially available for robotic training including:

SimSurgery Educational Platform (SEP)

It consists of a console connected to two instruments with seven degrees of freedom; the console is capable of tracking the position of controllers in the space and duplicates this movement on a computer screen. The images in this simulator are 2D unlike the *da Vinci* robot.

The simulator is capable of measuring the time taken, error score and instrument tip trajectory for each performed task (22). Despite being commercially available, it did not gain wide acceptance as there is controversy regarding its validity (20).

The Robotic Surgical Simulator (RoSS)

It is another VR simulator with reported face, content and construct validity (19,23). It consists of a console that mimics that of da Vinci and offers 16 training modules with progressive difficulty. It currently integrates the Fundamental Skills of Robotic Surgery (FSRS) curriculum in the form of four modules (orientation, psychomotor skills, basic and intermediate surgical skills) (19,23).

ProMIS simulator

It is face, content and construct validated for robotic training. It is a box trainer that allows trainees to deal with virtual and physical models. It is also capable of objectively assessing trainee's performance (24,25).

Mimic dv Trainer (dVT)

It was released in 2007 and it is considered the most validated robotic simulator. It is face, content, construct and predictive validated (26,27). It is a portable offline virtual reality simulator that is characterized by 3D visual output, two fingers manipulators similar to that of the da Vinci robot and foot pedals. It is also capable of providing basic (Endowrist manipulation, camera, clutching and troubleshooting) and advanced skills training (needle control, suturing, cutting and dissection) (19,27).

Da Vinci Skills Simulator (dVSS)

The dVSS backpack is attached to the console of *da Vinci* Xi or Si enabling the trainee to practice directly on the *da Vinci* robot in a virtual environment either in the operation room or outside it. The use of *da Vinci* robot console for this simulator is considered a point of strength as it provides training with the same manipulators of the actual surgical robotic system. At the same time, it is a point of weakness as it limits the use of this simulator as it can be used only when the robot is free (20,28). The high cost of this simulator is another disadvantage. It has undergone extensive validation as regards to face, content, construct and concurrent validity (28,29).

Tube-3 Simulator

It is a VR model developed by Kang et. al. (30) in co-operation with Mimic Technologies in the USA, and it is used to practice vesicourethral anastomosis, which is considered one of the complex steps of robotic-assisted laparoscopic prostatectomy. It was designed to simulate the running sutures of the vesicourethral anastomosis using double-armed needle (31). Kang et al. (30), demonstrated face, content and construct validity of the Tube-3 simulator, while Kim et al. (31), demonstrated its concurrent and predictive validity.

RobotiX Mentor TM (3D systems, Simbionix Products, Cleveland, OH, USA)

It uses a da Vinci interface characterized by 3D vision, freely movable hand control and flexible foot pedals. It includes four training modules that provide training for many tasks. Multiple operative modules are available for training; however, the prostatectomy module is not yet validated. RobotiX Mentor shows face, content and construct validity (32).

Augmented Reality (AR) simulators

Augmented reality simulator is one of the most complex forms of simulators and the most realistic ones as it is capable of creating realistic surgical circumstances with anatomical illustration, narrative instruction and guided movements (33). However, their main disadvantages are the high cost and lack of real instruments and they can be best used for full procedure training (20).

There are two main AR simulators available, which are the Maestro AR and Hands-on-Surgical Training (HoST).

Maestro AR simulator

It combines both VR and AR to provide a procedure specific training. The AR component includes 3D high definition videos of the actual procedure integrated into an interactive exercise to aid improving cognitive (surgical anatomy and operative steps) and technical (tissue retraction, dissection and cutting) skills. This AR platform has gained face, content, construct and concurrent validity (34). The current available Maestro AR modules include partial nephrectomy, hysterectomy, inguinal hernia repair, prostatectomy Si, and prostatectomy Xi (35).

Hands-on-Surgical Training (HoST)

It is another AR simulator, which is an optional part to be integrated with the RoSS simulator. HoST simulator is enriched with narrative audio and video illustration of the designated procedure and anatomical explanation. This simulator has gained face and concurrent validity (36).

