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5.1 The Rationale Behind the Need for Validated Robotic Surgery Training Curricula

Under the influence of technological evolution, surgery has undergone a major transformation leading to the development and application of minimally invasive surgical techniques. Starting in the early 1980s, minimally invasive surgery quickly and widely became the “gold standard” for many surgical interventions which previously were performed only in the classical, “open” approach. This innovation has allowed for less surgical trauma, postoperative pain, shorter length of stay, better cosmetic results, and earlier functional recovery relative to open surgery [1].

Over the last decades, robotic surgery has emerged as a novel technology which has revolutionized the field of minimally invasive surgery. This innovative technique has become an integral part of many different surgical specialties such as urology, general, thoracic, cardiac, and head and neck surgeries [2–5]. Since the introduction of robotic surgery in the mid-1990s, its implementation has increased exponentially, with more than 5,000,000 robot-assisted procedures performed by 2017 with the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, USA) [6]. Moreover, in specific surgical fields, such as urology, robotic surgery has become the preferred surgical approach for several procedures [3, 4, 7–10].

However, this innovation has also created new challenges in terms of training and teaching. Robotic surgery comes with specific difficulties since the platform is very different from other forms of surgery [11]. Just as the Fundamentals of Laparoscopic Surgery (FLS), a validated, evidence-based skills program, was born in response to the need for specific training in laparoscopic surgery, the same need for training is developing in robotic surgery. Although seen as an evolution of laparoscopic surgery, the skills needed in robot-assisted surgery are unique and cannot be compared to those needed in laparoscopic or open surgery [2, 4, 5, 12, 13]. In robotic surgery, the required skills are mainly for console control, maneuvers without haptic feedback, and communication with the bedside assistant. Conversely, in laparoscopic surgery, the required skills are mainly for 2D surgery with instruments with a restricted range of motion. The guidelines that exist for training in laparoscopic surgery therefore cannot be considered an equivalent to robotic surgery [2, 4, 12].

While the role of robot-assisted surgery is expanding rapidly and widely, there is lack of structured training in robotic surgery. Specified and centralized competency standards for new robotic surgeons do not exist [9]. In 2013, a group of experts expressed concern that robotic surgery training is random and insufficient to ensure patient safety [4]. An independent review from the Emergency Care Research Institute (ECRI), an institute on health technology hazards, in 2015 identified a lack of robotic surgical training as one of the top 10 risks to patients [14]. Therefore, the development of standardized and validated training programs is urgently needed. In order to introduce robotic surgery to surgeons in a safe and efficient way without compromising surgical outcomes and patient safety, new, specific, and structured educational curricula as well as proficiency-based credentialing processes are needed. Furthermore, in robotic surgery, the importance of team training is essential. Specific trainings for all members of the surgical team, consisting of the console surgeon, the bedside assistant, the scrub nurse, the circulating nurse, and the anesthesiologist, are necessary since they all need to understand the spatial relationships

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of the instruments outside the vision of the surgical field to ensure patient safety and avoid involuntary tissue injury [3].

Robotic surgery training curricula increase preclinical exposure avoiding patients to be used as a training module, which is unacceptable from an ethical point of view. Validated curricula will help standardization of training in robotic surgery with accreditation and certification of surgeons for robot-assisted surgery [2–4, 9, 12, 15].

The aim of this chapter is to highlight the aspect of training in robotic surgery. We will discuss the organization and validation of training curricula with robotic surgeon credentialing as a final goal, including an overview of all currently available robotic surgery training curricula and the status of their validation.

5.2 What Does a Proper Robotic Training Curriculum Look Like?

Training should occur in a modular fashion with a well-structured road map (Fig. 5.1) [2].

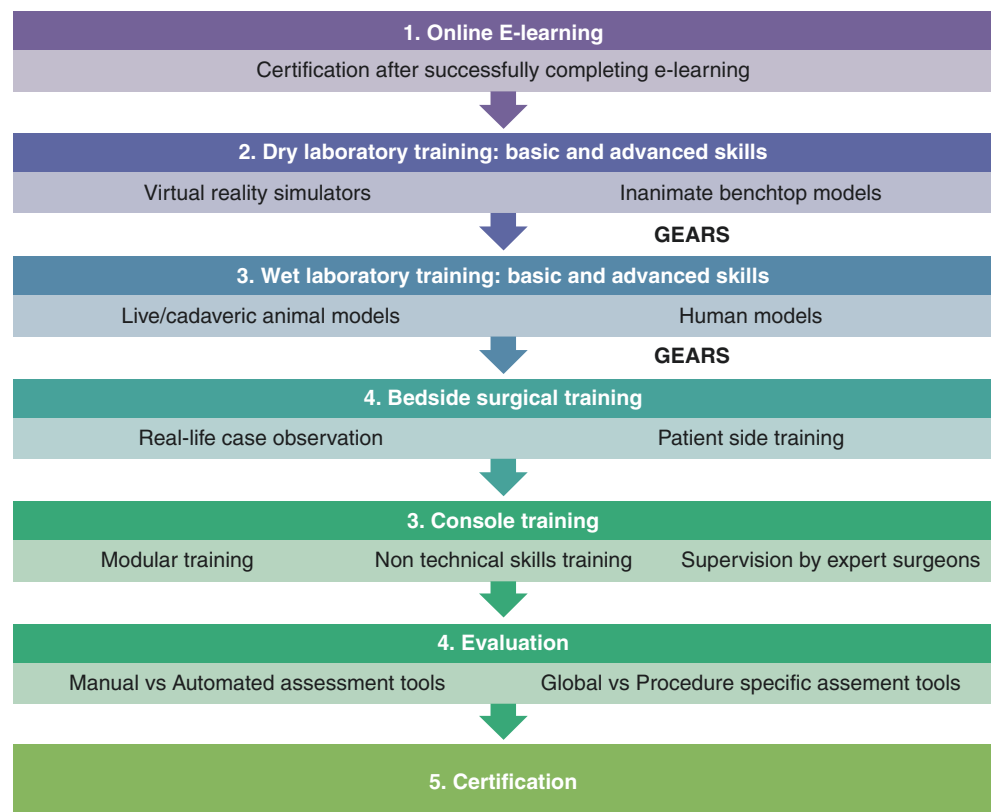
A training curriculum should start with adequate theoretical knowledge development. A trainee should become familiar with the robotic technology by education on the specific robotic device's parameters and functions. Knowledge and working of the console are of the utmost importance.

Instructions on troubleshooting and the limitations of the operating system are essential. Online modules are available that introduce the basic concepts of the only commercially available system, the Da Vinci Robot (<https://www.davincisurgerycommunity.com/Training?tab1=TR>). Certification in these online modules is essential before starting any console training [2–4, 15].

After a trainee is well educated on the robotic platform, the training of robotic technical skills can start. The first step consists in performing dry lab exercises on inanimate benchtop models or virtual reality-simulated environments. These exercises are an important step in achieving basic and advanced console skills and improving coordination development, bimanuality, dissection, and suturing techniques. Simulators are cheap to run, well tolerated, convenient, and efficient [2, 4, 12, 15]. However, the exercises that we can perform with virtual reality simulators lack bleeding and do not compare with real-life surgery.

The wet lab should be the next step in training after basic surgical skills are acquired in the dry lab. In the wet lab, surgical techniques are trained on cadaveric (i.e., dog model) or live animals (i.e., porcine model) or human cadavers. These anatomical models are more comparable to real-life surgery, allowing the trainees to learn to recognize the robustness and consistency of real tissues and to simulate complete surgical procedures and emergency scenario such as vascular/organ

Fig. 5.1 The structure of a robotic training curriculum



injuries. However, wet labs imply great costs and a large number of animals to be sacrificed [2, 4, 12, 15]. Worldwide, there are 24 recognized, fully equipped educational centers for wet lab training. In Europe, there are three recognized training centers offering a wet lab: the European Robotic and Minimal Invasive Surgery Institute ORSI Academy (Melle, Belgium), the Center of Advanced Simulation and Education (CASE) (Istanbul, Turkey), and Practicum Clinical Skills Centre (Lund, Sweden).

Subsequently, real-life case observation in a training center is essential. This should include patient-side training with learning of basic surgical skills such as patient positioning, establishing pneumoperitoneum, procedure-specific port placement, robot docking, and basic laparoscopic skills [2, 12].

Only after going through all these steps a trainee can start performing supervised surgery in a modular fashion under the supervision of expert surgeons. The presence of a dual console is strongly encouraged, allowing two surgeons to interact and operate at the same time, thus resulting in better control [3, 12, 15]. The learning curriculum ends with independent performance of surgery [3, 4, 12, 15].

Besides training in technical robotic surgical skills, trainees should also be trained in nontechnical skills, including surgical cognitive skills (surgical knowledge, decision-making, planning, and situational awareness) and social skills (abilities of leadership, communication, and teamwork). Cognitive and interpersonal skills and team organization lead to effective transmission of robotic surgical care, but a lack of nontechnical skills may impact patient safety and can lead to adverse events [2, 8, 9]. Nontechnical skills training and team training therefore must be an integral part of robotic training curricula, with the possibility to learn through a simulation training that can replicate common and emergency scenarios in robotic surgery [16].

The curricula must include a final evaluation that allows to verify the learning of the procedure. Only after positive evaluation, the trainee should be certified as a robotic surgeon.

Nowadays, the training in robotic surgery is not organized, and centralized competency standards do not exist. Moreover, the process of robotic surgery certification lacks consistency [3, 4, 9, 17–19]. Therefore, consistent and validated surgical curricula are essential in the standardization of training, accreditation, and certification of surgeons for robot-assisted surgery.

