Review Article

Simulation-based training in laparoscopic urology – Pros and cons

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ABSTRACT

Surgery is traditionally taught by using Halsteadian principle, which includes "see one, do one, teach one". This principle relies on sheer volume of surgical exposure rather than a specific course structure. Simulation in minimally invasive surgery allows the learner to practice new motor skills in a safe and stress free environment outside the operating room, thereby decreasing the learning curve.

A non-structured exhaustive MEDLINE search was done using MeSH words: "Simulation, Urological Training, Training Models, Laparoscopy Urology, Laparoscopic Skill, Endotrainer, Surgical Simulators, Simulator Validation". The " Pros and Cons of simulation based training in laparoscopic urology" were studied.

Results were discussed along the following lines : 1. How does skill acquisition occur? 2. Factors affecting simulator-based training. 3. Description of types of simulators and models. 4. Validating a simulator. 5. Task analysis after training on a simulator. 6. How effectively does simulation based training, translate into improved surgical performance in real time?

Pros: Simulators have the ability to teach a novice basic psychomotor skills. Supervision and feedback enhance learning in a simulation-based training. They are supplements to and not a substitution for traditional method of teaching. These models can be used as a part of most of the surgical training curriculum.

Cons: Cost and availability are the key issues. The cost will determine the availability of the simulators at a center and the availability in turn would determine whether a trainee will get the opportunity to use the simulator. Also, teacher training is an important aspect which would help teachers to understand the importance of simulation in student training. The domains in which it would improve and the extent to which simulation will improve surgical skills is dependent on various factors. Most simulators cannot train a surgeon to deal with anatomical and physiological variations. At present, it is not possible to re-validate all the surgeons in terms of their surgical skills, using simulators.

INTRODUCTION

Simulation by definition means imitation of a situation or a real-world process.[1] Simulation-based training is a part of curriculum in professions such as aircraft pilots and defense personnel. Surgery is traditionally taught using Halsteadian principle, which includes "see one, do one, teach one."[2] This principle relies on sheer volume of surgical exposure rather than a specific course structure. Although effective, it may be less efficient, more expensive, and would potentially put the patients at risk.[3-5] Urology as a subspecialty has evolved rapidly in the last five decades and is highly technologically dependent. This rapid evolution has made training of new generation urological surgeon a big challenge.[6] Urological surgeries like the ones involving laparoscopic urology, percutaneous nephrolithotomy, and other endourological procedures are conceptually different from open surgery and require skill sets, which are extremely alien to an open surgeon. Particularly, laparoscopic urology, which requires three-dimensional (3D) imagination of the 2D vision, surgeon has to accommodate for loss of tactile feedback and fulcrum effect is pronounced. Malcolm

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Gladwell in his book titled "Outliers" described that to be very best in your field you need to spend 10,000 h training, this is true for all top-level athletes, musicians, and other sportsperson.[7] It is not possible for a urological trainee to practice these many hours directly on patients due to stipulated working hours, limited caseload, and increasing number of residents getting enrolled for urology training programs. Directly training on the patients can be frustrating for both the trainee and the faculty, it is time-consuming, costly, and stressful for all the involved personnel. Fahlenkamp *et al*.[8] in his review of 2047 laparoscopic cases found that complication rates decrease significantly after first 100 cases, this only means that a there is a need for pretraining before starting laparoscopic urological surgery on patients. Simulation in minimally invasive surgery allows the learner to practice new motor skills in a safe and stress-free environment outside the operating room (OR), thereby decreasing the learning curve. There is a large body of evidence supporting the use of simulators in minimally invasive surgery; also, there have been many attempts to validate these simulators in different studies. A more widespread use of simulation as a part of training curriculum in urology is the need of the hour.

MATERIALS AND METHODS

A nonstructured exhaustive MEDLINE search was per done using MeSH words: "simulation, urological training, training models, laparoscopy urology, laparoscopic skill, endotrainer, surgical simulators, simulator validation."

Relevant articles published in English language were critically reviewed and included. The "Pros and Cons of simulation-based training in laparoscopic urology" were discussed along the following lines: (1) How does skill acquisition occur? (2) factors affecting simulator-based training, (3) description of types of simulators and models, (4) validating a simulator, (5) task analysis after training on a simulator, and (6) how effectively does simulation-based training, translate into improved surgical performance in real time.