Bench top simulators

The bench top or synthetic models simulators (low fidelity) represent the most basic form of simulators like dry lab laparoscopic simulators and they are characterized by being less expensive, capable of improving surgical skills and their lightweight rendering them movable. Their main disadvantages are the lack of feedback, teaching only skills but not full procedures, the inability to create an environment that duplicates real environment and lower acceptance by trainees (19).

An example of the dry-lab is the Fundamental Inanimate Robotic Skills Tasks (FIRST) that consists of four inanimate skills including horizontal mattress running suture, clover pattern cut, pick and transfer and circular needle target. FIRST dry-lab simulator is face, content and construct validated (37).

3D Models

The 3D printed or synthetic models are mostly patient-specific models rendering them helpful for surgical planning, pre-surgical practice and training and thus can play an important role in improving the outcomes of difficult cases while minimizing the risk to the patient but it an expensive model for training (20). Von Rundstedt et al. (38), created 3D silicone kidney models based on the pre-operative Computed Tomography (CT) and Magnetic Resonant Imaging (MRI) for 10 patients with complex renal tumor and reported the construct validity of this robotic assisted partial nephrectomy training model.

Animal tissue and Living animals' simulator models

The use of animal tissue models for robotic training of special procedures has been reported in the literature (39,40). Simulators using animal tissue is cost-effective but they can be used only for single time and special facilities are required for their storage (20). Living animal simulators are high fidelity simulators that are capable of creating a more realistic environment for the trainee but they are not readily available because of their high cost, legal issues, anatomical variation and availability for single use only (33). Living animal simulators can be used for improving the dissection skills and full procedure training (20).

In vivo training in living animal models is still considered one of the most satisfactory training methods before practicing on real patients (41).

Cacciamani et al. (39), developed a new training model using chicken digestive apparatus for robot-assisted vesicourethral anastomosis that allows additional training on the posterior musculofascial reconstruction reported by Rocco.

Moreover, the most commonly used animals are porcine and chicken and they have been used for robotic and laparoscopic training of many procedures especially pyeloplasty, nephrectomy, partial nephrectomy and renal transplantation showing high efficacy (41).

Currently, the use of animals in training is becoming illegal in several countries like Great Britain and Canada because of the fear of contamination of healthcare workers with bovine spongiform encephalopathy (BSE) and other infectious diseases (42).

Human cadaveric simulators

One of the best simulators for training are the cadaveric model simulators which are high fidelity simulators that help the trainee understand the full procedure, give a better idea about the anatomical consideration of the procedure and give more confidence to the trainees. Nevertheless, they are available for single use only and characterized by high cost, low availability, different tissue quality between living and cadavers and potential risk of infection. They can be used for teaching advanced procedure especially minimally invasive surgeries and they are the gold standard for anatomic training (42).

Full Immersion Simulation and High Fidelity operating room simulation

These types of simulators focus mainly on non-technical skills simulation. They aim to improve all the robotic team performance and help them establish protocols to be strictly followed in cases of crisis (20). Overall, both trainees and trainers recognize the importance of different types of simulators so much so that many of them promote the idea of including it as a part of routine urological curriculum (41). Simulators play an important role especially during the initial period of the learning curve. Interestingly, it was reported in the literature that low fidelity simulators are more cost-effective than high fidelity ones when training novices (5).

e- Video Training

Video recording and replaying is one of the widely accepted methods of surgical training that is characterized by its ability to decreases the trainees' mental burden, shortens their learning curve and reduces the trainers' workload. It can be efficiently transferred to robotic surgery training so as to provide feedback to the trainee and thus help to shorten the learning curve. An efficient robotic video recording should not only include the operative field view but it should integrate a full description of the procedure including: the use of robotic manipulators, ergonomic position and the use of pedals (43).

EVALUATION OF ROBOTIC SKILLS

Skills evaluation is the key factor for a successful training program. Several tools have been proposed for evaluation of robotic skills including:

Robotic-Objective Structured Assessment of Technical Skills (R-OSATS)

The R-OSATS for each task assesses four main items that are, depth perception and accuracy, tissue handling, dexterity, and efficiency. Each item is given a score from 1-5 with a maximum score of 20 per skill. The higher the score the more efficient the skill was performed (44).

