Chapter 2
Simulations for Procedural Training

While the art of simulation has been known for many centuries the science of simulation has only come to the fore in the late twentieth and early twenty-first century. Simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviors of a selected physical or abstract system. Simulation is used in many contexts, including the *modeling* of natural systems or human systems in order to gain insight into their function. Other contexts include simulation of *technology* for performance optimization (automobile engine design, *safety engineering*, *testing*, *training*, and *education*). Simulation can be used to demonstrate the eventual real effects of alternative conditions and courses of action. For example, what might happen to the flight path or handling ability of an airplane under certain wind conditions or at certain speeds? Key issues in simulation include acquisition of valid source information about the relevant selection of key characteristics and behaviors, the use of simplifying approximations and assumptions within the simulation, the fidelity of the simulation (i.e., how "realistic" it is) and the validity of the simulation outcomes (i.e., how likely are the outcomes portrayed in the simulation likely to happen in real life). The first medical simulators were simple models of human patients (Lanier and Biocca 1992). Since antiquity, these representations in clay and stone were used to demonstrate clinical features of disease states and their effects on humans. Models have been found from many cultures and continents. These models have been used in some cultures (e.g., Chinese culture) as a "*diagnostic*" instrument, allowing women to consult male physicians while maintaining social laws of modesty (Rosen 2008). A model is a simplified version of something complex. It is used in analyzing and solving problems or making predictions and are typically used when it is either impossible or impractical to create the original conditions. For example models are used to help students learn the *anatomy* of the *musculoskeletal, vascular, and organ systems*. A simulation is the implementation of a model over time. It brings a model to life and shows how a particular object or phenomenon will behave under certain conditions. It is useful for testing, analysis, and training on real-world systems or concepts that can be represented by a model. The models

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Table 2.1 Simulator category options list Penn. State minimally invasive surgical skills laboratory*

	Model driven	Instructor driven	VR/haptic	Computer programs	Task specific model
Physical body	Yes	Yes	Some	No	Some
Automatic responses	Yes	No	Some	Yes	No
Performance feedback	No	No	Yes	Yes	No
Independent learning	No	No	Yes	Yes	Yes
Start-up cost	Medium to high, depending on model	Medium	High	Low	Low

*With permission from Prof. Randy Haluck

can be dynamic such as full physics computer generated virtual reality simulation of the human vascular and cardiovascular system that responds to real-time vessel–instrument interaction or a synthetic pad in which a trainee can excise a sebaceous cyst or practice suturing. Both model some aspect of human anatomy which facilitates a learning activity through simulation of characteristics of that anatomy. On the VR simulator it is possible to learn how not to behave dangerously with interventional devices such as catheters and wires and on the synthetic pad it is possible to learn how to suture while minimizing trauma to the sutured tissue and while closing the incision as neatly as possible.

Professor Randy Haluck (Hershey School of Medicine, Penn State.), one of the early adopters and pioneers of simulation, has compiled a comprehensive list which included descriptions of medical simulation technology. A complete list of the names of owners and description of these simulators can be found on the Minimally Invasive Surgical Training Unit, Hershey School of Medicine website (Halluck, accessed April 2010). A summary table is included which attempts to categorize the simulators by type and how they think each simulator works and what type of start-up costs might be associated with each type of simulator. This information is given below in Table 2.1. Please note that simulation nomenclature is not as yet standardized and the use of these terms may differ from site to site, and between manufacturers.

Physical body – Is the user interacting with a physical object (manikin body or part of a body) representing relevant patient anatomy?

- *Automatic responses* – Does the simulator autonomously respond (give immediate feedback) to interventions performed by the user with no instructor input?
- *Performance feedback* – Can the simulator itself evaluate performance and give feedback to the user after the session without an instructor being present?
- *Independent learning* – Can a user work through a module without instructor presence?
- *Start-up cost* – What is the average relative start-up cost for a system?

This list is based on the majority of simulations in a given category. There are exceptions in each category. Professor Haluck and his team have provided a very useful summary and information source on available simulators but do not make any critical appraisal. In order to supplement this information for the novice on medical simulation additional comments are provided below. Specific criticisms associated with a particular simulation/educational product are not provided unless, of course, we are commenting on data which has been published, which bears direct relevance to the point being made or it is something that has to be discussed openly at scientific or clinical meetings. To facilitate our discussion of available simulators we have organized our comments around the different types of available simulations (Table 2.2).

The different types of simulation have been divided into bench-top models, computer-generated experiences such as online simulations and different virtual realities experienced from part task trainers or emulators through to high fidelity full physics simulators. The use of animal models, cadavers and real patients as simulation models for the training and acquisition of skills are discussed. An extensive list of all the simulators available is not the function of this chapter. What we have done is given an outline of some of the more common types of simulators which are currently used in the training of residents and consultants in surgical skills. Throughout this book it is emphasized that the simulator one uses is probably not that important because there are numerous others which will probably do a similar job. What is important is that the right simulator is chosen for the job (taking account the costs). What is probably of paramount importance for trainers is that a simulator is simply a tool for delivering the curriculum, and for trainees the curriculum is king. When assessing the functionality of a potential simulation task there are two important questions: (1) Will this simulation task allow you to teach and train the required skills? and (2) will the simulation task allow you to assess the skills you wish the trainee to acquire? If one understands the purpose of these two questions and one (genuinely) knows how to go about answering them one truly understands the science of simulation. The different types of simulation (not an exhaustive list) to be discussed are shown in Fig. 2.1. They have been chosen as exemplars of the main categories or type of simulation because they are widely available and because the authors have direct personal experience with them.

Bench-Top Models

Animal Tissue

One of the most basic types of simulation task that has been around for decades and has been successfully used to help train medical students and junior doctors the skill of surgery, is the use of animal tissue such as pieces of chicken, pork, liver, or bowel. These models can be used for training a wide range of surgical skills

Table 2.2 A summary of the strengths and weaknesses of different types of simulations