An adequate and effective robotic surgery training curriculum should encompass a complete preparation on performing robotic surgery in a safe way with good clinical outcomes. Therefore, the development of these training curricula requires a systematic approach. Once learning needs are identified and integrated in a curriculum, validation is essential before implementation (Fig. 5.2) [4].

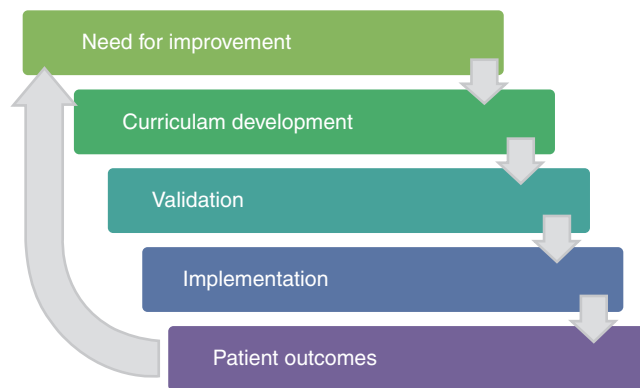


Fig. 5.2 Pathway for development of a training curriculum

5.3 How to Validate a Robotic Surgery Training Curriculum

To develop a structured and validated curriculum, it is fundamental first of all to identify the right population to be trained and to assess the time needed for each step of the curriculum [20]. A training curriculum to be validated and implemented should undergo different degrees of validation (face, content, construct, concurrent and predicted validity) and should be reproducible (reliability), feasible (feasibility), and acceptable (acceptability) [21]. Educational impact and cost-effectiveness are also mandatory to assess before its implementation (Fig. 5.3) [21–23].

The main goal of training curricula in robotic surgery is to objectively demonstrate that performing a proposed training program will result in improved robotic surgical performance in clinical practice, thus proving concurrent validity (Fig. 5.3) [23]. Seen the need of robotic surgeons to have a defined, clear, and coherent training, it is necessary to specify the validation modality of the programs in which these surgeons are trained. The validation of a robotic training curriculum proves its educational impact and its potential to differentiate between different levels of competence and is therefore essential [24].

A recent review performed by Ahmed et al. [24] on observational tools for assessment of procedural skills underlines that the validation process of a study in which technical skills are assessed should be performed in a well-powered, experimental study in a controlled environment. Trainees should be evaluated by different independent and blind assessors (inter-rater reliability). The results of different test items should be compared for internal consistency (inter-item reliability), and the same assessor should rate the performance of the same subject at two different occasions (e.g., on different times) for test-retest reliability. Construct validity can be determined by dividing different tests for various levels of training, and concurrent validity may be established by

Fig. 5.3 Definition of construct

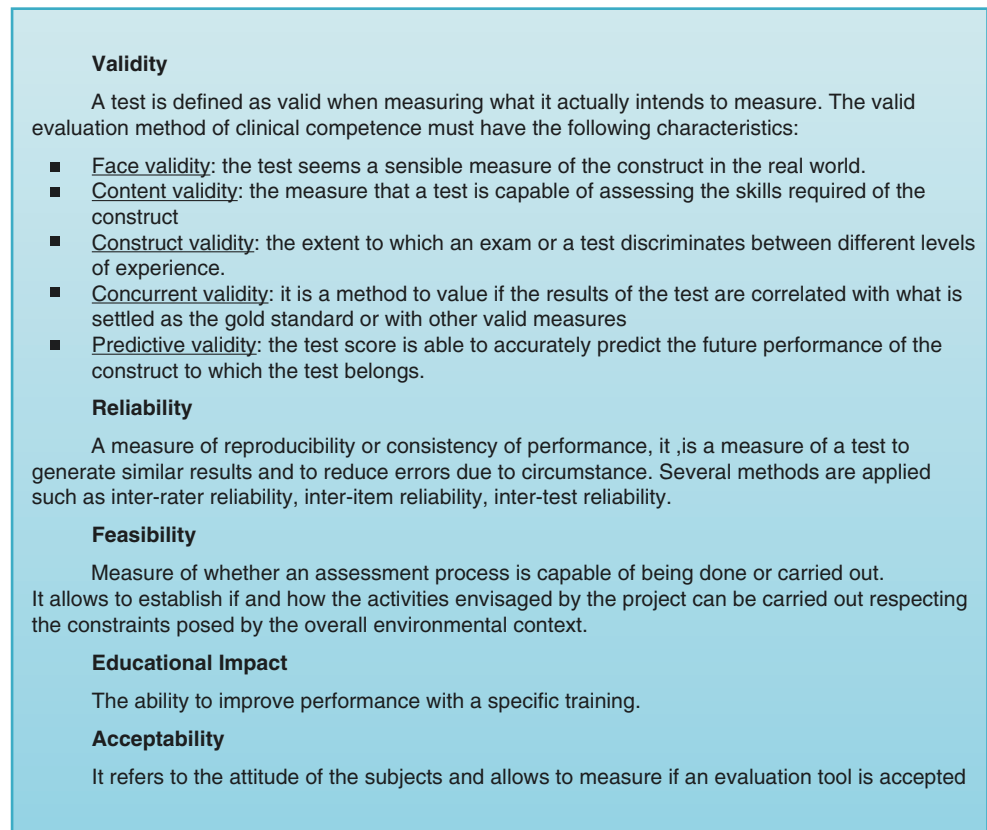
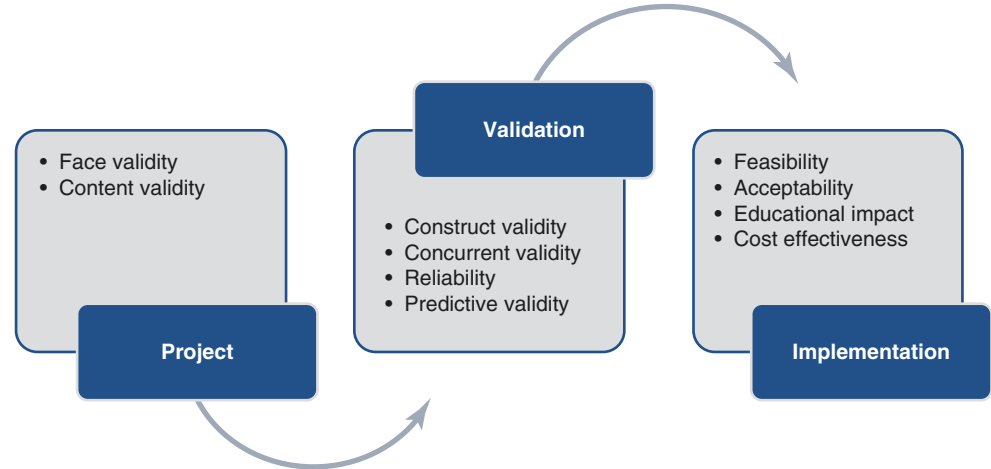


Fig. 5.4 Recommended design of a curriculum for validation and implementation



correlating the tool to a gold standard method if available [24]. In practice, the validation of a robotic surgery training curriculum should occur in a randomized study, performed in a robotic surgery center of excellence. The performance of trained and untrained participants should be evaluated and compared objectively by use of validated assessment tools. In order to make the curriculum internationally recognized, the leading, recognized world-governing bodies for the specific specialty must be involved [4].

Before implementation at the institutional level, training curricula need to be evaluated for feasibility, acceptability, educational impact, and cost-effectiveness. Using surveys or interviews with trainees, it is possible to recognize the feasibility and acceptability of the training, while the educational impact can be assessed by providing constructive feedback to the participants. Cost analysis of the process depends on many aspects including the evaluation environment and the geographical area in which the program is run (Fig. 5.4) [23].

5.4 Robotic Surgery Training: Virtual Reality Robotic Surgery Simulators

To familiarize with the robotic system, it is necessary to start the practice with the use of virtual simulators. Indeed, virtual reality robotic surgery simulators are an integral part of all currently available major robotic surgery training curricula. Simulators give a safe environment for trainees to learn how to use the robotic surgery platform and to develop robotic surgical skills. The robotic system is ideal to integrate different forms of simulation next to classical surgical teaching [3, 17]. In this way, trainees may pass their basic learning curve on a simulator and use it as a bridge before starting with real-life surgery. Patient safety and surgical outcome are thereby ensured [3, 17, 18].

Evidence suggests that simulators should be integrated into proficiency-based curricula for training in basic robotic surgical skills and procedural tasks prior to independent practice since training on VR training consoles may improve performance in real life [2, 3, 19, 25]. However, there is lack of strong evidence on the predictive validity of the simulators, i.e., the application of skills gained using simulators to real-life robotic surgery [2, 7, 10].

The first virtual reality robotic surgery simulator was introduced in 2010. So far, six virtual reality simulators are commercially available for robotic surgery training: the da Vinci Skills Simulator (by Intuitive Surgical, Sunnyvale, USA), the Robotic Surgical Simulator (RoSS) (by Simulated Surgical Systems, Buffalo, USA), the SEP robot (by SimSurgery, Norway), the dV-trainer (by Mimic Technologies Inc., Seattle, USA), the ProMIS (Haptica, Ireland), and the RobotiX Mentor (by 3D systems, Israel) [2, 4, 10, 26].