DISCUSSION

Steps involved in learning a motor skill

New motor skills that the surgeon acquires are based on a three-stage theory proposed by Fitts and Posner.[9,10] They proposed that the first stage of learning a motor skill is cognitive stage in which the student intellectualizes the task and performs it in small distinct steps, for example, if the task is to cut a circle marked on a surgical glove using a laparoscopic box trainer, here the student first learns how to hold the instrument, he slowly tries to hold the glove with the instrument in the nondominant hand and then cut it with the scissors in the dominant hand. In the process, the skills being developed are hand–eye coordination, dexterity, depth perception, precision, and spatial orientation. During this phase, the movements are erratic, but by practice and feedback, the trainee enters the second phase, which is the integrative phase. In the integrative phase, all the technical information that the trainee has is converted into motor performance.[9,10] If we consider the above task of circle cutting, the trainee is still thinking about the task but, his movements are more synchronized and fluid. The third and the last stage of motor learning is automation. In this stage, the motor movements are quick, precise, and efficient. There is appropriate use of instruments and ability to adapt to a particular situation develops in this stage.

Factors affecting simulator-based training

Having stated that simulators are training tools, it is very important to realize that not all the simulators are equivalent, type of training provided by the simulator is a critical variable in deciding whether this skill set can be reproduced in the real-time scenario.[11] Factors determining the effectiveness of simulator-based training include:

Effective feedback

In a nutshell, feedback in simulator-based training means that the trainee knows what measures he can take to improve his performance. Feedback is either intrinsic or extrinsic. Intrinsic feedback is the input that one gets by visual, auditory, and haptic cues, for example, a trainee realizes after practice on laparoscopic box trainer that the objects nearer to the camera appear brighter and move faster.[12] Extrinsic feedback is the one provided by a mentor; it can be provided as a summary of expert feedback at the end of the training session or as a concurrent feedback during the training session.[13] Although both are equally effective initially, it is seen that when residents are evaluated at the end of 1 month, summary expert feedback is more effective as it does not distract the student while doing a task. Furthermore, the commentary during the task may make student dependent on the teacher.[13] Hence, feedback is critical it should be brief, given by an expert at the end of the training session.

Deliberate practice

Practice will definitely improve performance, but the critical questions that remain to be answered are: what kind of practice? What duration? And for how long?

Deliberate practice means the mindful practice of the executional steps of a particular surgery. Like if one thinks of practicing the motor skill sets required in colonic reflection during a laparoscopic nephrectomy. Skill sets required for executing this step are dexterity, precision, and hand-eye coordination. So to practice these, trainee can use a circle cutting exercise, in this exercise a circle is drawn on the palm of a glove, the aim is to cut the circle precisely along the drawn line, without injuring the posterior leaf of the glove. These mindful exercises will help the trainee develop motor skills for all the executional step of a surgery, ultimately leading to better transference of skill in the OR.[14] It has been suggested in various studies that the practice should be distributed in time rather than doing it continuously at a stretch, distributive practice allows integration of the motor skills.[15-17] Based on the opinion of experts, the trainees should practice for 45 min to 1 h on simulators daily till the time they do not reach a stage of automation of motor skills,[18] this may take anywhere between 3 and 6 months depending on individual capabilities.

Concept of a pretrained novice

Gallagher coined the term "Pretrained Novice" it is referred to an individual who has developed his motor and cognitive skills to a level where his task performance in a simulated minimal access environment is automated.[19] This also means that when such an individual is faced with a real-time operating scenario, he would concentrate on learning minute details of the surgery or focus on managing complex situations, rather than struggling with basic instrument movements. The hindside of using such a system is that we do not know what is the time an individual requires to reach benchmark stage of automation of motor skills.[19] Subjective and objective task analysis is extremely critical to find out who can be labeled as a "Pretrained Novice," while evaluating these task the examiner also has to keep in mind that these tasks are proficiency based with a caveat of time added to them.[20-23] Ericsson has attempted to define an expert in surgery as a person who has consistently better outcomes than other surgeon.[14,24]