Simulation examples	Strengths	Weaknesses
Bench-top models e.g., Limbs & Things, animal parts etc.,	Ready to use today, inexpensive, good face validity, no hygiene/health and safety issues, hygienic (for some)	Cost, reusability, assess ability, cost of real instruments, hygiene/health and safety issues, messy, ethics
Computer simulators		
Online simulation e.g., School for Surgeons (RCSI), ESSQ (RCSE), FLS (SAGES), CASES (SCAI) etc.,	Flexible, easily configurable, easily delivered, huge (as yet untapped) potential Most have no automatically generated metrics	
Part task trainers/VR emulators e.g., MISTVR, PROMIS, surgical science	Ready to use today, configurability (easy to hard), poor face validity, extremely well validated, costs, can be set up anywhere, multidisciplinary use	Costs (PROMIS)? use once and throw away, space, technical support, need for critical mass, teaching bad habits,
High fidelity e.g., Endoscopy, urology/endovascular Ophthalmic, SimSuite	Ready to use today, configurability (easy to hard), case library, multiple instruments on the same simulator, good face validity, reasonably well validated, good assessment, reliable, multidisciplinary usage	Costs, teaching bad habits, Well reported on, well accepted by professions, summative metrics, not a full physics simulator
Human patient simulator (anesthetics)	Well reported on, widely used	Lack of standardized metrics, time-consuming to use and assess, subjective assessments which are time-consuming
Full physics virtual reality simulator VIST & ES3	Real patient data, good face validity, configurability, new procedures, new cases library, new devices, objective feedback, real-time and summative metrics	Expensive, fragile, time-consuming to produce new cases, require a lot of technical support
Real tissues Animal models, cadavers, real patients	Good to excellent face validity, devices behave the same as on real patients	Supply problems, model realism (e.g., appendix in a pig); health and safety, storage, availability just-in-time, ethical issues, performance measurement, inadvertent events (killing the animal), very expensive, specialized facilities and support (e.g., vets, animal anesthetist), hygiene/health and safety, messy

from suturing to the making and closure of incisions. These types of models are readily available in most butcher shops on the high street, are relatively inexpensive and disposable. Another advantage of this type of model is that it gives trainees appropriate exposure to what it is like to work with real tissues – including fragility and consequences of inappropriate or rough handling. Thus, for the trainee these models have good face validity and for the trainer they give a good idea of how the trainee will handle human tissue. One of the major disadvantages of working with animal tissue is that special facilities are required by health and safety (RACS 2010). Special benches and special cleaning for health, safety and hygiene

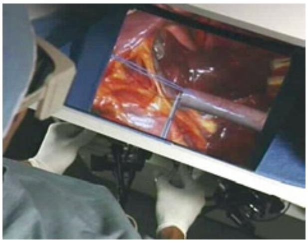
Fig. 2.1 Simulation examples

Online education/simulation models

Organization	E-learning package	Function
American College of Surgeons	ACS E-learning resource	The ACS E-learning resource provides access to webcasts, MP3 audio recordings of named lectures and panel sessions at clinical congresses
Royal Australasian College of Surgeons	Planned for	2011 – 2015 Strategic Plan: Implement e-learning strategy with Learning Management System and Knowledge Hub on web
Royal College of Physicians and Surgeons of Glasgow	NHS Scotland Knowledge Network	Fellows and members of the College have access to a wide range of e-resources through the NHS Scotland Knowledge Network
Royal College of Surgeons of Edinburgh (and University of Edinburgh)	Edinburgh Surgical Sciences Qualification (ESSQ)	Three-year M.Sc. course in Surgical Science with significant online educational resources
Royal College of Surgeons of England	School for Surgeons	In 2001 the College pioneered surgical e-learning, reconfiguring its *Surgical Training Education Programme (STEP®*, established in 1993) to incorporate an e-learning component, *e*STEP®
Royal College of Surgeons in Ireland	School for Surgeons	Virtual Grand Rounds, MRCS short courses and assignments, online discussions and debates, critical appraisal of the literature
European Association of Endoscopic Surgeons (EAES)	Fundamentals of Laparoscopic Surgeons (FLS)	Standardized modules in preparation for EAES/SAGES accredited skills laboratory training
Society of American Gastrointestinal and Endoscopic Surgeons (SAGES)	Fundamentals of Laparoscopic Surgeons (FLS)	Standardized modules in preparation for SAGES accredited skills laboratory training

Fig. 2.1 (continued)

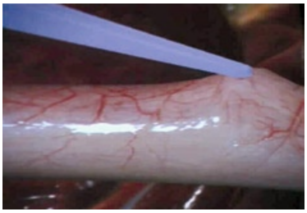
Part-task VR trainers



Anastomosis simulator

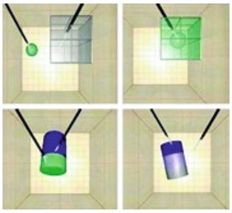
MIST VR

LapSim



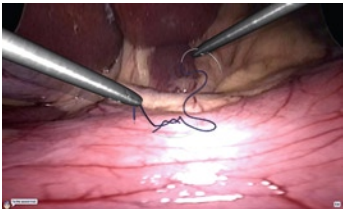
Anastomosis simulator vessel

Courtesy of Marc Raibert, BDInc, 1998



MIST VR tasks

Courtesy of Mentice AB, Gothenburg, Sweden



LapSim suturing tasks

Courtesy of Surgical Science AB, Gothenburg, Sweden

High fidelity VR simulations

Simbionix GI Mentor

Simbionix Lap Mentor

Simbionix Angio Mentor Ultimate

Courtesy of Simbionix, Cleveland, OH, USA

Fig. 2.1 (continued)

High fidelity VR simulations (contd.)

Bronchoscopy simulator
(formerly Immersion)
Courtesy of CAE, Montreal, Canada

EYESI virtual reality simulator,
Courtesy of Vrmagic, Mannheim
Germany

High fidelity/human patient simulators

Dr. David Gaba
Pioneer of simulation in medicine

Gaba simulation
Courtesy of Dave Gaba

Medical Education Technologies
Inc. (METI) simulator, Courtesy
of METI, Sarasota, Fl, USA

SimMan® is a portable and advanced
patient simulator for team training.
Courtesy of Laerdal, Stavanger, Norway

Fig. 2.1 (continued)

High fidelity/human patient simulators (contd.)

SimSuite simulator

UltraSim (the first ultrasound simulator)
Courtesy of MedSim; MedSim,
Kfar-Sava, Israel.

Simantha(R) Endovascular Simulator,
Courtesy of Medical Simulation Corporation,
Denver, Colorado

High fidelity complete operating room/cath. lab.

Orcamp complete operating room/cath lab. Courtesy of Orzone AB, Gothenburg, Sweden.

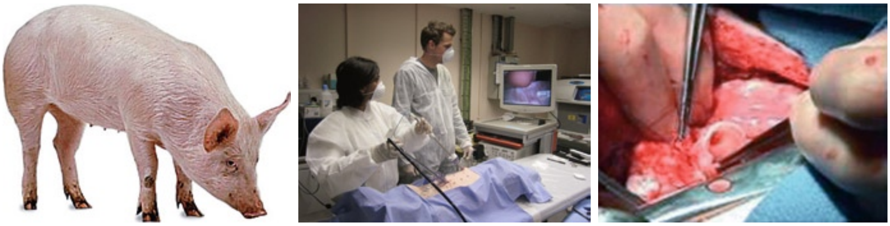
High fidelity/full physics virtual reality simulators

ENT Sinusoscopy Simulator (prototype)
Lockheed Martin 1999

Vascular Intervention Simulation
Trainer (VIST),
Courtesy of Mentice AB,
Gothenburg, Sweden

Fig. 2.1 (continued)

High fidelity/live tissue models as simulators



Pig model

Pig operating model

“Minor” surgery procedures

High fidelity/cadaver tissue models as simulators

Dr. Nicholas Tulpe (City Anatomist, Amsterdam Guild of Surgeons) by *Rembrandt*, 16th January, 1632.