All these simulators underwent evaluation of their validity in different studies. Different degrees of validation are possible [2, 10, 12]:

- **Face validity:** The extent to which the simulator resembles a real-life situation. This is generally determined by a group of experts.
- **Content validity:** The extent to which the skills tested by the simulator accurately represent the skills required in robotic surgery.
- **Construct validity:** The extent to which the assessment exercise measures the intended content domain or the extent to which the simulated task discriminates between operators of different levels of surgical skill.
- **Discriminant validity:** The extent to which a simulator is able to differentiate between ability levels within a group with similar experience.
- **Concurrent validity:** The extent to which the simulator scores and actual robotic scores are comparable for a similar task.

- **Predictive validity:** The extent to which the performance on the simulator predicts future performance on the robotic platform when used clinically.

All simulators (regardless of add-ons) have been evaluated in literature to have at least face, content, and construct validity, except for RoSS which did not show evidence of construct validity [2, 27].

The most frequently used simulator today is the da Vinci Skills Simulator (dVSS). This simulator is actually a customized computer package that runs on the actual surgical console. It exists for both the Si and the Xi da Vinci systems and offers basic to advanced training modules [12]. The simulator allows instant feedback with an overall score that takes into account both performance efficiency in time, movement economy, and penalty metrics. Modular training add-ons for specific complex procedures, such as radical prostatectomy and hysterectomy, are available. Face, content, construct, concurrent, and predictive validity have been proven in literature [12, 26, 28–30].

The Mimic dV-Trainer (MdVT), RoSS, and RobotiX Mentor are stand-alone virtual reality robotic surgery simulators that mimic the da Vinci Surgical System. All three simulators offer multiple basic to advanced training modules with comprehensive performance metrics, evaluated by an automated, integrated system [3, 12, 17, 26, 31–34].

MdVT, RoSS, and the RobotiX Mentor offer procedure-specific modules in which trainees interact with a 3D virtual reality anatomical environment. Maestro AR, the procedure-specific add-on of the MdVT, offers training in right partial nephrectomy, hysterectomy, inguinal hernia repair, and radical prostatectomy for both da Vinci Si and Xi [2, 26]. The Tube 3 module of the MdVT is specifically designed to train the vesicourethral anastomosis, thereby increasing the performance of trainees in one of the most complex steps in robot-assisted radical prostatectomy [26, 34]. The Hands-on-Surgical Training (HoST) add-on of RoSS offers training in radical hysterectomy, radical prostatectomy, radical cystectomy, and extended lymph node dissection [2, 26]. The RobotiX Mentor offers training in complete surgical procedures such as radical prostatectomy, hysterectomy, lobectomy, inguinal hernia repair, and right hemicolectomy [17, 26, 35].

Both the RobotiX Mentor and the MdVT offer a laparoscopic assistant component in parallel with the virtual reality console. This allows simultaneous training of both a surgeon and a bedside assistant, improving coordination, communication, and teamwork. For the MdVT, this is a specific add-on called the Xperience Team Trainer [2, 26, 36–38].

The SimSurgery Educational Platform (SEP) Robot and the Da Vinci-ProMIS surgical simulator are two robotic surgery simulators that are modifications of previous laparoscopic simulators. In these simulators, the basic lapa-

Table 5.1 Properties of currently available robotic surgery simulators

Name	dVSS	MdVT	RoSS	SEP	ProMIS	RobotiX Mentor
EndoWrist manipulation	Yes	Yes	Yes	Yes	No	Yes
Camera control and clutching	Yes	Yes	Yes	No	No	Yes
Fourth-arm control	Yes	Yes	Yes	No	No	Yes
System settings	Yes	Yes	Yes	No	Yes	Yes
Needle driving	Yes	Yes	Yes	No	Yes	Yes
Energy and dissection	Yes	Yes	Yes	No	No	Yes
Performance measures	Yes	Yes	Yes	Yes	Yes	Yes
Developed for robotic surgery	Yes	Yes	Yes	Yes	No	Yes
Cost (US dollars)	89.000	158.000	120.000	62.000	35.000	95.000

EndoWrist manipulation: The instruments are designed to have seven degrees of freedom and to reproduce the movements of the surgeon's hand
 Camera control and clutching

Fourth-arm control: It allows to integrate the movement of the fourth arm and to reason on its use

System settings: Settings for the console

Needle driving: Needle control, movements that help surgeons to manipulate needles

Energy and dissection: Modules that help user to understand the different type of energy instruments and change type of energy and arm with the footswitch panel

Performance measure: A score after all the module is given and its values, for example, economy in motion, instruments conflict, time to complete the entire module, etc.

Table 5.2 Overview of currently available robotic surgery simulators and add-ons and the status of their validation

Name	Face validity	Content validity	Construct validity	Concurrent validity	Predictive validity
Da Vinci Skills simulator (dVSS)	Yes	Yes	Yes	Yes	Yes
Mimic dV-Trainer (MdVT)	Yes	Yes	Yes	Yes	No
Maestro AR	No	No	No	No	No
Tube-3 Module	Yes	Yes	Yes	Yes	Yes
Xperience Team Trainer	Yes	Yes	No	Yes	No
Robotic Surgery Simulator (RoSS)	Yes	Yes	No	No	No
SimSurgery Educational Platform (SEP) Robot simulator	Yes	Yes	Yes	No	No
ProMIS	Yes	Yes	Yes	No	No
RobotiX Mentor	Yes	Yes	Yes	No	No

roscopic instruments have been replaced by the wristed instruments with seven degrees of freedom as found in the da Vinci Robot. The SEP robot is a virtual reality simulator which offers different exercises in which trainees are evaluated based on instrument tip trajectory, time, and error scores [39]. Although being a cost-effective alternative to other simulators, SEP has a lot of shortcomings: it does not offer the possibility to train clutching, needle control, and driving or dissection exercises as in other simulators. Furthermore, a fourth robotic arm, three-dimensional images and performance feedback are not provided by SEP [3, 26].

The da Vinci-ProMIS surgical simulator is a hybrid simulator in which the da Vinci Surgical System is docked to the ProMIS bodyform, a plastic mannequin covered with neoprene. Inside the simulator, three camera-tracking systems detect the instruments inside the simulator, offering evaluation of time, economy of motion, and instrument path length for both virtual and physical training models [26, 40].

Properties of all virtual reality robotic surgery simulators and the status of their validation are summarized in Tables 5.1 and 5.2 [22].

5.5 Training Curricula in Robotic Surgery

Although multiple, well-developed training programs exist for both open and laparoscopic surgical skills development, the versatility in training curricula in robotic surgery is much smaller.

A large number of available "training curricula" are available worldwide (Table 5.3). However, the term "curriculum" is broad. Some curricula are industry-led short training sessions which lack any formal assessment of competency, whereas others are all-inclusive fellowship-style courses that take months to complete [5, 43, 59]. Of all existing curricula for robotic surgical training, only a few were validated [9, 18, 19, 43, 59].

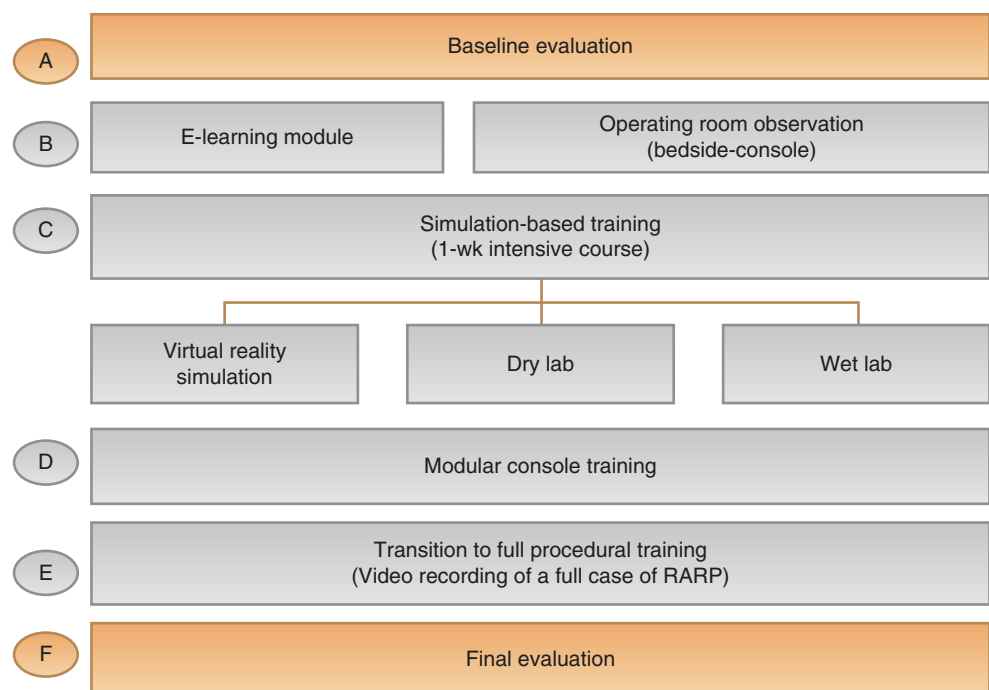
Table 5.3 Currently available robotic surgery training curricula and the status of their validation