Graded and sequential practice

Increasing levels of difficulty in performing tasks on simulators will improve the psychomotor skills; Ali *et al*. demonstrated that at with a higher level of difficulty on virtual reality (VR) simulator, there was increased learning.[25] During the period of training, practicing the same task may be monotonous, increasing level of difficulties keep the trainee interested and motivated, this is very important in long-term skill acquisition.[19]

Cognitive learning

Merely, practicing motor skill will only lead to incomplete training; simulator training has to be integrated with cognitive teaching, which includes understanding of a correct sequence of events, knowledge of anatomy, and procedural surgical steps. Further, the procedural steps are divided into executional steps, for example, colonic reflection in a transperitoneal laparoscopic nephrectomy is a procedural step which is subdivided into number of executional steps such as incising the peritoneum along the white line of Toldt, incision to be made at the level of kidney, identify the difference between the colonic and retroperitoneal fat, incising the splenorenal ligament so on and so fore. This detailed cognitive knowledge will help learner practice the component steps and also will decrease complications. Imparting cognitive skill is time-consuming, but still, it does not impact the technical skill acquisition.[26]

Classification of simulators

Mechanical simulators using inanimate training models

a. Commercially available box endotrainers [Figure 1]
b. Homemade endotrainers [Figure 2].

Commercially designed box endotrainers consists of a box with a camera and a light source, which is connected to a screen for visualization. The box replicates the abdominal cavity, abdominal wall, and port sites and since these are intended for commercial use, they are specifically designed and ready to use. They are costlier as compared to the homemade endotrainer but are easy to assemble and have undergone some form of validation testing [Tables 1 and 2].

The homemade endotrainers have same essential components as the commercial endotrainer, but they are made of, off the shelf products, which include plastic boxes, cardboard boxes, wooden frames, or steel frames designed for some other purpose [Table 3]. Many of these endotrainers do not use an additional light source and rely on the room light for illumination, in a study,[27-29] only 38% of the homemade endotrainers had a separate light source. Other simulators used laparoscope (17%), light-emitting diode (8%), torchlight, lamps, and web cameras with built-in light as light source.[30] For visualization, these trainers use a web camera attached to a computer screen. Recently, many models have used mirrors, tablet computers, video cameras, and mobile phones as a camera and screen both [Table 3].[28-32]

In the study mentioned above, the cheapest homemade endotrainer could be built for 5 USD as compared to this, cheapest commercially available endotrainer was available for 100 USD. We have developed an office endotrainer, which costs 500 Indian rupees [Figure 2]. A study on simulators identified 73 endotrainers, of which 60 were

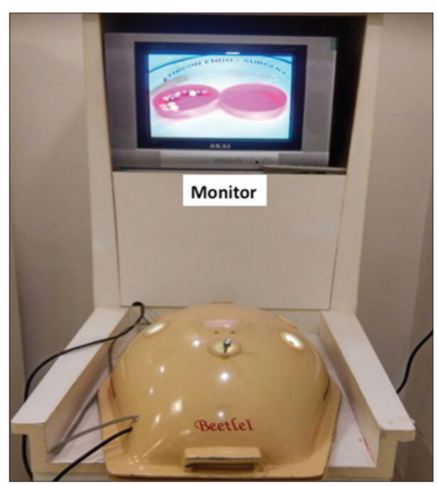

Figure 1: A commercially available endotrainer

noncommercial or homemade and 13 were commercially available. The authors of the above study evaluated the validity of these trainers and concluded that the commercially available endotrainers had a better face validity with a mean score of 5 out of 6 as compared to noncommercial endotrainers, which had a mean score of 3 out of 6.[30]

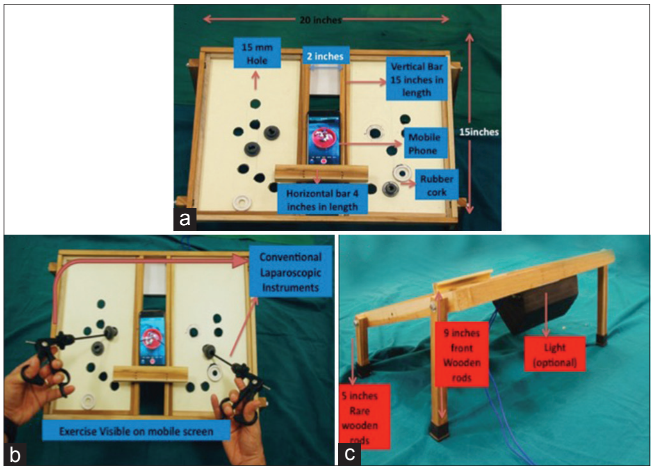

Figure 2: (a-c) A homemade, noncommercial endotrainer designed by the author, using a plywood frame with multiple holes as ports and for visualization mobile phone and tablet cameras can be used

Mechanical simulators using animate models

a. Human cadaveric models
b. Animal cadaveric models (Porcine, Chicken)
c. Living Animal Models.