Interior of an unidentified classroom, students posing next to three cadavers and a skeleton USA, ca. 1910. Photograph. National Library of Medicine

The dissection of human cadavers in medical school imparts not only the lessons of gross anatomy, but lessons on dealing with death.

Read more: Cadaver Experiences - body, life, time, human, Changes in Medical School http://www.deathreference.com/Bl-Ce/Cadaver-Experiences.html#ixzz0ZHgRgfV7

High fidelity/live human (damaged) tissue models as simulators

Gangrenous foot; Schneider, Rayfel; Laxer, Ronald; Ford-Jones, Elizabeth Lee; Friedman, Jeremy; Gerstle, Ted; Atlas of Pediatrics, Volume IA, Chapter 23. (2006) With Kind Permission from reproduced with permission from Springer Science+BusinessMedia B.V.

Fig. 2.1 (continued)

reasons are normally required. This type of training model also has a limited shelf life, and it can only be used a certain number of times before it becomes a health hazard. A further difficulty with this type of model is that it is difficult to assess. For optimal assessment of the trainee’s performance the trainer should observe the trainee during most of their performances. The reason for this is important as when assessing the trainees performance the trainer needs to get as complete a picture as possible about their performance. In surgery it is important to assess not only the finished product of the operation, but also how it was achieved by the trainee. For example, the trainee may present a pig trotter which has a series of beautifully aligned sutures that are equally distant apart, with very neat knots and a series of suture tails that are all of the same length. However what may not be apparent is the amount of trauma caused to the tissue by the trainee inappropriately scraping and driving the needle through the tissue. While the finished product may look neat and, tidy it may hide damage to deeper level tissue. If this happened to a real patient it could lead to deep tissue infection which in surgery can have significant consequences.

How easily a training model facilitates the assessment of a trainee's performance is no small matter. Two lessons should be taken from the example cited above. The first is that the assessment of performance is very important in the training process and the second is that the look of the finished product can be deceiving. The finished model, i.e., the pig's trotter, appeared to be very well done, since the wound was closed with a series of very nice sutures. However, if only the finished product was assessed, there is no way of knowing how well or how badly the trainee performed in the process of performing the wound closure. This sort of problem does not just occur with very basic types of simulation models such as those described here but it also occurs with more advanced and very expensive simulation models. This problem will be discussed again in the context of virtual reality (VR) simulations for a carotid artery stenting.

Synthetic Models

Synthetic models for the education and training of skills in medicine have been used for some considerable period of time. However it was the introduction of minimally invasive surgery in the early 1990s that led to an increase in the demand for synthetic models for the training of laparoscopic surgical skills. One of the first companies to identify this growing market was Margot Cooper. In 1990, Mrs. Cooper established the Bristol-based company "Limbs & Things," which specialized in three-dimensional models for the minimal access surgery market. The company quickly identified a major opportunity in the development of materials, molding, and casting techniques to allow soft tissue to be simulated effectively and invested heavily in developing and refining materials for the simulation of human skin and tissue. We have used these models extensively in skills laboratories which we have worked in throughout the world. Indeed, in the National Surgical Training Centre at the Royal College of Surgeons in Ireland we used large volumes of "Limbs & Things" products for the training and assessment of surgeons in Ireland, and this has been reported on elsewhere (Gallagher et al. 2008; Kennedy et al. 2008; Carroll et al. 2009). Overall, these types of simulation products (of which Limbs & Things is just one manufacturer) are very valuable tools for any trainer to consider for the training and assessment of surgical skills. However, synthetic models are not without problems. The advantages of these products is that they are ready to use, they have good face validity in that they look like the anatomy of the surgical procedure they are supposed to simulate and there are no health and safety issues associated with their use. Consequently, they can be used in the dry skills laboratory, or in any hotel room or other place one wants to run a course. However, the tasks can be very messy. Some of the tasks illustrated in Fig. 2.1, particularly the laparoscopic cholecystectomy and the sapheno femoral junction ligation models are particularly messy as they contain fluids which leak out when the seal has been breached. Although these models could be used in a hotel room to run courses, they probably should not. Their use is more appropriate in a dedicated to dry skills laboratory. The models have other more substantive problems. For example, at the RCSI, the use of the in-growing toenail surgical model was stopped since it was believed to be anatomically incorrect. The company is receptive to feedback and will try to correct the model as soon as possible. These bench-top simulation models are quite expensive in the training situation. While the suturing pads can be used on numerous occasions, they still have a discreet “use”-life since only so many incisions can be made on a pad before it becomes unusable. Some of the surgical procedure tasks such as laparoscopic cholecystectomy or ingrowing toenail excision can only be completed once. Moreover, simple tasks such as suturing pads do not really respond the same way as human tissue or animal tissue to needle and thread dynamics and structure. For example, when teaching certain types of suturing technique such as subcuticular suturing, the synthetic tissue tends to rip which makes training this type of technique very difficult with synthetic models.

The trainer may develop their own tasks for the training of particular surgical skills. Intra-corporeal suturing is one of the most difficult advanced surgical skills that surgeons must acquire before they can perform advanced laparoscopic surgical procedures. At the Yale and Emory Universities’ surgical training labs, some of the core advanced laparoscopic skills were taught to *all* trainees (Pearson et al. 2002; Van Sickle, Iii, Gallagher, et al., (2005); Van Sickle, Smith, McClusky, et al., (2005). The reasoning was that advanced intracorporeal suturing skills were the building blocks on which advanced laparoscopic surgical skills should be built. Unfortunately, there were no good simulation training models for intracorporeal suturing in existence, so the trainers developed their own. The intracorporeal suturing task was divided into two training components: the first was knot tying and the second was intracorporeal suturing by driving the needle atraumatically through the tissue. The tasks these trainers developed are illustrated in the third line of Fig. 2.1. The models developed were relatively simple and inexpensive but very effective training devices. The first model consisted of teaching trainees to tie a square knot, using both laparoscopic instruments, without dislodging the foam covered pipe from the contained sponge. This task taught the trainees two skills. The first skill was to be able to tie a square knot that did not slip inappropriately and the second was not to inflict undue trauma to the tissue. For the suturing part of the task a second simple model was devised. In this task, the trainees had to drive a needle, atraumatically, through clearly identified target areas on two plastic tubes with a middle suture which had to pass through the outer foam of the plastic tube that they used in the knot-tying task. This taught the trainees the skills of atraumatic suturing within clearly defined target areas. The assessment component for the first task was how they performed, for example, did they tie good knots which did not slip and were they able to suture on target and atraumatically. The assessment strategy for the second task was at the time a unique approach to the assessment of the task.