Global Evaluative Assessment of Robotic Skills (GEARS)

GEARS consists of 6 domains that are depth perception, bimanual dexterity, efficiency, autonomy, force sensitivity and robotic control. Each of which is given a score of 1-5 points on Linkert scale with 1 representing the worst performance and 5 resembling expert performance. The overall GEARS ranges from 1- 30. GEARS is a simple, validated and efficient robotic skill scoring system (45).

Peer assessment and Crowdsourcing evaluation

Blinded video assessment of trainees' or robotic surgeons' technical skills by an expert surgeon is an effective method of robotic skills evaluation that can improve the surgical outcomes but this is expensive and time consuming for the robotic expert (46). Crowdsourcing means obtaining the needed ideas, services or content by requesting it from a large group of people especially the online community rather than the classic supplier (47). It is demonstrated in the literature that both surgeons and crowd workers were able to spot differences in robotic skills, however the crowd workers were significantly faster than surgeons in reviewing videos of operative procedure and this emphasizes the important role of crowdsourcing in the evaluation of robotic skills (46, 47).

Robotic-Assisted Radical Prostatectomy (RARP) Assessment Score

RARP assessment score is a training and assessment score that evaluate the technical skills in robotic-assisted radical prostatectomy. A multidisciplinary team shared in mapping the steps of RARP into 17 processes and 41 sub-processes to develop this score. Each of which is given a score of 1-5 knowing that 1 is the worst performance of a skill and 5 is the highest. It is used to give an overview of the technical skills of the RARP operator (48).

CURRICULUM COMPARISON

Several surgical societies and surgeons have promoted the need for a standardized approach for basic training, assessment, testing, and certification in robotic surgery (8). Overall, all surgical curricula aimed towards one goal, which is safe and cost-effective acquisition of robotic skills.

FUNDAMENTALS OF ROBOTIC SURGERY

Recently, a multi-specialty group including the AUA proposed a structured curriculum for robotic training called Fundamentals of Robotic Surgery (FRS). FRS is a multi-specialty, proficiency-based curriculum of basic technical skills to train and assess surgeons in order to increase the patients' safety profile and the surgeons' efficiency (49). FRS is a model based on five-simulated tasks including camera targeting, pegboard, ring walk, energy dissection, and suture sponge, based on skill simulator for Da Vinci Si. The FRS focuses mainly on three main components: cognitive components, psychomotor skills, and team-based training and communication (49).

It is divided into four modules including (50):

1. Introduction to Surgical Robotic Systems: this the surgeon's gate to the robotic world as soon as he decides to get involved with robotic activity.

2. Didactic Instructions for Robotic Surgery Systems: this module is concerned with introducing and improving the cognitive skills of the trainee.

3. Psychomotor Skills Curriculum: this module is responsible for training and evaluating the skills of surgeons interested in robotic surgeries. It includes seven simulated tasks:docking/instrument insertion, ring tower transfer, knot tying, railroad track, fourth arm cutting, puzzle piece dissection, and vessel energy dissection.

4. Team Training & Communication Skills: team-based training approach and communication skills are among the important factors affecting robotic training.

Despite FRS is a complete model, it is not yet transferred to real practice. This model forms the outline for the development of a well-structured and standardized robotic training program that can fit in any specialty. Currently, FRS model is in the process of validation (8,51).

FUNDAMENTAL SKILLS OF ROBOTIC SURGERY (FSRS)

This curriculum consisted of well-structured models designed for acquiring basic skills of robot-assisted surgery. The FSRS curriculum is virtual reality based, and it consists of 4 modules; module one is known as the orientation module and it is concerned with robotic knowledge, how to get familiar with robotic and it is divided into: instrument control, camera control, coordinated tool control and 4th arm control. Module two is the motor skills and it is concerned with teaching technical skills, moreover, it is divided into: ball drop, ball placement, spatial control I (pass a ring along a curved wire) and spatial control II (pass a thread through a series of ring). The third module is known as basic surgical skills, it focuses on integration, and it consists of needle handling and exchange, needle removal, basic electrocautery and tissue cutting. Finally, module four is the intermediate surgical skills. It also focuses on integration and is divided into: tissue retraction, blunt tissue dissection, vessel dissection and knot tying (52). The FSRS curriculum has been validated for construct validity (51).