Human cadaveric models are high fidelity but require a setup similar to an operating room setup and instrumentation similar to OR room [Tables 1 and 2].

There is a limited availability of cadavers and requirement of OR setup makes it very costly training modality. Although it mimics the anatomy in greatest detail, pathology is not same and it does not account for individual variability. Bloodless field and noncompliant tissue make training slightly difficult.

Animal cadaveric model [Figure 3] is a good replacement to human cadavers, the small animals and parts of larger animals can be placed in box trainers [Figure 4] and using the training instruments and laparoscope, procedures can

Table 1: Describing types of simulation models

Type of simulation model	Pros	Cons	Application in training
Bench models/mechanical box trainers (homemade or commercially available)	Cheap, office use possible, can be reused, no ethical issues involved, no hazards	Low fidelity, Specific tasks can be done rather than surgical procedures, Poor acceptance by the trainee	Used for mastering basic skills such as grasping, cutting, suturing Getting trained in 2D environment
Human cadaveric models	High fidelity, replicate human anatomy the best, real-time surgical scenario can be recreated	Costly, not easily available, Can be used only once, Requires a wet laboratory setup Tissues do not bleed and are noncomplaint Potential risk of infections	Best used to gain real-time anatomical knowledge, Dissection skills can be mastered
Animal models live and cadaveric	Relatively high fidelity, In live model bleeding gives real-time feeling and surgeon can practice achieving hemostasis Surgical procedures can be practiced	Animal laboratory setup required, costly Ethical issues Risk of infections Single use Does not exactly replicate Human anatomy	Best used to train in tissue dissection Surgeon can practice achieving hemostasis Procedural and executional steps of a surgery can be practiced
Virtual Reality surgical simulators	Do not require a laboratory set up, easy to set up Can be reused Can be high or low fidelity depending on the design Not labor intensive	Costly Not easily available Fedility will depend on the design Most of them are not portable	Used for mastering basic psychomotor skills Depending on the software, can replicate the real-time situation well

Table 2: Describing types of simulators

Type	Construction	Utility
Box trainer	They are mechanical type of simulators in which objects or organs are placed and motor skill exercises can be carried out	Basic laparoscopic skill training Dextirity training Hand-eye coordination Depth perception Acclimatization to environment with loss of haptic's and reduced freedom of movement Steps such as grasping, cutting, suturing, and dissection can be practiced
Hybrid trainers	They are box trainers, which have some kind of feedback mechanism. This can be done by virtue of being connected to a computer	Motor skills same as above can be practiced, but the entire act is monitored by a computer-based device and trainee gets inputs on task performance, also he gets objective assessment of the task being performed
Virtual reality trainers	These are computer-generated software programs depicting a surgical scenario. They are operated by joysticks, which mimic laparoscopic instruments	The trainee performs all the motor skills as above, but the results of his actions are displayed as graphics on computer screen, also for each action there is a feedback mechanism. There is objective assessment and a scoring system that can be incorporated to assess the trainee. These trainers can be high as well as low fidelity

be carried out. Real-time situation like bleeding can be created by cannulating larger vessels of the animal and infusing colored water. Once the vessel is cut, it emulates real-time bleeding which trainee can control using a clip or ligature. These cadavers when fresh have good tissue handling properties. Hindside of using these models is that there is a potential risk of infections and these models do not replicate human anatomy.

Living animal models have been studied for training in laparoscopic surgery.[33-35] Use of larger living animal like pigs are banned in parts of India and wherever permitted the regulations are so stringent that most of the institutes cannot abide by them. Setup required for living animal model training is extensive.However, they offer a naturalistic OR room experience. Again, the cons are the ethical issues associated with these models and the anatomy in these models is different from humans.