For the second assessment both of these tasks were placed inside a ProMIS™ hybrid, virtual reality training system also shown in Fig. 2.1 (third line). In the simulator the movement of the surgical instruments as a trainee tied the knot or performed the suture could be tracked. This provided a fairly reliable measure of how efficiently the trainee was performing the task as benchmarked against experts at intracorporeal suturing performance on the same tasks. In a validation study, the trainers were able to demonstrate that the training model worked very well in comparison to traditional intracorporeal suturing training programs (Van Sickle et al. 2008). The lessons to be learned from this account are: (1) If what you want does not exist, do not be afraid to develop a training model. (2) Do not be afraid to combine simulations as there are probably no ideal training solutions for many of the problems that exist out in the real world. The results from the study demonstrated that trainees who undertook the training program using these models performed the suturing component of a Nissen Fundoplication significantly better on real patients than those who took a traditional suture training program. The main issue when using simulation is knowing what you want to achieve and which simulation models will help you to achieve that goal. It should also be remembered that when evaluating any simulation and training product, how "pretty" it looks is only a small part of the assessment. The more important questions relating to the product assessment should be, does it train the skills it is supposed to train, what is the evidence for this and how well does it facilitate assessment of the trainee. In addition the trainer should always be mindful of the costs of achieving a training goal.

Online Education/Simulations Models

One of the most powerful education and training tools which has come into the educational and for training armamentarium of medical educationalists is the ability to deliver material via the World Wide Web (the Web). The potential of this medium for education and training is only limited by the imagination of those who are using it. There are some excellent examples of material delivered via the Web but, equally there are many disappointing examples of the way this medium has been used. Many medical education users of the Web for delivery of material seem to use it to deliver PowerPoint presentations or book chapters electronically. This is very disappointing and as stated earlier in connection with simulation; E-learning like simulation is just a very powerful tool for the efficient and effective delivery of the curriculum in medical education and training. The web should serve the same function, and indeed augment the entire training process on simulation by preparing and equipping the trainee with the knowledge and/or skills relevant to the training process.

Major surgical training organizations around the world recognize the power of the Web for training purposes. All of the Royal Colleges in the UK and Ireland, the Royal Australasian College of Surgeons, the American College of Surgeons as well as the Society of American Gastrointestinal Surgeons (SAGES) and its sister organization the European Association of Endoscopic Surgeons (EAES) have developed online training programs for surgeons in training.

The Royal College of Surgeons in Edinburgh has developed their e-learning program into a 3-year M.Sc. course in Surgical Science. SAGES and EAES are organizations which deal primarily with surgeons and physicians who practice minimally invasive procedural skills and are principally interested with the teaching and the assessment of these skills. Over about a decade they have developed a program called Fundamentals of Laparoscopic Surgery, better known as FLS (SAGES 2011). This training and education program includes two major components, one is an online e-learning component and the second is a technical skill component which can only be completed at a SAGES accredited skills laboratory. These training components are linked and the technical skills component must be completed after the online module. They have also standardized these modules for the USA. Consequently all trainees undertake the same training package, which should mean that the training program produces a fairly homogenous skills and knowledge set. Moreover, they have completely validated the technical skills training program which they are delivering. Prof. Gerry Fried (McGill University in Montréal) has completed the majority of the validation work for the technical skills component of this training package, and he has done a first class job in his psychometric and clinical validation studies of the FLS skills training package (Fried et al. 2004; Peters et al. 2004; Sroka et al. 2010). However, the problem for surgery is that laparoscopic surgical skills represent only a subcomponent of the skills a surgeon requires in his/her day-to-day professional practice.

One of the most comprehensive and elegant online education and training programs has been developed by the Royal College of Surgeons in Ireland (RCSI). Prof. Sean Tierney and Prof. Oscar Traynor developed “SCHOOL for Surgeons” (Surgical Conferencing with enHanced Opportunities for Online Learning) as part of a structured education and assessment program for trainees on the Basic Surgical Training, Irish Surgical Residency Program, and Higher Surgical Training and Programme for the Royal College of Surgeons in Ireland (Beddy et al. 2009). The program provides the trainee with regularly updated clinical material designed to promote self-directed learning; it challenges the trainees to actively seek to expand their knowledge base, and to develop analytical and clinical decision-making skills. The program is delivered using an open source virtual learning environment (Moodle), which is based on a social constructionist pedagogic model. Tierney and Traynor argue that while no program can substitute for experience at the bedside, in the clinic or in the operating theatre, SCHOOL for Surgeons can teach trainees to use a structured approach to clinical problems in order to allow them to make best use of the increasingly scarce time they spend with patients. A faculty of online tutors work with the surgical trainees during weekly program of education including, Virtual Grand Rounds, MRCS (Membergship of the Royal College of Surgeons) short courses and assignments, online discussions and debates, critical appraisal of the literature, an online journal club for discussion of important papers from major journals and training on ICT skills. This online education and training program is linked to a technical skills training program in which all of the trainees must spend a certain number of days each year in the skills laboratory. Trainees must make satisfactory progress on both units to progress in their training.

If the SAGES FLS training program could be criticized for being too specific for surgeons in general, in contrast the RCSI training program could be criticized for being too general. In personal communications with both Sean Tierney and Oscar Traynor suggestions have been made to improve this training program. The first suggestion was that the online component needs to have a more rigorous and systematic assessment process. Currently work is assessed on whether it was submitted or not, whether the answer is right or wrong or just like an essay. This seems an inefficient way to assess online performance. The second suggestion relates to linking the online education didactic component to the skills training sessions in the skills laboratory. To ensure that the skills laboratory facilities are used efficiently and effectively trainees should arrive well prepared for the skills they are about to learn. For example, if the trainees are coming to the skills laboratory to learn the skills necessary for flexible endoscopy they should know what types of conditions they would investigate using this type of technology and what types of symptoms a patient would present which would lead them to consider using this type of investigation. Prior online education and training would avoid the situation where some trainees participating in skills training have barely heard about the use of endoscopy never mind whom it should be used on and for what reasons. The majority of trainees turn up for their training at the skills laboratory well prepared. However, a small number of individuals turn up having made no preparation and tend to anchor the level of training that day to their level of “expertise.” This can be very frustrating for their peers as well as the tutors who have frequently given up a day of clinical practice to pass on their expertise to the next generation of surgeons. This situation is not acceptable. The online training program should be changed so that trainees would take the module most appropriate to the next skills training session they are going to attend and they should be required to demonstrate a requisite knowledge level on the online module before being eligible to participate in the technical skills training. This may seem harsh, but training in the skills laboratory must be viewed as a high value-added component. It is certainly very expensive to organize, run, staff, and equip. As such, trainees and supervising consultants must ensure that the maximum value is elicited from the skills laboratory during training. This issue will recur in subsequent chapters when the issue of how much training constitutes enough training is discussed.