Robotic surgery training curricula								
Name	Study	Year	Dry lab/ simulation	Wet lab	Modular training	Real-life surgery	Validation	Specialty
Fundamentals of robotic surgery (FRS)	Smith R et al. [13]	2014	Yes	No	Yes	No	Not validated	Multispecialty
Fundamental Skills of Robotic Surgery (FSRS)	Stegemann AP et al. [18]	2013	Yes	No	No	No	Validated	Multispecialty
Roswell Park Cancer Institute Robot-Assisted Surgical Training (RAST) program	Attalla K et al. [41]	2013	Yes	Yes	Yes	No	Not validated but uses FSRS	Multidisciplinary
ERUS robotic surgery training curriculum	Volpe et al. [19]	2014	Yes	Yes	Yes	Yes	Validated	Urology
Proficiency-based robotic curriculum	Dulan G et al. [42]	2012	Yes	No	No	No	Validated	Multidisciplinary
University of Toronto Basic skills training curriculum (BSTC)	Foell K et al. [43]	2013	Yes	No	No	No	Validated	Multidisciplinary
Society of European Robotic Gynaecological Surgery (SERGS) curriculum	Rusch P et al. [44]	2018	Yes	Yes	Yes	Yes	Validated	Gynecology
“Western Protocol” Cardiac Surgery Virtual reality curriculum	Valdis M et al. [45]	2015	Yes	No	No	No	Validated	Cardiac surgery
Fundamentals of robotic surgery: Orlando group	Macgregor JM et al. [46]	2012	Yes	No	No	No	Not validated	Multidisciplinary
Association of Program Directors for Colon and Rectal Surgery (APDCRS) Robotic Colorectal Surgery Training Program	Not published [47]	2017	Yes	No	No	Yes	Not validated	Colorectal surgery
East Carolina University (ECU) robotic surgery training program	Chitwood WR et al. [48]	2001	Yes	Yes	No	No	Not validated	Mitral valve repair, cholecystectomy, Nissen fundoplication
Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) Robotic Surgery Curriculum	Hanky EJ et al. [49]	2005	Yes	No	No	No	Not validated	General surgery
University of Pittsburgh Medical Center (UPMC) Center for advanced robotics training (CART) Robotic Head and Neck surgery program	Not published [50]	2015	Yes	Yes	No	No	Not validated	Head and neck surgery
University of Pittsburgh Medical Center (UPMC) Center for advanced robotics training (CART) thoracic surgery robotics training program	Not published [50]	2015	Yes	Yes	No	No	Not validated	Thoracic surgery
University of Pittsburgh Medical Center (UPMC) Center for advanced robotics training (CART) Surgical oncology Robotics Training program	Not published [50]	2015	Yes	Yes	No	No	Not validated	General surgery and hepatopancreaticobiliary surgery
British Association of Urological Surgeons (BAUS) Robotic surgery curriculum	Not published [51]	2015	Yes	Yes	Yes	Yes	Not validated	Urology
University of Alabama at Birmingham (UAB) Robotic surgery Curriculum	Not published [52]	NA	Yes	No	Yes	Yes	Not validated	Gynecology
Samaritan Hospital General and Colorectal Surgery group Robotic Surgical Training program	Madureira FAV. et al. [53]	2017	Yes	Yes	Yes	Yes	Not validated	General surgery and urology

(continued)

Table 5.3 (continued)

Robotic surgery training curricula								
Name	Study	Year	Dry lab/ simulation	Wet lab	Modular training	Real-life surgery	Validation	Specialty
Texas Association of Surgical Skills Laboratories (TASSL) Training collaborative	Lyons C et al. [54]	2013	Yes	No	No	No	Not validated	Multidisciplinary
Robotic Training Network Curriculum	Not published [55]	NA	Yes	No	Yes	Yes	Not validated	Gynecology and general surgery
Fellowship of International College of Robotic Surgeons (FICRS)	Not published [56]	NA	Yes	No	No	Yes	Not validated	Multidisciplinary
Transoral Robotic Surgery Curriculum (TORS) Training curriculum	White J et al. [57]	2018	Yes	Yes	No	No	Not validated	Otorhinolaryngology
Emory University School of Medicine Robotic Surgery Training Curriculum	Not published [58]	NA	Yes	No	No	Yes	Not validated	General surgery

Fig. 5.5 Structure of the European Association of Urology Robotic Training Curriculum. (Reproduced with permission [19])

5.5.1 The European Association of Urology Robotic Training Curriculum

The European Association of Urology Robotic (ERUS) training curriculum (Fig. 5.5) is a 3-month comprehensive training course which was developed based on an expert panel discussion with the robot-assisted radical prostatectomy as index procedure [19]. After undergoing a specifically developed e-learning module, trainees observe and assist during live surgery for 3 weeks. This is followed by an intensive week of simulation-based training, including virtual reality simulation (using the dVSS), dry lab, and wet lab training platforms. The technical robotic skills included are EndoWrist manipulation, camera movement and clutching, use of energy and dissection, and needle driving.

Improvement of technical skills is assessed by comparing the scores at baseline and on final assessment using the inbuilt validated assessment metrics on the dVSS [9, 19].

After the simulations, trainees move on to the fellowship stage, which consists of a supervised modular training program in robot-assisted radical prostatectomy with proficiency-based, progressive training of surgical steps with increasing complexity.

The training continues until trainees fulfill a complete robot-assisted radical prostatectomy. During these procedures, the surgical quality of each step is assessed by use of a validated RARP procedure-specific scoring scale. Procedural skills are evaluated by the mentor using the validated Global Evaluative Assessment of Robotic Skills (GEARS) score [9, 19].

A video of the final RARP performed by the trainee is recorded and reviewed by two blinded expert robotic surgeons. They use a generic dedicated scoring criterion for each procedural step to make a final overall score for each trainee, which can then be compared to the score of expert robotic surgeons.

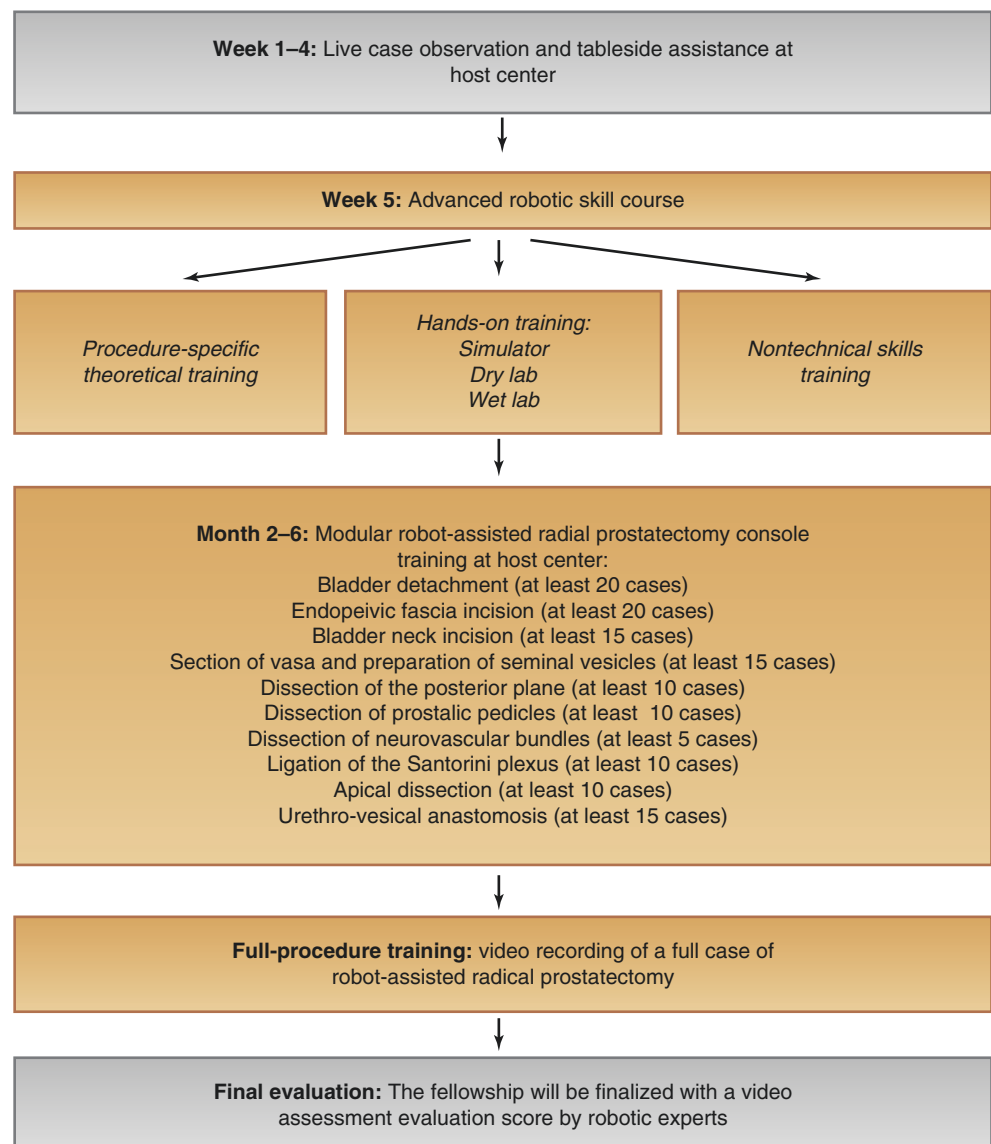
Volpe et al. [19] assessed the validity of the ERUS training curriculum, enrolling ten international fellows in the training program. All trainees completed the e-learning module and passed the final test for the assessment of theoretical knowledge successfully. Afterward, the trainees observed and witnessed a minimum number of procedures (>12 cases) during 3 weeks. The trainees then followed an intensive week of laboratory training, after which their overall score for dVSS tasks significantly increased. In the next 8 weeks, trainees started with supervised modular training, in which they were involved as surgeons in, on average, 18 operations. After completing the curriculum, 80% of train-

ees was deemed able by their expert supervisors to perform a RARP independently, effectively, and safely. Volpe et al. [19] proved that the structured 12-week ERUS training curriculum is feasible, acceptable, and effective in improving the robotic technical skills and abilities of young surgeons with limited robotic experience to perform the crucial steps of robotic radical prostatectomy [9, 19]. The face, content, and construct validity of the ERUS training curriculum have been demonstrated [9, 19, 59].