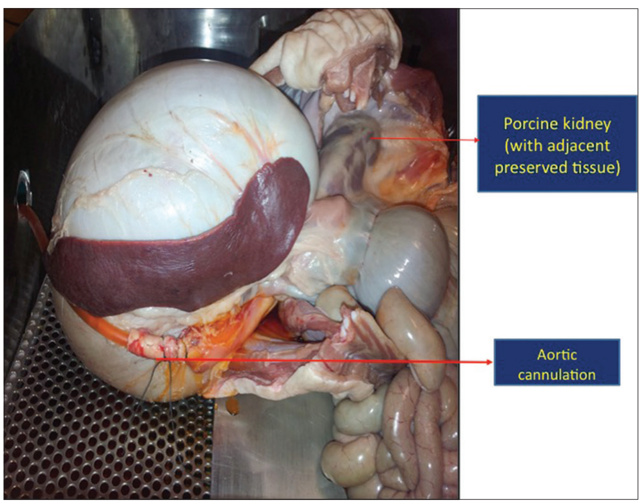

Figure 3: Cadaveric porcine model for nephrectomy, porcine aorta isolated, and cannulated so that colored fluid can be infused mimicking blood flow

Available animal training models for urolaparoscopic and robotic procedures are

Laparoscopic nephrectomy simulator

A porcine cadaveric model may be used, the porcine aorta is cannulated with a catheter and red colored fluid is infused. The cadaver is placed in a box endotrainer and conventional instruments are used. If the renal artery is cut, there is a gush of red colored fluid, which mimics real-time situation. A trainee learns to dissect, cut, clip, use energy source, and manage emergencies like bleeding [Figure 3].

Laparoscopic partial nephrectomy simulator

Again, a porcine cadaveric model can be used. The trainer marks out an area with electrocautery on the kidney mimicking a renal tumor, trainee dissects the kidney, and then he is instructed to excise the tumor and suture the renal parenchyma [Figure 5]. The precannulated aorta with red fluid can be used to check the integrity of repair. Taylor *et al*. injected agarose into the porcine kidney to mimic a

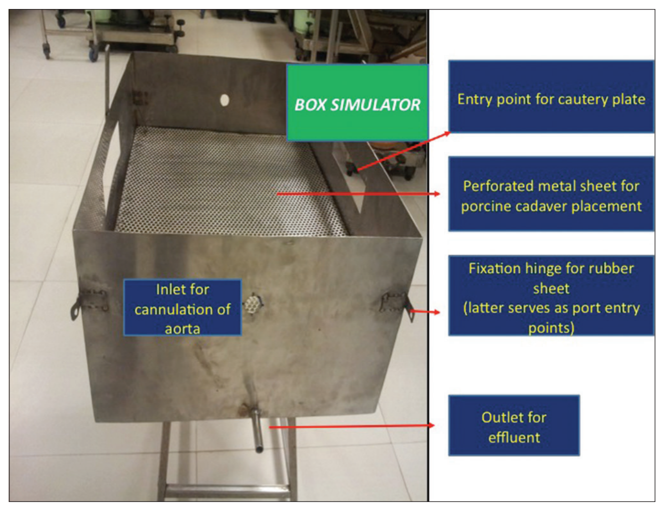

Figure 4: Specially designed box trainer for cadaveric porcine models

Table 3: Describing types of non-commercial endotrainers

Author	Material used	Ports	Light source	Imaging	Validation
Walczak *et al*.	Translucent plastic box with opaque lid	Metal washers and trocars	LED	Mirror	No
Beard *et al*.	Translucent plastic box with lid	Hole into plastic lid covered by flexible material	External light	Webcam	Yes
Omokanye *et al*.	Plywood box	Hole covered with foam	Inbuilt light bulb	IR CCTV camera	No
Alfa-Wali *et al*.	Shoebox made of cardboard	Hole in cardboard	Torchlight	Mobile phone camera	Yes
Ramalingam *et al*.	White colored box with lid, made of unspecified material	Hole in lid covered with rubber sheet. Tube passed through the hole as trocars	Laparoscope	Laparoscope	Yes
Jaber *et al*.	Box made of metallic wire basket and acrylic sheet	Hole with rubber	External lighting	Web camera	No
Helmy *et al*.	Food storage box with lid	Hole in lid with trocar	Built-in web camera	Web camera	Yes
Martinez *et al*.	Metallic box with lid. Semi-cylindrical in shape	Hole in lid covered with rubber	Fluorescent lamp	Video camera and mirror	No
Tak *et al*.	Plywood frame mounted on stand	Multiple holes in the frame with rubber washers	CFL	Tablet, mobile camera	Yes
Lee *et al*.	Computer game station, with table top	Trocars anchored to table top	External lamp	Video camera	No