Part-Task Virtual Reality Trainers/Emulators

Col. Richard Martin Satava, first developed the idea of using virtual reality simulation to train surgeons in the late 1980s and early 1990s (Satava 1993). At that time, he was a program manager at the top-secret Defence Advanced Research Projects Agency (or DARPA, in the USA). During the 1990s, he spent millions of dollars funding research efforts into the development of virtual reality simulators for surgical tasks. Many of the simulators he funded were taken no further than prototypes or proof of concept. There were many reasons for this at the time. These included lack of enthusiasm from the medical community, absence of a viable market, and absence of low-cost high performance computing. However, the important lessons learned from these research projects were taken and applied to a wide variety of simulators that were developed around the world and subsequently taken to market. One of the most elegant surgical simulators ever built and developed during this period was the anastomosis simulator developed by BDInc., in Boston Mass. This device simulated the tissues, instruments, and images required to perform an end-to-end anastomosis. However, there were only two prototypes ever completed, and one of them currently resides in the training center of the National Capital Area Medical Simulation Centre in Washington DC. Although it looked and felt like a “real” surgical simulator little validation science was conducted on it.

In contrast, the Minimally Invasive Surgical and Trainer Virtual Reality or MIST VR (Wilson et al. 1997) looked nothing like a virtual reality surgical simulator. The first time we saw this simulator we thought it looked something like two laparoscopic surgical instruments attached to a purple motorbike engine frame. The developers of MIST VR did something rather clever when they were building this simulator. It was built in the mid-1990s, when desktop computers simply did not have the processing speed to render human tissue and surgical instrument interaction in real-time. Instead of trying to simulate the tissues in real time the MIST VR developers cleverly asked, “what skills are we trying to train and assess?” They then concentrated on developing tasks that they could present in real-time, which in turn trained and assessed the skills required to perform a laparoscopic cholecystectomy.

The first time we saw MIST VR we were pretty sure that a psychologist or a human factors person had been involved in its design and development. In contrast to MIST VR, simulators that had been developed by surgeon-engineer teams concentrated on how “pretty” the simulation looked rather than developing an effective training and assessment device. The MIST VR tasks moved in real-time, but increased in complexity as training progressed, requiring two-hand coordination of virtual tasks in three-dimensional space and on the final task required, hand-eye-foot coordination. It gives real-time feedback to the trainee on their performance as they progress through the tasks. For example if a trainee made an error on the task, the instrument they were using or the task they were working on (or both) turned red to indicate an error had been enacted. As well as real-time feedback on performance the trainees are given summative scores at the end of their training trial, both being components of an optimal training program. The tasks were also easily configurable from very easy to very difficult. These are all components of an optimal training program which has been developed with the research evidence on skills acquisition clearly informing development. Despite not really looking like a “proper” virtual reality surgical simulator MIST VR remains the best validated simulator in surgery today. Indeed, the first prospective, randomized, blinded clinical trial of virtual reality training for the operating room was completed on MIST VR. In 2001 a team of surgeons from Yale University in USA and an experimental psychologist from Ireland showed that training on MIST VR to a predetermined level of proficiency significantly outperformed a case-matched group of surgical trainees in the performance of part of a laparoscopic cholecystectomy (i.e., excision of the gallbladder from the liver bed) on real patients. The results were presented for the first time at the American Surgical Association in 2002 (Seymour et al. 2002) and was widely praised by these very senior surgeons.

This was an important milestone in the evolution and integration of simulation into surgical training as it was the first time that the clinical benefits of simulation training had been demonstrated in a robust scientific, clinical study. These results have since been replicated with other simulators (Ahlberg et al. 2007; Grantcharov et al. 2004). The Yale study is also important because it helped to define the methodology used to assess the transferability of clinical skills from the virtual training environment to the operating room (Gallagher et al. 2005). Other simulators similar in design and configuration to the MIST VR training system (currently supplied through Mentice, Gothenburg, Sweden) have since entered the market place. The LapSim™ from Surgical Science (Gothenburg, Sweden) occupies the same niche in the market as the MIST VR system. The manufacturers of the LapSim surgical training system have made special efforts to try and give their simulator more face validity than the MIST VR system. Some of the tasks bleed, almost all of the tasks look like tissue, and they move when prodded with surgical instruments. However, the issue of face validity aside, neither of these two virtual reality systems is what could be truly described as virtual reality simulators. Virtual reality emulators may provide a more accurate description of what they do.

The difference between a simulator and an emulator is that the emulator tries to imitate certain aspects of the tasks that are to be trained. In contrast, a simulator tries to represent as realistically as possible as many aspects of the simulated task as possible. In the MIST VR tasks, no attempt is made to actually simulate the tissue. The processing capacity of the computer is devoted to emulating the tasks, and the instrument–task interaction that are required to train the psychomotor hand–eye coordination required to perform a laparoscopic cholecystectomy. In contrast, the LapSim program makes some effort to make the tasks at least look tissue-like. Indeed, many surgeons have commented on the highly realistic looking LapSim tasks when compared to the MIST VR tasks. However, this “prettiness” of the tasks makes not a jot of difference to the training effectiveness of both machines. Indeed it could be argued that the MIST VR tasks are more parsimonious. The advantage about these types of “simulator” is that they are relatively inexpensive to purchase, and they include metrics on task performance built into the training modules as standard. Another advantage with these trainers is that they can be set up almost anywhere and require very little technical support. There are also no recurrent costs since the tasks are all computer-generated. However, new modules will cost extra and for the companies that manufacture these types of training devices, the hardware and to some extent the software markets must be considered as discrete.

High Fidelity Simulators

High fidelity virtual reality simulation has become more and more common with the widespread acceptance of minimally invasive surgical procedures. Two of the most successful manufacturers in this area are Simbionix (Cleveland, USA) and Immersion Medical (San Jose, USA). Simbionix is a company that originated in Israel but currently has their head office located in Cleveland in the USA. Both companies are important for different reasons. Immersion Medical is an US company which started research on the emerging medical virtual reality market, i.e., when Satava was with DARPA. The long-term impact of this has been that Immersion Medical holds the vast majority of patents relating to virtual reality simulation technology in medicine. This is particularly important in relation to the issue of haptics in virtual reality simulation. Haptics is the science and engineering that deals with the sense of touch (Monkman 1992). The emulators which were discussed in the previous paragraph have no haptic feedback. The surgical community considers this to be a particular weakness of these types of simulators and that haptic feedback is a crucial aspect of learning for the operating surgeon. Because Immersion Medical were one of the first companies to work on medical simulation they were also one of the first companies to work on haptics in simulation and to develop solutions and to patent them. In practice this means that other companies have to either find a way to give haptic feedback to the surgeon by using technology or software other than the types patented by Immersion Medical and which does not breach their patent or alternatively pay Immersion Medical a license fee for each unit sold. This issue recurs repeatedly in the medical simulation industry occasionally supported with legal representation and will almost certainly recur.