In 2016, an update of this training was published that extends the training period of 3 months for a total of 6 months (Fig. 5.6) so that even the most inexperienced participants are confident to continue and finish the training with the awareness of having the time to improve [9].

A model of this type could represent the ideal training opportunity for naïve surgeons who need both theory-based and practical (domain and technical knowledge) for a specific surgical procedure [9].

Fig. 5.6 Structure of the European Association of Urology Robotic Training Curriculum (Update). (Reproduced with permission [9])



5.5.2 Fundamental Skills of Robotic Surgery (FSRS)

The Fundamental Skills of Robotic Surgery (FSRS) training curriculum is a validated, structured, simulation-based training program that was created by the Roswell Cancer Institute in Buffalo, USA. The curriculum consists of four modules (orientation, motor skills, basic and intermediate surgical skills) with a series of 16 tasks, with each task containing three difficulty levels and an evaluation phase (Fig. 5.7). The curriculum is performed on the validated RoSS simulator, which automatically records and saves performance metrics of trainees. The tasks were specifically created by a group of expert robotic surgeons with integration of previously validated tasks from the Fundamentals of Laparoscopic Surgery curriculum [18, 59].

In the validation study of the FSRS, 53 participants without any previous robotic surgical experience were included whose performance was assessed by three tasks that had to be performed three times each on the da Vinci Surgical System: ball placement, suture pass, and fourth-arm manipulation. The participants were randomized in two groups: an experimental group (EG) and a control group (CG). Participants of both groups received a didactic session to introduce the

da Vinci Surgical System, led by an experienced operator. Participants included in the EG completed the FSRS training curriculum once in three to four sessions before completing the three tasks, while participants of the CG had to complete the tasks without completing the FSRS curriculum. Finally, after completing the three tasks, the participants included in the CG were offered to complete the FSRS curriculum and redo the three tasks afterward as a crossover group (CO).

The participants' performance on the three tasks was evaluated by video assessment by two trained, blinded, and independent reviewers. Assessment parameters included time to complete the tasks, the number of camera and clutch movements, the number of collisions, the number of drops, and the number of movements of instruments outside of the field of view. These assessment parameters were scored for each of the three takes of each task, and mean values were used for comparison of performance of the different study groups. Participants in the EG demonstrated significantly less drops and moved their instruments outside the view of the camera significantly less often than the CG. When comparing the results of the CG and CO participants, there was a significant improvement in time to completion and a significant decrease in number of errors with significantly less drops and movements of instruments outside of the camera's

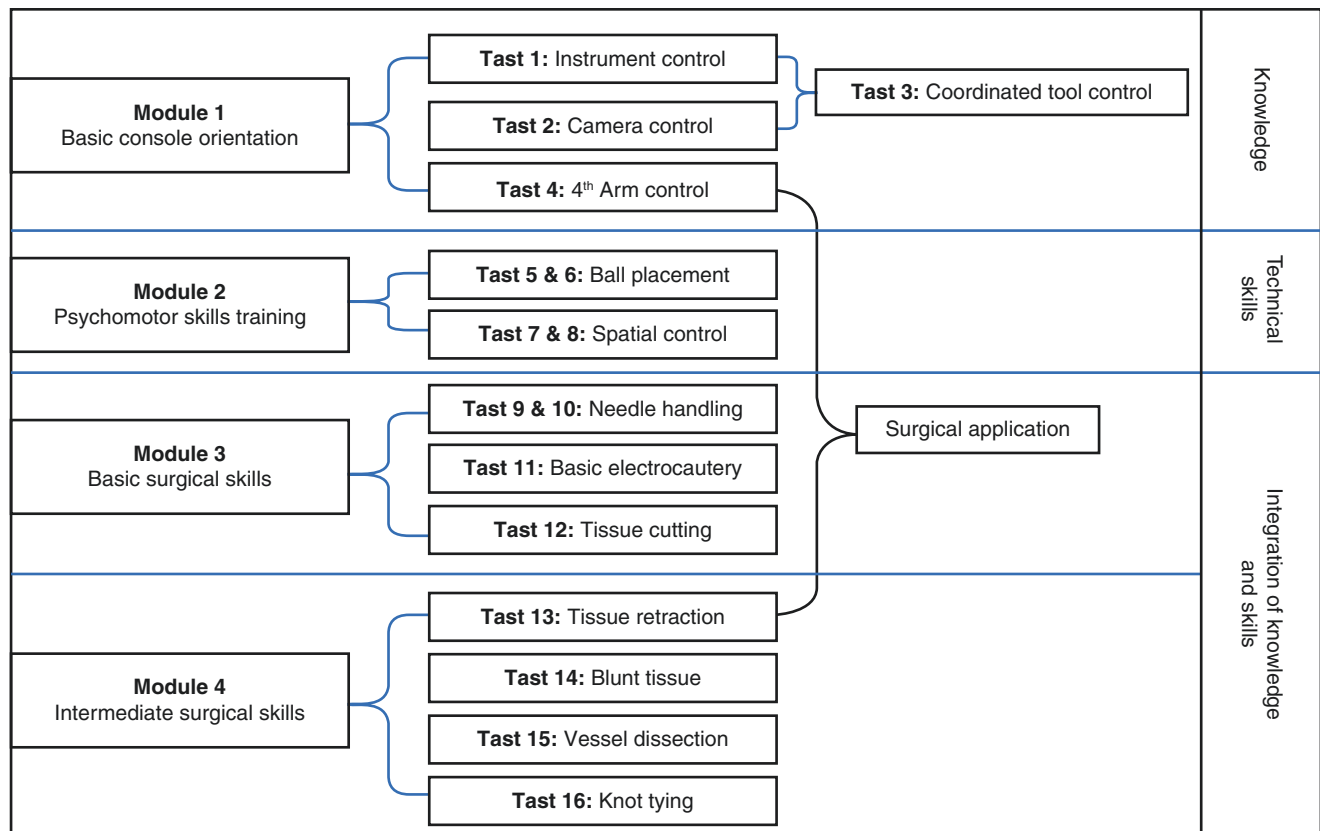


Fig. 5.7 The Structured Fundamental Skills of Robotic Surgery (FSRS) curriculum. (Derived from Stegemann et al. Reproduced with permission [18])

view. Therefore, Stegemann et al. [18] demonstrated that the FSRS curriculum is a valid and feasible training curriculum that can improve trainees' basic robotic surgical skills.

In 2014, construct validity of the FSRS curriculum was demonstrated by Raza et al. [60]. Sixty-one surgeons of variable surgical experience (49 novices and 12 experts) were evaluated when performing four tasks (ball placement, coordinated tool control, fourth-arm control and needle handling and exchange), which were selected on expert consensus and represented the core of the three modules of the FSRS curriculum. The performance of participants was assessed by use of the built-in software in the RoSS, which evaluated 10 metrics in each task. Depending on their surgical experience, participants were able to perform one or three preliminary levels of each task, before the final evaluation started. Raza et al. [60] demonstrated that the expert participants performed significantly better than the novices at all aspects of the individual tasks, thereby proving construct validity of the FSRS curriculum.

The Robot-Assisted Surgical Training (RAST) program is a 5-day to 3-week training curriculum that was developed at Roswell Park Cancer Institute and consists of the validated FSRS curriculum combined with other forms of hands-on training, including HoST training and wet lab training. Attalla et al. [41] showed that RAST has an educational impact on trainees [59].

5.5.3 Proficiency-Based Robotic Curriculum

The proficiency-based robotic curriculum is a validated, comprehensive training program created by the University of Texas Southwestern Medical Center. The curriculum consists of three curricular components: an online tutorial (by Intuitive Surgical) covering fundamental aspects of robotic surgery, a half-day interactive session, and hands-on practice with nine inanimate exercises (Fig. 5.8, Table 5.4) [5]. These exercises were developed by interviewing robotic surgery experts and through observation of live robotic surgery and aim to train 23 unique robotic skills (Fig. 5.9). The exercises are performed on a standard da Vinci system with box trainer and show increasing degrees of complexity to facilitate proficiency-based skill acquisition. It takes 2 months to complete the training program, and trainees have to self-practice the nine exercises.

All exercises are assessed using an objective scoring system based on the validated FLS approach time and errors [5].