LED=Light-emitting diode, CCTV=Closed-circuit television, CFL=Compact fluorescent lamp, IR=Infra red tumor; similarly, Hidalgo *et al*. used plastic injections.[36-38] Eun *et al*. demonstrated the use of mixture of gelatin, Metamucil, and methylene blue to create tumor-like bulge in porcine kidney.[39]

Laparoscopic pyeloplasty simulator

Ramachandran *et al*. describe the use of a chicken model where the chicken crop and chicken esophagus was, respectively, presumed to be the renal pelvis and ureter.[40] The esophagus and the crop are surgically dismembered and resutured to mimic pyeloplasty [Figures 6 and 7]. The suture line can be checked for any leak by injecting saline through the presumed ureter. Ooi *et al*. constructed a pyeloplasty training model using reconfigured chicken skin.[41] McDougall *et al*. created a ureteropelvic junction obstruction in a porcine model by ureteric ligation, and after 6 weeks, a pyeloplasty was done in this model. Chiu *et al*. and Fu *et al*. have also described porcine models for pyeloplasty.

Simulator for urethrovesical anastomosis post laparoscopic radical prostatectomy

In a chicken model, assuming the chicken gizzard to be bladder and chicken proventriculus to be the urethra, one can practice urethrovesical anastomosis [Figure 6]. The two structures are cut and then resutured to each other using a bidirectional suture. Laguna *et al*. have described a similar model.[42] Katz *et al*. developed a urethrovesical anastomosis model using chicken skin and Boon *et al*. used porcine intestine for the same.[43,44]

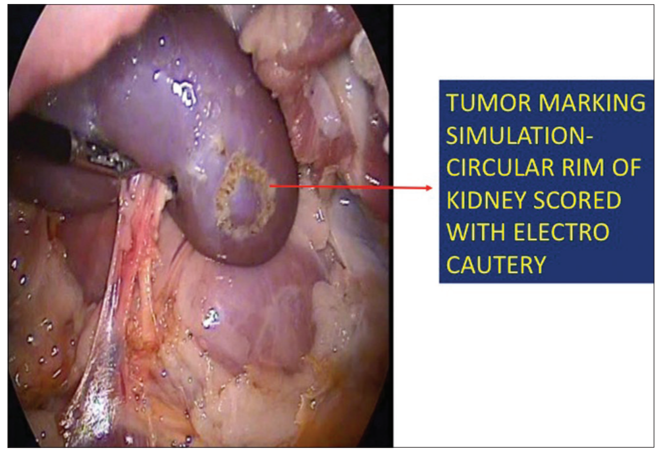

Figure 5: Porcine partial nephrectomy model. Tumor is mimicked by the electrocautery marking

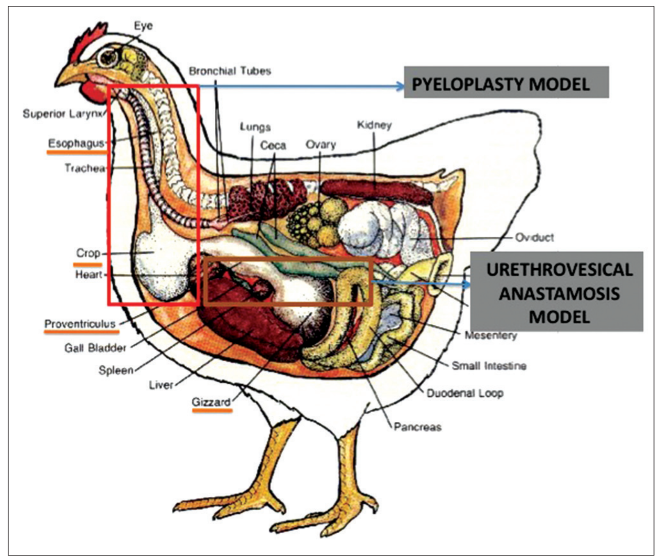

Figure 6: Anatomy of chicken and the parts that can be used for developing surgical simulation models