These issues aside, both companies have produced impressive high fidelity virtual reality simulators. Both companies produce, flexible endoscopy simulators, laparoscopic simulators with haptic feedback, as well as endovascular and fluoroscopically guided simulators. It is difficult to distinguish between the simulations produced by both companies since their products are very good. Although these simulators are relatively expensive, it is our opinion, they are good value for money. Most of the simulation platforms from these companies can be used to perform multiple procedures, for example, the endoscopy simulator can double as a colonoscopy simulator.

Another relatively new group of simulators are in ophthalmic surgery such as the EYESI™ (Fig. 2.1). The tasks and metrics built into this simulator are very impressive and the ophthalmic surgical community have set about the process of validating these types of simulators. What all of these simulators have in common is the ability to simulate surgical procedures that are performed within a finite volumetric space and they lend themselves to image guided intervention. However, these simulators are not without problems. Keeping them running requires some technical support and when they develop significant problems technical support from the company has to either come from Israel or the USA, which can be problematic. Another more serious problem with these simulators is the fact that they sometimes may allow technical and procedural skills which are without doubt, dangerous. For example, in some of the endoscopy simulations it is possible to push the flexible endoscope straight down through the vocal cords which in reality is never that easy on a real patient. The problem with this type of training fault is that if the trainee learns that it is this easy on the simulator there is a chance they will behave the same way toward their first patient, which could result in serious injury. This issue highlights how certain types of training on simulators could be dangerous for the patient if it goes unchecked. When supervising training on a real patient a consultant would never allow the trainee to perform in a way that exposes the patient to increased risk. However, when a trainee is training on a simulator, and at times is unsupervised, this provides opportunities for them to learn bad habits. The problem with learning bad habits is that they are very easy to acquire and they are very difficult to extinguish or unlearn. One potentially easy solution to this problem is the development of valid and reliable metrics that flag up dangerous behavior as soon as it occurs and records it for summative assessment feedback to the trainee at the end of their training session.

High Fidelity/Human Patient Simulators

It is assumed that human patient simulators are referred to as high fidelity simulations because the trainee is actually dealing with a physical mannequin that is attached to a computer. This branch of simulation, also known as full environment simulation, has been extensively developed and validated by anesthesiologists during the 1960s. Originally developed to teach airway management and resuscitative skills it was coupled with a computer to enhance the simulators capabilities and realism. One of the pioneers in this area is Prof. David Gaba an anesthetist from Stanford University, who in the late 1980s helped develop this branch of simulation into a realistic training environment with the aim of improving patient safety (Gaba and DeAnda 1988). The development of mathematical modeling programs for human physiology and drug pharmacodynamics and pharmacokinetics led to the development of mannequin and screen-based simulators. Currently the human patient simulator (HPS) based on these early models are manufactured by companies such as Medical Education Technologies Inc, also known as METI (Sarasota, USA) and Laerdal Medical AS (Stavanger, Norway). The HPS simulators can be used to stage full scale simulations whereby realistic monitoring, physiologic response to drugs, and high fidelity, pathological conditions can be encountered by trainees. This type of simulation facility affords the ability to integrate this practice into a complete curriculum, allows the trainer to alter the degree of difficulty of the simulation, and enables practice in controlled environments that can capture clinical variation that validly approximates to clinical experience. The use of the human patient simulator can add considerably to the training resources of any medical school or hospital training program. However, the mannequin is very expensive and it requires a dedicated space and technical support to ensure optimal training use.

Regular software updates are required and these are not inexpensive. It also requires a very experienced faculty of trainers to run and assess the training curriculum. This facility is probably best used as a team training environment for the emergency or the critical care scenarios. This facility might be integrated into a surgical training program and it would probably work best during medical school years, intern years, or when the trainee has acquired specific interventional procedural skills that they can implement in an operating room or emergency room environment. It would be pointless trying to teach these procedural skills during a team training exercise.

New additions to this group of simulators are continuously coming onto the market place; simulating different types of medical scenarios and clinical functionality as well as training such skills as ultrasound assessment. A relative newcomer to this group developed in the early twenty-first century is the SimSuite, supplied through Medical Simulation Corporation (Denver, USA). The manufacturers claim their simulator replicates a real-life catheterization laboratory, with a library of cases which mirror the types of cases which the interventional cardiologist would typically face in their daily practice. The manufacturer emphasizes the fact the technology replicates the real-life catheterization laboratory. It is also the case the physician can learn the appropriate devices to use for different types of cardiovascular pathology, and they may also learn how to deploy instruments such as stents. However, we are not convinced the trainee will acquire the subtle hand–eye, catheter–wire technical skills on this simulator. The reason is simple: this is not a full physics simulator, which replicates the human vascular system and catheter–wire interaction. Consequently this restricts the ability to assess trainee performance on a second-by-second business. The trainer is able to assess whether the right catheter was used, with the correct wire, with an appropriate sized balloon and stent and what percentage of the lesion was covered. However other real-time performance metrics such as advancing the catheter without wire in front of it or advancing the catheter or wire too quickly, or scraping the catheter against the vessel wall will be very difficult to assess using this simulator. Also, this is a very expensive simulator to acquire (usually leased), which requires dedicated space (permanent or temporary) and very experienced technical support to run it.

Although anesthetists and emergency room personnel are strong supporters of the mannequin type of simulation and claim to have this type of training well validated it is uncertain that this type of validation work would stand up to close scrutiny for high-stakes assessment (Bond et al. 2004). There is little doubt that training and this environment will improve team performance and enhance an understanding of how and what can go wrong in the operating room or in the emergency room situations. However, the team training environment scenario is not the optimal situation to acquire the procedural skills necessary to perform surgical procedures. While it is acceptable to indicate that someone performed well in a team, but it is quite a different matter to state that they performed well in the team, they were unable to perform the procedure well or safely. In procedural-based medicine such as surgery, interventional cardiology, and interventional radiology the unit of physician performance that is nonnegotiable is the ability of the interventionalist to perform the procedure to an adequate level, safely and in a timely fashion.