Content and face validity of the proficiency-based robotic curriculum were demonstrated by Dulan et al. [61] when 12 expert robotic surgeons rated each of the 23 deconstructed skills and performed the 9 exercises. They concluded that all 23 deconstructed skills were highly relevant and that all 9 exercises effectively measure relevant skills [59]. Dulan

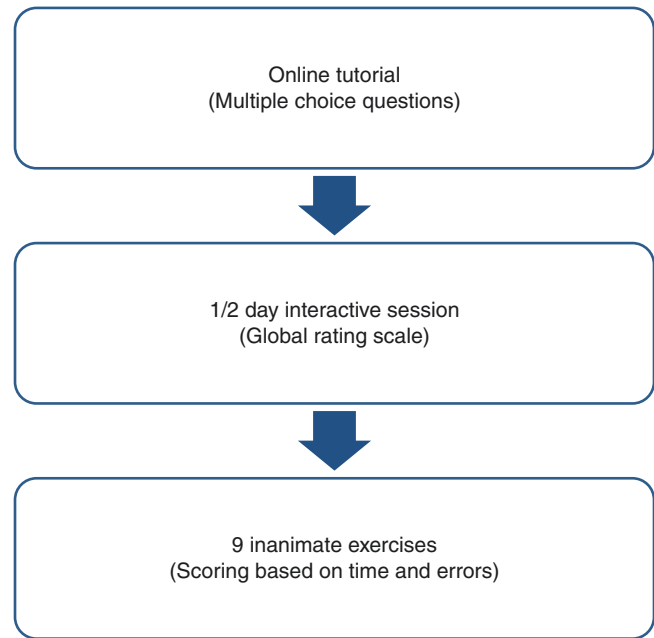


Fig. 5.8 The proficiency-based robotic curriculum. (Reproduced with permission [5])

Table 5.4 List of nine inanimate tasks of the proficiency-based robotic curriculum

Exercise number	Task description
1	Peg transfer
2	Clutch and camera movement
3	Rubber band transfer
4	Simple suture
5	Clutch and camera peg transfer
6	Stair rubber band transfer
7	Running and cutting rubber band
8	Pattern cut
9	Running suture

et al. [42] also demonstrated construct validity of this curriculum in a group of eight expert robotic surgeons and four novice trainees (medical students). After watching a video showing error avoidance strategies and the correct method to perform the nine exercises of the curriculum, the participants completed the nine exercises themselves. Every task of each participant was scored by a single trained proctor for time and accuracy using modified FLS metrics. Expert surgeons were found to achieve significantly better performance than inexperienced students according to each of the nine task scores [59].

5.5.4 Basic Skills Training Curriculum (BSTC)

The basic skills training curriculum (BSTC) [43] is a validated 4-week training program developed by the

<i>Rating scale</i>				
<i>Not relevant or required in any case</i>	<i>Relevant in a few cases</i>	<i>Relevant or necessary in some cases</i>	<i>Relevant or necessary in a majority of cases</i>	<i>Relevant or necessary for every case</i>
1	2	3	4	5
<i>Content domain</i>		<i>Description</i>		
1. Console settings		Setting up and adjusting console settings as needed during surgery		
2. Docking		Surgeon guides OR nurse in positioning bedside robot and attaches arms to trocars		
3. Robotic trocars		Appropriate port location strategies and placement technique		
4. Robotic positioning		Placing the bedside cart in the location where the operative field is most accessible		
5. Communication		Closed loop communication between console surgeon, bedside assistants and OR team		
6. Energy sources		Activation and control of cautery or other energy sources		
7. Robot component names		Knowledge of robotic component terminology		
8. Camera		Maneuvering the Camera to obtain a suitable view		
9. Clutching		Maintaining comfortable range of motion for manual controls		
10. Instrument names		Knowledge of instrument terminology		
11. Instrument exchange		Changing out instrument used in the operation		
12. 4th arm control		Activating the fourth arm through clutching and using it in the operation		
13. Basic eye–hand coordination		Using the manual controls to accurately manipulate bedside instruments and perform tasks		
14. Wrist articulation		Understanding and using the full range of motion of the EndoWrist (Intuitive Surgical)		
15. Depth perception		Appreciating spatial relationships of instruments and tissue		
16. Instrument to instrument transfer		Passing objects between the instrument		
17. Atraumatic handling		Using graspers to hold tissue or surgical material without crushing or tearing		
18. Blunt dissection		Using instruments to separate tissue bluntly		
19. Fine dissection		Using instruments to perform precise dissection of delicate structures		
20. Retraction		Holding tension on an object to facilitate surgical manipulation		
21. Cutting		Using the scissors to cut at a precise location		
22. Suturing interrupted		Suturing single stitches with the robot		
23. Suturing running		Suturing continuous stitches with the robot		

Fig. 5.9 Task deconstruction list of 23 unique and necessary surgical skills. (Reproduced with permission [5])

University of Toronto. Trainees undergo a series of didactic lectures and self-directed online training modules (including Fundamentals of Robotic Surgery) before being introduced to the da Vinci Robot. The theoretical module, focusing on the cognitive objectives of the BSTC, includes advantages and disadvantages of robotic technology, analysis of the various robotic systems and its equipment, introduction to the patient cart, surgeon console and vision cart, review of the robot installation principles, placement of trocars, docking, exchange of tools, grafting and resolution of common technical problems, and several practical training sessions. After the theoretical module, a 2-hour hands-on robotic training session starts, focusing on the topics dealt with in the theoretical module. Thereafter, trainees start exercising basic skills on the dVSS such as EndoWrist manipulation and camera

navigation, instrument clutching, instrument and third-arm functionality, object manipulation, needle guidance, suturing and binding of the nodes, cauterization, and dissection. This standard set of exercises is repeated for three individual 1-hour sessions on the simulator organized at weekly intervals. The robotic surgical skills of the trainees are evaluated by the built-in assessment tool of the simulator. A trainee passes the test when at least 80% of success has been achieved. Wet lab or real-life surgery training is not included in this training curriculum.

Pre- and post-course skills tests have been conducted on two skill exercises standardized with inanimate models: ring transfer and needle passage. Studies have demonstrated improvement of robotic surgical skills among trainees, regardless of specialty, previous robotic experience, or level of training [43, 59].

5.5.5 Society of European Robotic Gynaecological Surgery (SERGS) Curriculum

The Society of European Robotic Gynaecological Surgery (SERGS) curriculum [44] is a fellowship-styled, validated tri-modular training curriculum that was designed after the ERUS training curriculum (Fig. 5.10) [19]. The SERGS curriculum uses radical hysterectomy and pelvic lymphadenectomy as index procedures.

The curriculum starts with a didactic introduction at the home education center. It consists of 2 days of e-learning and 1 month of assistance in robot-assisted gynecological procedures. E-learning is evaluated by online test modules. In this first module, trainees are encouraged to perform virtual reality exercises.

After completion of the evaluation tests, the second module starts and consists of a 1-week hands-on procedural training at a European education center for robotic surgery. This includes half a day of theoretical system training, followed by 3–4 days of both dry lab training on the dVSS and wet lab training on live anesthetized pigs and cadaver models.

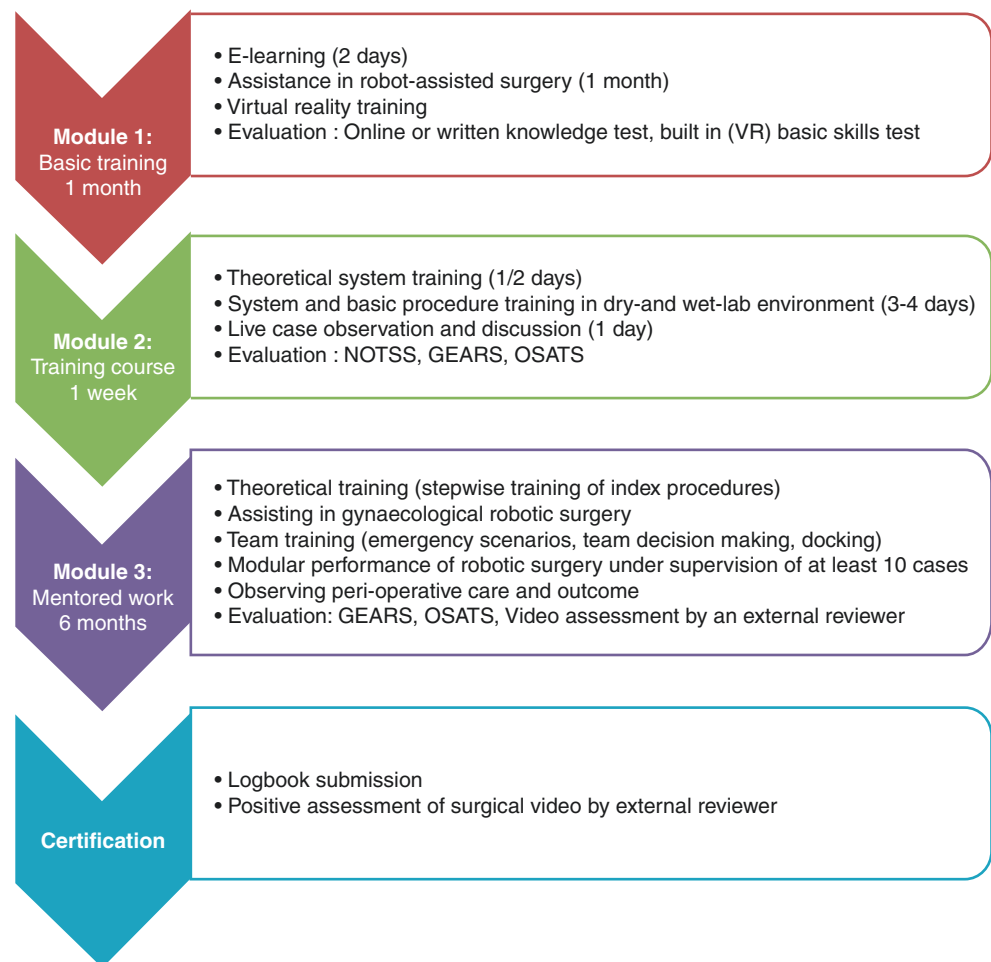
Trainees perform hysterectomies, adnexectomies, and pelvic and para-aortic lymphadenectomies under supervision of an expert robotic surgeon. The progress of robotic surgical skills for each individual trainee is evaluated by comparing the overall score on a dVSS virtual training test at the beginning and the end of the week. At the end of the training, the performance is assessed by Non-Technical Skills for Surgeons (NOTSS) for modular training and by Global Evaluative Assessment of Robotic Skills (GEARS) and Objective Structured Assessment of Technical Skills (OSATS) for procedural training.