These four modules contain 16 tasks each of which has 3 difficulty levels followed by a stage of evaluation (53). The FSRS tasks have been integrated in a validated VR simulator (RoSS TM) that is developed by the same team. In order to assess the level of robotic skills, a validated score was used known as Robotic Skill Assessment score (RSA-Score). RSA-Score mainly focuses on safety in operative field, critical error, economy, bimanual dexterity and time. This score showed construct validity and despite it is developed for FSRS, it can also be used with other simulators (23).

EAU ROBOTIC UROLOGY SECTION CURRICULUM

The European Urological Association (EUA) section of Robotic Urology (ERUS) developed a structured training program and curriculum in urology that concentrates mainly on robotic-assisted radical prostatectomy (RARP). This curriculum is developed based on panel discussions of robotic experts (54). The ERUS fellowship program is a 6 months program that consists of progressive learning goals. It starts with E-learning where the applicant gains knowledge about the basics of robotic surgery and anatomic consideration and this is considered the stage of theoretical training. Later on, the trainee starts live surgery observation for 1 month. Starting from the 5th week, trainee starts advanced robotic skill course that includes procedural-specific theoretical training, hands-on-training in the form of simulators, dry-lab and wet-lab and non-technical skills training which are represented by social, cognitive and personal skills. Finally, from the 2nd month till the 6th month, the trainee starts modular robot-assisted radical prostatectomy console training and full procedure training where RARP is divided into 10 steps each with different degree of difficulty and each step is performed by the trainee for a specific number of times until he masters the step. Then the full procedure training is recorded after 6 months and sent for blind evaluation without any editing. Throughout the 6 months, an assessment of the technical skills on simulator and dry lab is performed on days 1, 28, 35 and 180 (55).

The 10 steps of modular robot-assisted radical prostatectomy console training are divided into 4 groups (55):

• Group A (steps requiring repetition for at least 20 cases before mastering the technique): bladder detachment and endopelvic fascia incision.

• Group B (steps requiring repetition for at least 15 cases before mastering the technique): bladder neck incision, section of vasa and preparation of vesicles and urethra-vesical anastomosis.

• Group C (steps requiring repetition for at least 10 cases before mastering the technique): dissection of posterior plane, dissection of prostatic pedicles, ligation of Santorini plexus and apical dissection.

• Group D (steps requiring repetition for at least 5 cases before mastering the technique): dissection of neurovascular bundles.

In their initial experience, the mentor's evaluation with validated tools showed a satisfactory performance for 80% of the trainees. So, this course has shown significant improvement in robotic skills in its infancy validation stage (54).

OTHER CURRICULA

Proficiency-based curriculum was designed and developed by a group from the University of Texas Southwestern Medical Center. It consists of 3 curricular components: firstly, an online tutorial (multiple choice questions) that is offered by Intuitive Surgical for free and it include audiovisual tutorials for different *da Vinci* systems. Secondly, a half-day interactive session (global rating scale is used to determine the proficiency of each domain) consisting of a 4-hour session in skill lab on actual *da Vinci* systems with a proctor giving lectures and hands-on-training. Thirdly and finally, hands-on practice using 9 inanimate exercises with a scoring system to determine the level of proficiency in each skill based on error and time. The course duration is 2 months and consists of 9 tasks to be performed by trainees until they reach suitable levels of proficiency (49).

FUTURE PROSPECTIVE OF ROBOTIC TRAINING

Societies and organizations are exerting more and more efforts to provide a well-structured, validated and accepted robotic training curriculum. The path of robotic training is still long and we are taking our first steps along this road. The exerted efforts will result in the formation of a crediting curriculum that will become in the future an essential requirement for robotic surgeons before independently operating on real patients. Telementoring and augmented reality simulators are believed to play a bigger role in the future and help improving the quality of trainees.

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