High Fidelity Full Physics Virtual Reality Simulators

These types of virtual reality simulators are probably the "holy grail" in medical simulation. They simulate in real time, the anatomy and physiology of real patients whose anatomy and pathology have been rendered from the imaged data of real patients; they simulate real interventional instruments that appear and interact with the simulated tissue almost the same as inside a real patient. The two full physics virtual simulators that we have some experience of are the ENT Sinusoscopy simulator or the ES3 system (Edmond et al. 1997) developed by Lockheed Martin and the Vascular Interventional System Training (VIST™) formerly known as the Interventional Cardiology Training System (Dawson et al. 2000). The ES3 simulator was a state-of-the-art virtual reality simulator when it was built. However, more than a decade after it was built the high-end computer platforms (two of them) that it was built on now seem antiquated. Although a very good simulator in its day it now needs to be ported down to a high-end PC computer system. The ES3 simulates the full ENT surgical procedure using the same endoscope and surgical instruments that would be used during a real procedure on a real patient. The surgical cases were developed from real patients and the instruments look, feel, and behave the same way they would inside a real patient. Unfortunately, only three prototype systems were ever built. The system that has been best funded and researched resides in the ENT department at Albert Einstein Hospital in New York. Funded by a grant from AHRQ, Prof. Marvin Fried has completed a series of validation studies that demonstrate that the ES3 is a pretty good simulation (Fried et al. 2010; Fried et al. 2007; Uribe et al. 2004). However, he continues to struggle with the antiquated computer platform that powers the ES3.

In contrast, the VIST simulator has had a much more colorful developmental history. It started out life in Dr. Steve Dawson's laboratory (CIMIT) in Harvard funded in partnership with Mitsubishi Technology. However in the late 1990s Mitsubishi withdrew their support for the project and the simulator was sold to a London-based company called Virtual Presence who in turn sold the simulator to a Swedish company called Mentice AB (Gothenburg, Sweden). One of us (AGG) purchased the first VIST system in the UK, and VIST is probably the most successful full physics simulator on the market today. It simulates a wide variety of endovascular procedures from coronary artery stenting, coronary angiography, carotid artery stenting, renal stenting, and a variety of other peripheral vascular endovascular procedures. It runs on a high-end dual processor PC system and simulates the real anatomy and pathology of a variety of patient cases, which can be completed with a range of manufacturers' devices. Because it is a full physics simulator, performance of the trainee can be assessed on a second-by-second basis and the trainee can receive intraoperative feedback on their performance as well as feedback at the end of the procedure. It has been extensively studied in the skills laboratory (Gallagher and Cates 2004a, b; Nicholson et al. 2006; Patel et al. 2006; Van Herzeele et al. 2007) with some clinical validation including a study where the data from the patient who was to be operated on was downloaded and formatted in the simulator so that the physician could rehearse performing the procedure before actually completing the procedure on the real patient, i.e., mission rehearsal (Cates et al. 2007). It is our opinion that this simulator is one of the best virtual reality simulators ever built. However, VIST is also not without its problems! The VIST requires dedicated space in a temperature controlled room, very knowledgeable technical support, and gentle handling by trainees. It is very expensive (but probably not as expensive as the SimSuite system) as are new modules. A further problem is that the system does not always run reliably. Although the system can take patient specific data, the case data must be formatted by the developers and can take up to a week before a workable model can be produced.

High Fidelity Live Tissue Models as Simulators

Surgery and interventional medical disciplines have used live animals for training for decades and this is unlikely to cease in the foreseeable future. Working on live animals under real operating room conditions, with real surgical instruments is very reassuring for surgeons. It also provides valuable information on how the instruments behave or interact with real anatomy. It is difficult to simulate inside a computer environment how a surgical instrument with an electric charge at the end of it (i.e., a cautery instrument) will behave in close proximity to moist live tissue. There are also numerous other advantages to using live animals for training purposes such as making the initial incision, operating on real beating tissue, and practicing wound closure. However, there are as many if not more disadvantages associated with training on live animals (not least of which is the ethics associated with training on live animals). There are also very significant costs associated with housing the animals, feeding them, and providing a dedicated operating room which is equipped to a similar level as a hospital operating room. Furthermore, when these animals are being operated on a vet technician, or indeed, a veterinary surgeon or an anesthetist must be present throughout the procedure. All of these aspects of animal work make training on animals, very, very expensive. Moreover, there is the whole issue of performance measurement. For example, if one is trying to train the safe and appropriate deployment of mesh for the treatment of a ventral hernia, it is very difficult to assess on an animal model how well the mesh has been placed and secured unless and until one sacrifices the animal. However, in a bench-top simulation model such as a synthetic abdomen produced by Limbs & Things, it is relatively easy to assess performance by simply removing the top of the simulator and examining how well the mesh has been stretched and tacked to the abdominal wall. Furthermore, these types of training scenarios may be run in hotel facilities and do not require dedicated operating room conditions.

Cadaver Tissue Models as Simulators

Human cadavers have always been and likely will always be an important means for discovering the intricacies of human anatomy during medical training. In 1542

Vesalius inaugurated the age of science and science-based medicine by testing published anatomical information against the facts revealed by cadaveric dissection. By placing the deceased human at the core of his investigations Vesalius had implicitly affirmed the patient centered Hippocratic cannon (Nuland 1988). Coulehan and colleagues (Coulehan et al. 1995) noted that medicine is unique in allowing the dismemberment of the whole body during professional training. In medical education the value of cadaveric dissection is still regarded as important in the education of medical students but probably not as important as it was for most of the twentieth century. Surgeons have been particularly strong advocates of cadaveric work during training. In particular, they value the development by the trainee surgeon of a touch-based topographical map of the human anatomy. Indeed touch-based learning is one of the aspects of virtual reality simulation that continues to require further development. Although the science of touch in medical simulation or "haptics" has been investigated for at least two decades considerable debate ensues as to the value of the haptics that currently exist in medical simulators. This is no small issue since the cost of adding a haptics component to a virtual reality simulation is enormous. Although the psychophysics of touch sensation has been investigated by experimental psychologists for almost two centuries (Gregory 1983) little effort was made by engineers to tap into this expertise. Instead, engineers sought the opinions of physicians who were performing the procedures, which may have been useful for qualitative insights but probably was not the optimal way to look for a solution to the problem. This issue will be dealt with in subsequent chapters when the issues of metrics identification, development, and operational definition are discussed (Chap. 5).

Surgeons have also argued that cadaveric work can also provide a good method of teaching and understanding of deep seated structures, and a framework and rational approach to understanding three-dimensional organization of anatomical structures as well as their dimensions, densities, and the strength of various tissues (Mutyala and Cahill 1996). They also point out that dissection facilitates the acquisition of manual skills which are essential to almost every branch of interventional medicine (Ellis 2001). Dissection is also a necessary exercise in the development of touch-based skills which are so important in surgery. In summary, surgeons argue that training on the human cadaver paves the way for surgeons to learn the techniques and the instrumentation of tomorrow and is key to their medical education. Of course it is not just medical students who use human cadavers for education and training purposes. Human cadavers are in much demand for postgraduate surgical training courses such as for laparoscopic colorectal procedures.