Finally, trainees move on to the last module, which focuses on in-house training with supervised real-life surgery. In this stage, trainees perform moderate to complex gynecological procedures under direct supervision of an expert robotic surgeon.

Certification as a robotic gynecological surgeon is possible after formal approval of a completed logbook and assessment of video-recorded surgery by an SERGS expert.

Rusch et al. [44] presented data in which four fellows performed a hysterectomy after completion of the SERGS curriculum. Videos of their performance were assessed by the

Fig. 5.10 The SERGS curriculum



validated GEARS assessment tool. All trainees were able to perform a hysterectomy without supervision of their mentor with good or acceptable surgical quality. After 1 week, all participants performed better on the virtual reality simulator compared to their baseline performance [11, 44].

5.5.6 “Western Protocol” Cardiac Surgery Virtual Reality Curriculum

In this virtual reality curriculum, participants train different robotic surgical skills exercises on the dVSS that are needed in cardiac surgery, more specifically in the harvesting of the internal thoracic artery (ITA) and in mitral valve annuloplasty (Table 5.5) [45]. The training protocol consists of nine exercises that were selected according to the robotic skills needed for these two surgical procedures, which were defined by two expert robotic cardiac surgeons.

For the validation study of this curriculum, Valdis et al. [45] recruited 20 surgeons with little experience with the Da Vinci console or with robotic simulators. The study included a video of the interventions to highlight the basic operative techniques and the relevant anatomy. The training program includes an initial evaluation of a surgical procedure on a porcine chest wall with the aim of collecting a length of 10 cm of the ITA peduncle. Subsequently, the trainees had to perform a suture on a pig cardiac model of the mitral valve, completing the first three sutures of an annuloplasty valve. Each activity was performed only once by each student and was timed and evaluated using the time criteria of the Laparoscopic Fundamentals program.

Of the 20 participants in the study, half were able to practice on the simulator several times (up to 80 times to reach the level of competence established by experts). The other half did not receive any additional training (control group). After the training period, the trainees were compared again on the robotic procedure on the animal model. Intraoperative

surgical skills were assessed by GEARS [45]. Trainees randomized to the VR group were faster than the control group for both surgical procedures and scored significantly higher with the intraoperative scoring tool. Furthermore, trainees included in the VR group achieved a proficiency level similar to the experts for both time-based scores and the intraoperative assessment, whereas the control group was not able to meet this level of proficiency for any of the primary outcomes. Hereby, Valdis et al. [45] proved that the Western Protocol Cardiac VR Curriculum significantly improves the efficiency and quality of learning in robotic cardiac surgery.

5.6 Assessment Tools to Evaluate Performance of Robotic Surgery Trainees

Although credentialing is essential to guarantee safe clinical practice, there is currently no official credentialing process for robotic surgeons needed to perform robotic surgery. Standardized, proficiency-based and procedure-specific training curricula are an important step toward this credentialing process since the performance of participants is evaluated stepwise before performing live surgery [3–5, 8, 12]. Assessment of skills during, at the end of, and beyond training thus is an important factor for credentialing since this forms the basis for validation of training curricula. Increasing complexity of health-care technologies and the decrease in exposure of trainees as a result of working-time regulations have led to an even more distinct need for objective assessment of performance and competence. Different tools exist to assess performance of trainees during their training.

5.6.1 Global Assessment Tools

The most commonly used validated rating scale in surgery is the Objective Structured Assessment of Technical Skills (OSATS) [3]. This scale evaluates general surgical technical skills and the surgeon’s knowledge of a specific procedure and flow of an operation. OSATS has been used to evaluate robotic training. However, since it was not specifically designed for robotic surgery, it cannot evaluate all aspects of robotic surgical skills properly [7, 8]. Therefore, the Robotic Objective Structured Assessment of Technical Skills (ROSATS) was developed. This is an assessment tool specifically created for evaluation of robotic surgical skills in which four categories of skills are assessed: depth perception and accuracy, force and tissue handling, dexterity, and efficiency. Each category is scored subjectively from 1 to 5 [62].

In 2012, the Global Evaluative Assessment of Robotic Skills (GEARS) tool was developed by Goh et al. [7] by including features unique to robotic into a validated tool for

Table 5.5 The nine exercises of the Western protocol cardiac VR curriculum

Virtual reality simulation exercise	Level	Skill tested
Matchboard	2	EndoWrist manipulation
Pegboard	2	EndoWrist manipulation
Camera targeting	2	Camera control
Energy switching	2	Energy control
Matchboard	3	Fourth-arm manipulation
Ring walk	3	Fourth-arm manipulation
Energy dissection	2	Energy control
Suture sponge	3	Needle driving—advance
Vertical defect suturing		Needle driving—advance

Fig. 5.11 The Global Evaluative Assessment of Robotic Skills (GEARS) assessment tool

Depth perception	<ul style="list-style-type: none"> • Overshoots target, slow correction • Some overshooting or missing target, quick correction • Accurately directs to target 	1 3 5
Bimanual dexterity	<ul style="list-style-type: none"> • Use only one arm, poor coordination • Not optimize interaction between the two hands • Expertly use of two hands with best exposure 	1 3 5
Efficiency	<ul style="list-style-type: none"> • Uncertain movements, constantly changing without progress • Organized slowly movements • Safe conduct, fluid and confident movements 	1 3 5
Force sensitivity	<ul style="list-style-type: none"> • Poor control, injuries nearby structures, suture breakage • Less trauma of nearby structure, rare suture breakage • Right tension, no injures, no suture breakage 	1 3 5
Autonomy	<ul style="list-style-type: none"> • Not able to compare task, even with tips • Able to complete task with some tips • Able to complete task alone 	1 3 5
Robotic control	<ul style="list-style-type: none"> • Not optimize view, hand position and more collisions • Occasionally arms relocation, collisions and rare not optimize view • Optimal control fo camera and arms, no collision 	1 3 5

intraoperative laparoscopic skill assessment surgery, Global Operative Assessment of Laparoscopic Skills (GOALS). GEARS is the first consistent, validated, and standardized clinical assessment tool for intraoperative robotic surgical skills. It was modeled after global rating scales for open and laparoscopic surgery by expert robotic surgeons.

In practice, GEARS is a rating scale in which six domains (depth perception, bimanual dexterity, efficiency, force sensitivity, autonomy, and robotic control) are subjectively evaluated by use of a Likert scale ranging from 1 to 5 (Fig. 5.11) [7]. An overall score is created by summing all scores, in which higher scores resemble better performances. GEARS hereby provides a valid, reliable, and reproducible measure of intraoperative robotic surgical skills [7, 8] in dry lab, wet lab, and real-life surgery environments. Studies show that GEARS scores of specific steps in robot-assisted radical prostatectomy are associated with patient outcomes, such as continence and readmission [7, 8].

In 2014, a validated assessment tool was developed related to robotic microsurgery, the Structured Assessment of Robotic Microsurgery Skills (SARMS) [63]. This tool for robotic microsurgical evaluation originates from the Structured Assessment of Microsurgery Skills (SAMS) in which domains strictly related to robotic surgery have been added. The domains included into this tool are dexterity, visuospatial ability, operative flow, camera movement, depth perception, wrist articulation, atraumatic tissue handling, and atraumatic needle handling. The evaluation is assigned with a score ranging from 1 to 5 [63].

The Assessment of Robotic Console Skills (ARCS) [64] is a validated assessment scale which consists of six catego-

ries that identify a group of skills to be acquired at the da Vinci Robot console for its proper use: bimanual wristed manipulation, camera control, master clutching activating energy sources, appropriate depth perception, and awareness of forces applied by instruments [64].

The Generic Dedicated Scoring Criteria (GDSC) [19] is a validated evaluation tool used in the European Association of Urology Robotic Training Curriculum to assess the quality of video-recorded surgical steps of trainees. Parameters evaluated were instrument use, tissue handling, errors made, and the end result, with each parameter being scored from 1 to 4.

Global assessment tools such as GEARS are able to evaluate essential and basic robotic surgical skills. Therefore, these tools are primarily used in lab settings and preclinical training in order to evaluate if trainees can safely move on from training labs to the operating theater (Table 5.6) [8].

5.6.2 Procedure-Specific Assessment Tools

Next to global assessment tools, different procedure-specific assessment tools exist for more detailed evaluation of specific surgical steps (Table 5.7) [8]. These tools provide cognitive evaluation of surgical skills in a task-deconstructive fashion, identifying specific steps for improvement for individual trainees. There are different examples of procedure-specific assessment tools, of which most were created for urological robot-assisted procedures.