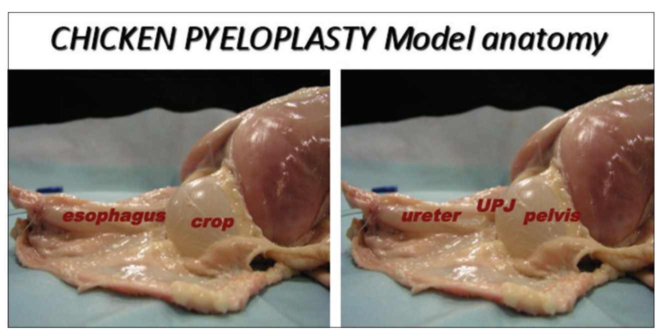

Figure 7: Chicken model, simulating a pelviureteric junction obstruction, where pyeloplasty can be practiced

Virtual reality simulators

VR refers to "a computer-generated representation of an environment that allows sensory interaction, thus giving an impression of actually being present."[45] These trainers help the trainees train in real-life situations without touching the patients. Hallmark of these training systems is the feedback that they offer, there is a real-time tracking of the human movements, which can be recorded. Objective assessment of the movements and actions can be made; critical evaluation of these procedures can be used in training curriculum. Many of the VR systems replicate the visual, haptic, and physiological clinical situations for the trainee. A variety of VR simulators have been described in Table 4. VR simulators are good training tools though they have variable fidelity depending on design. Cost and availability to trainee is also an issue with these gadgets.

Validating a simulator

It is important to validate all the simulator models because we need to ascertain scientifically, whether these models have utility in training or not. There are five different types of validities and each one has a validation method. Face validity is the simplest validity, where a novice by answering a simple questionnaire, tests the device.[46] An expert tests content validity and he opines on the utility of the device. When the device in question is compared to a standard device, it is known as concurrent validity. Whether the skill acquired by training on simulator can be transferred to a real procedure is tested by predictive validity. Last type of validity is the construct validity; by virtue of this, the simulator can distinguish between a

Table 4: Describing types of virtual reality models		
Model	**Advantage**	**Disadvantage**
MIST - VR® (Mentice , Gothenberg, Sweden)	Extensively validated Two laparoscopic instruments mounted on a frame connected to a personal computer Real-time display of instruments Objects appear randomly on screen which are to be grasped and manipulated Time taken, error in grasping, and economy of movement recorded	No haptic feedback Only basic laparoscopic skill can be taught No surgical scenarios included
Lap Sim® (surgical science, Gothenberg, Sweden)	Realistic Structures can be deformed and bleeding occurs Outcomes assessed by time, tissue damage, and errors	No haptic feedback
Xitact® (Xitact, Morges, Switzerland)	Dissection, clip application and tissue separation can be performed in virtual abdomen It provides force feedback	It does not provide case scenarios
ReachIn® (Reachin , Stockholm, Sweden)	Provides basic skill training and is a laparoscopic cholecystectomy model Dissection, clip application, cutting, and tissue separation can be performed It provides haptic feedback	Cannot simulate the surgery from start to finish Providing haptic feedback may not improve training
ProMIS™ (Haptica, Dublin, Ireland)	Combines VR simulator with box trainer Uses laparoscopic instruments, which can be followed by the laparoscope Haptic feedback is present	Haptic feedback may not be important in early part of the training
Select-IT VEST™	Has two components one for basic skill training other for cholecystectomy and gynecological procedures	No haptic feedback
LapMentor™ (Simbionix, Cleveland, OH)	Simulates complete procedures Accounts for anatomical variations Basic skill training model as well as complex surgical procedure-based model Can simulate port positioning Virtual instructor teaches the trainee It has good construct validity	Very costly

VR=Virtual reality, OH = Name of the state ohio, MIST = Minimally invasive surgical trainer, VEST = Virtual electrosurgical skill trainer

novice and expert.[36,46] [Table 5] describes various types of validation methods and how they can be tested.