As a basic tenet of medical education we have no doubt about the value of cadaveric work for the medical student and junior doctor. Although still widely used in medical education, a review on the use of cadavers during the 1980s led to a significant reduction in instructional time. In an extensive review of the human cadaver use in medical education Aziz et al. (2002) give a number of reasons for the decrease or elimination of dissection in medical education and these are summarized in Table 2.3. Although the reasons were offered in relation to dissection and medical school education, many of these reasons are equally applicable to the training of junior and more advanced surgeons. The reasons offered by Aziz et al. include the fact that it is time consuming to prepare a cadaver for a surgical course,

Table 2.3 Reasons given for eliminating or reducing cadaver dissection in medical education

1. *Time consuming*
   Contention: dissection is overly time-consuming activity
2. *Labor intensive/shortage of anatomists*
   Contention: dissection is labor-intensive; partly due to shortage of mollified faculty
3. *Fact-filled/requires excessive rote memory*
   Contention: faculty requires students to memorize excessive often clinically irrelevant facts
4. *Cadaver unavailability*
   Contention: it is necessary to protect due to cadaver shortage
5. *Undesirable due to post-mortem changes*
   Contention: cadaveric anatomy is different from living anatomy. It misleads due to post-mortem changes
6. *Expensive*
   Contention: cadaver is costly to obtain, embalm, store, maintain, and dispose
7. *Unaesthetic*
   Contention: smells, looks ugly, repulsive, etc.
8. *Involves outdated archaic technology*
   Contention: uses "primitive" instruments; "draculasque"
9. *Potential health hazard*
   Contention: danger from the embalming fluid and infectious disease; stress provoking
   A. *Dangers of embalming fluid components* (formaldehyde, xylene)
   B. *Infectious diseases*
      (i) Transmissible spongiform encephalitis
      (ii) Human immunodeficiency virus
      (iii) Tuberculosis bacillus
      (iv) Hepatitis
   C. *Psychosocial impact* (promoting fear and anxiety)

there is a lack of appropriately trained and qualified faculty, there may be undesirable post-mortem changes in anatomy, and cadavers do in fact pose a potential health hazard. However, other factors have come to the fore more recently; these include the unavailability of cadavers for surgical training, and the expense of acquiring cadavers, both of which have not been helped by a number of very high-profile scandals involving cadavers.

Donations of human bodies for medical research have declined in recent years correlated with a marked decline in public confidence in the medical profession. With scandals such as Alder Hey and The Bristol Case (Senate of Surgery 1998) Royal Bristol Infirmary Inquiry; (Senate of Surgery 1998) people are less confident that their wishes on what will happen to their body will be carried out, so instead have not donated to medical science. Compounding this problem has been the legislation that followed the scandals, namely, The Human Tissue Act 2004 has tightened up the availability of resources to anatomy departments. The Alder Hey scandal started with the evidence from a medical witness to the Bristol Royal infirmary enquiry in 1999. Although the Bristol Royal Infirmary enquiry was investigating the deaths of children after cardiac surgery at the Royal Infirmary this witness drew attention to the large number of hearts held at the Alder Hey Children's Hospital in

Liverpool. As the details of the Alder Hay's organ retention began to come to light the public learned that the program went back decades. An investigation was opened in December 1999. However in Liverpool, it was not just Alder Hey that was affected. Walton Hospital stored the organs of 700 patients (which did not come to light until the investigation on Alder Hey was opened). This enquiry also revealed that a Dutch pathologist, Dick van Velzen systematically ordered the "unethical and illegal stripping of every organ from every child who had had a post-mortem" during his time at the hospital. To make matters worse it was revealed that this happened even to children of parents who had specifically stated that they did not want a full post-mortem on their child. When the report was published in January 2001 it revealed that over 104,000 organs, body parts, and entire bodies of fetuses and stillborn babies were stored in 210 NHS facilities. Additionally 408,600 samples of tissue taken from dead patients were also being held. To add insult to injury it also emerged that Birmingham Children's Hospital and Alder Hey Children's Hospital in Liverpool had also given the thymus glands removed from live children during heart surgery, to a pharmaceutical company for research in return for financial donations.

There is little doubt about the continued value of cadaveric dissection for the development and understanding of anatomy, of volumetric and substantial aspects of bodily structures, their dimensions, densities, and the strength of various tissues for traditional open surgery. Indeed a good case can also be made for the development of new surgical procedures by very experienced surgeons. However, the case for acquiring the skills necessary to practice minimally invasive surgery is becoming weaker as (virtual reality and bench top) simulators become more sophisticated. As we shall see in Chaps. 3 and 4 there is considerable degradation of the sensory and perceptual information that the surgeon has to use to perform minimally invasive surgical procedures on real patients (Gallagher and Smith 2003). The information they receive through surgical instruments is also degraded, as is the image that they view on the monitor. Although the image is extremely high-quality it is still a pixilated image which is orders of magnitude inferior to what the eye would perceive under natural viewing conditions. If these conditions can be realistically simulated in a virtual environment, or indeed in a bench-top simulation task, it considerably weakens the argument for training on cadavers.

High Fidelity Live (Damaged) Human Tissue Models as Simulators

When we first thought about writing this book a few years ago this category of simulation was not high on our inclusion list! In fact, we had not considered including it at all until something rather strange happened to one of us (AGG) during a lecture tour in a very highly populated far eastern country. We were running a course for very senior neurosurgeon's on carotid artery stenting using virtual reality training. We were training this procedure using a full physics, virtual reality simulator, and during these sessions we had informal discussions about the training conducted in that country. We happened to enquire how they would normally train and acquire the technical catheter-wire skills to perform such an advanced endovascular procedure. We were informed in a very matter-of-fact fashion, that they would train on patients in the hospital who were scheduled to have an ischemic limb amputated. Physicians would practice or learn their technical skills on the limb before it was amputated. We were also informed that although a full physics, virtual reality simulation was very nice to have they did not really need it. In response to this information we explained that this type of training probably would not catch on in Western medicine.

Summary

It is widely believed in medicine in general, but in interventional disciplines such as surgery in particular, that training on simulators is something new. It is not. It is also widely believed that virtual reality type simulations represent something new. They do not. Virtual reality simulation represents the most recent evolution of simulators for the acquisition of procedural skills. Medical disciplines such as surgery have had simulation type models available to them for training for centuries. These models have ranged from inanimate representations of the human body through to cadaveric dissections. However, all of them have been pioneered and developed for the purpose of improving medical knowledge and procedural skills. What has changed over the last two decades is how these training devices are construed and leveraged to deliver evidence-based training and assessment *within* a curriculum. In the coming chapters we will describe what makes for a good simulation, how to ensure that the chosen simulation is effective, efficient, and facilitates the acquisition of surgical and procedural skills. This systematic evidence-based approach to the use of simulations is new but it also builds on knowledge and research findings from the behavioral sciences that avoids reinventing the wheel. Evidence exists from prospective, randomized clinical studies that demonstrates unequivocally that simulation-based training improves operative performance. In the coming chapters we will describe and discuss how these results can be replicated in everyday surgical training environments. However, it is first necessary to understand in detail precisely what we mean when we say “training.”

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