The robot-assisted radical prostatectomy (RARP) assessment score [73] is a validated evaluation tool for RARP. The procedure was divided into 17 crucial phases and 41 subpro-

Table 5.6 Robotic surgical technical skills evaluated by global assessment tools

	OSATS	ROSATS	GEARS	SARMS	ARCS	GDSC
Tissue handling/force sensitivity	Yes	Yes	Yes	Yes	Yes	Yes
Instrument manipulation	Yes	No	Yes	Yes	Yes	Yes
Instrument movement efficiency	Yes	Yes	Yes	Yes	No	No
Depth perception	No	Yes	Yes	Yes	No	No
Bimanual dexterity	No	Yes	Yes	Yes	Yes	No
Use of assistants and third arm	Yes	No	No	No	Yes	No
Camera control	No	No	Yes	Yes	Yes	No
Master manipulator workspace	No	No	Yes	No	Yes	No
Energy application	No	No	No	No	Yes	No
Autonomy	No	No	Yes	No	No	No
Bleeding or organ damage	No	No	No	No	No	No
Flow of operation	Yes	No	No	No	No	No
Knowledge of specific procedure	Yes	No	No	No	No	No

OSATS Objective Structured Assessment of Technical Skills, *ROSATS* Robotic Objective Structured Assessment of Technical Skills, *GEARS* Global Evaluative Assessment of Robotic Skills, *SARMS* called Structured Assessment of Robotic Microsurgery Skills, *ARCS* Assessment of Robotic Console Skills, *GDSC* Generic Dedicated Scoring Criteria

Table 5.7 Procedure-specific robotic surgical skill assessment tools

Tool	Study	Year	Evaluation	Validation
Robot-assisted radical prostatectomy scale (RARPS)	Volpe et al. [19]	2015	Review by experts	Yes
Robotic Anastomosis Competency assessment and competency evaluation (RACE)	Raza et al. [65]	2015	Review by experts	Yes
	Ghani et al. [66]	2016	Crowd-sourced assessment vs experts	No
	Peabody, et al. [67]	2015	Crowdsourced assessment vs experts	No
Prostatectomy Assessment and Competency Evaluation (PACE)	Hussein et al. [23]	2017	Review by experts	Yes
	Ghani et al. [23]	2016	Crowd-sourced assessment vs experts	No
Pelvic Lymphadenectomy appropriateness and Completion Evaluation (PLACE)	Hussein et al. [68]	2017	Review by experts	Yes
Cystectomy Assessment and Surgical Evaluation (CASE)	Hussein et al. [69]	2018	Review by experts	Yes
Scoring for Partial Nephrectomy (SPaN)	Hussein et al. [70]	2018	Review by experts	Yes
Robotic Hysterectomy Assessment score (RHAS)	Frederick et al. [71]	2017	Review by experts	Yes
Competence Assessment in Colorectal Robotic Surgery (CACRS)	Petz et al. [72]	2016	Review by experts	No
Robot-assisted radical prostatectomy assessment score	Lovegrove et al. [73]	2016	Review by experts	Yes
	Lovegrove et al. [74]	2017	Review by experts	No
Robot-assisted partial nephrectomy assessment score	Lovegrove et al. [75]	2017	Review by experts	Yes
	Bruce et al. [76]	2016	Review by experts	Yes

cesses. Unlike other assessment tools, it is the only one that also analyzes the surgeons' learning curve. All phases are evaluated with a score of 1 to 5 assigned by expert surgeons.

The robot-assisted partial nephrectomy (RAPN) assessment score [75] is a similar tool to evaluate the performance of a surgeon in RAPN. It was created by identifying all possible failure modes and most dangerous steps in the procedure. It consists of 6 phases with 26 processes and 50 subprocesses. The six phases are "preparation of operative field"; "exposure of surgical field"; "dissection and control of hilum"; "preparation for hilar clamping and tumor excision"; "hilar clamping, warm ischemia time, and tumor excision"; and "finalizing and closure" [75, 76].

Another procedure-specific assessment tool for minimally invasive partial nephrectomy is the "Scoring for Partial

Nephrectomy" (SPaN) tool [70]. It is a scoring system that can offer objective and structured feedback on technical skills of trainees. This assessment tool was created by deconstruction of the critical steps of a robot-assisted partial nephrectomy into six domains (exposure of the kidney, ureteral and gonadal vessel identification and dissection, hilum dissection, tumor localization and exposure, tumor clamping and resection, and renorrhaphy). Each domain is then assessed for surgical skills by a Likert score from 1 (worst) to 5 (best).

The Robotic Anastomosis Competency Evaluation (RACE) [65] assessment tool analyzes bladder urethral anastomosis in robotic radical prostatectomy. It consists of six domains (needle positioning, needle entry, needle driving and tissue trauma, suture placement, tissue approximation, and knot tying) which are all scored independently. Scores

range from 1 (the worst performance) to 3 (intermediate) to 5 (the ideal performance) [65].

The Prostatectomy Assessment and Competency Evaluation (PACE) [23] is a validated assessment tool that was created by the analysis of RARP by 12 expert robotic surgeons. The procedure was subdivided into seven key points (bladder drop, prostate preparation, bladder neck dissection, posterior/seminal vesicle dissection, neurovascular bundle preservation, apical dissection, urethrovesical anastomosis), which are evaluated with a 5-point Likert scale [23].

The Pelvic Lymphadenectomy appropriateness and Completion Evaluation (PLACE) [68] is a validated, structured intraoperative scoring system to measure and quantify pelvic lymph node dissection (PLND) in robot-assisted radical cystectomy. It was created by a panel of 11 surgeons, who divided the PLND template into three zones. PLNDs of trainees may be evaluated using PLACE, in which the performed PLND is compared with a “perfect” PLND [68].

The Cystectomy Assessment and Surgical Evaluation (CASE) tool [69] was developed for radical cystectomy in men and provides a subdivision of the procedure based on eight key steps (pelvic lymph node dissection, development of the peri-ureteral space, lateral pelvic space, anterior rectal space, control of the vascular pedicle, anterior vesical space, control of the dorsal venous complex, apical dissection). Scores on each step are assigned by a 1–5 Likert scale [69].

These procedure-specific assessment tools evaluate both surgical technical skills and surgical knowledge, thereby assessing the competence of a surgeon to perform a specific procedure independently and safely. These tools could be used for robotic surgeon credentialing and licensing for specific robotic procedures. Although promising, there are currently no data on procedure-specific assessment tools that correlate with patient outcomes. Major disadvantages of manual assessment tools are that they are time-consuming to the evaluators, that they are making evaluation of complete procedures difficult, and that they are exposed to subjective bias, limiting inter-rater reliability [8].

5.6.3 Automated Assessment Tools

Automated performance metrics (APMs) are other tools that allow to evaluate the performance of trainees in surgical curricula (Table 5.8). APMs integrate objective data that is acquired automatically during surgical training using recording devices, robotic instrument kinematic tracing data, system events data, and surgical video data. Many of these APMs have shown a good ability to distinguish different levels of expertise between surgeons. These data are processed by learning algorithms, and meaningful evaluation and feedback are based on automatically recorded data (computer-aided automated evaluation).

Table 5.8 Examples of recording devices offering analysis of automated performance metrics

Name	Creator	Study	Year	Validation
trakSTAR	Ascension Technology (Shelburne, USA)	Tausch TJ et al. [77]	2012	Yes
ProMIS	Haptica (Dublin, Ireland)	Chandra V et al. [40].	2010	Yes
Application Programmer’s Interface	Intuitive Surgical (Sunnyvale, USA)	Kumar et al. [78]	2012	Yes
dVLogger	Intuitive Surgical (Sunnyvale, USA)	Hung AJ et al. [79]	2018	Yes

The implementation of APMs in evaluation of trainees holds many advantages: APMs eliminate the bias of human judgment and make robotic surgical technical skills quantifiable. Furthermore, the evaluation of trainees does not longer require major time investments of evaluators since data is collected automatically. On top, performance metrics on complete procedures can be recorded, offering comprehensive evaluation of complete surgeries. Large-scale surgical evaluation, surgeon credentialing, and recredentialing could be performed by computer-aided automated evaluation of surgical technical skill. However, assessment of surgical skills by computer-aided evaluation of APMs is still in early stages of development [8].

5.6.4 Nontechnical Skills (NTS) Assessments

Next to training and evaluation of technical skills, nontechnical skills (NTS) play an important role in robotic surgery and have the potential to impact patient safety and adverse events [16]. Different assessment tools for NTS have been developed and validated, such as the Non-Technical Skills for Surgeons (NOTSS) [80] and the observational Teamwork Assessment for Surgery (OTAS) [81]. However, specific assessment tools for NTS evaluation in robotic surgery do not exist [16, 82].

5.7 Conclusions

Over the past decades, a rapid diffusion of robot-assisted surgery in different surgical fields was observed. In order to introduce robotic surgery in a safe and efficient way without compromising surgical outcomes and patient safety, training is mandatory and should be structured in specific, validated proficiency-based training curricula.

Currently, there is no international consensus on credentialing for robotic surgeons. General, centralized competency standards do not exist. Validated training curricula in which the performance of trainees is evaluated by validated assessment tools are a crucial first step toward robotic surgery credentialing. These training curricula should be organized in a modular fashion with a well-structured road map in which trainees start with knowledge development, followed by basic and advanced skills training in dry- and wet lab environments before moving on to console training. Besides technical robotic surgical skills training, non-technical skills training should be included in these robotic surgery training curricula as well. The validation of training programs is essential since this proves their educational impact and potential to differentiate between different levels of competence. Validation of robotic surgery training curricula can be obtained by well-powered, randomized studies in which the performance of trained and untrained participants is compared by independent and blind assessors in a center of excellence. Several training curricula exist; however, only few were validated. Of these validated training programs, only two followed the aforementioned structure and offer online education, dry- and wet lab training, and real-life surgical modular training under direct supervision. These training programs are the ERUS training curriculum [19] and the SERGS curriculum [44]. The ERUS training curriculum is the first validated training curriculum in which participants are trained in a modular fashion to perform a complete surgical procedure alone. It is feasible, acceptable, and effective in improving the robotic technical skills and abilities of young surgeons with limited robotic experience to perform the crucial steps of robot-assisted radical prostatectomy.

Technological evolution will continue to bring new innovations in the field of minimally invasive surgery, and training should evolve accordingly. The evaluation of surgical skills is essential, and great future lies within computer-aided automated evaluation of surgical technical skills.

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