Task analysis after training on a simulator

There are a number of assessment tools for objective scoring of the surgical skill gained on a simulator. As it is difficult to rate the performance during the operative procedures, most of these systems use a scoring done on inanimate models outside OR. Objective structured assessment of technical skills is one such model of task analysis performed on inanimate models.[3] It consists of a 10–30 specific surgical steps in a checklist format, which are integral to the procedure being performed. Furthermore, 5–8 different surgical observations are made, such as tissue handling and judicious use of movements. These observations are rated on an objective scale. Objective structured clinical examination is another such tool.[3]

Mcgill Inanimate System for training and evaluation of laparoscopic skills consists of five laparoscopic exercises to be performed in laparoscopic box trainer, namely, bead transfer, designs cutting, loop ligation, intracorporeal suturing, and extracorporeal suturing.[36] This system has been validated by American College of Surgeons and is incorporated into fundamentals of laparoscopic surgery (FLS) program.[47,48] American Board of Surgery requires all surgeons to pass FLS program. Imperial college surgical assessment device is a more complex assessment tool, in which the movements of hands are recorded using sensors placed on the hand. These movements are plotted as tracings and compared against the set standards.

Table 5: Describing type of validation methods	
Face validity	Validates whether simulator does what it is proposed to do Nonexperts use the device and rate it on a scale using simple questionnaires
Content validity	It is a measure of usefulness of the trainer Experts in the field review the device and opine
Criterion Validity	It validates the accuracy of the device
Concurrent validity	Concurrent validity is proved by comparing the device to an existing standard
Predictive validity	Predictive validity is the ability of the device to train an individual in such a manner that the skills acquired can be transferred to real operating room. Testing the trainee with simulator and then in the operating room can establish this. It is difficult to test as many variables are involved
Construct validity	Construct validity is the ability of the simulator to distinguish between novice and expert. Testing large number of surgeons with variable experience can prove this; a score is given to each surgeon if the device is able to differentiate between the novice and an expert it is said to have good construct validity

Ideal task analysis tool will be the one, which will be able to predict the transference of the psychomotor skill to the real surgical situation; unfortunately, we do not have a tool, which can do this accurately.

How effectively does simulation-based training translate into improved surgical performance in real time?

There is a large body of literature on simulation in surgery, its effectiveness in teaching a learner basic skills and enabling him to progress along the learning curve. However, the current data has not been able to establish that, to what extent can these skills get transferred in a real operation scene.[33] If an objective system has to be developed as a part of training curriculum where we are able to establish whether a candidate is qualified to do minimally invasive surgery or not, the evidence will have to be more robust. The questions like what kind of simulation, for how long and how effective are these in real-time situation still need to be answered.

Scope for future development in the field of urology

With 3D printing coming in a big way, any desired model of a human organ or pathological state can be created. These models can be placed in laparoscopic box trainer and operated on. Silberstein *et al*. developed the 3D printed models of renal malignancies based on the imaging studies.[49] Cheung *et al*. described a pyeloplasty training model developed based on 3D printing.[50] VR models which will give haptic feedback, correct the surgeon if surgical step goes wrong are now being developed.

Ethical and technical hurdles while evaluating skills on human beings

The effect of simulation-based training on a surgeon's learning curve can only be evaluated in a real-time situation. The ethical problem in doing so in a trail setting is that the surgeon is conscious of the fact that he is being observed, his performance may alter, and this exercise may risk the patient being treated. Evaluating a surgeon without the surgeon knowing he is being observed is very difficult to achieve.

CONCLUSION

Pros

Simulators have the ability to teach a novice basic psychomotor skills. Supervision and feedback enhance learning in a simulation-based training. They are supplements to and not a substitution for traditional method of teaching. These models can be used as a part of most of the surgical training curriculum.

Cons

Cost and availability are the key issues. The cost will determine the availability of the simulators at a center and the availability in turn would determine whether a trainee will get the opportunity to use the simulator. Furthermore, teacher training is an important aspect which would help teachers to understand the importance of simulation in student training. The domains in which it would improve and the extent to which simulation will improve surgical skills is dependent on various factors. Most simulators cannot train a surgeon to deal with anatomical and physiological variations. At present, it is not possible to revalidate all the surgeons in terms of their surgical skills, using simulators.

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