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1 The Evolution of Basic Principles and Practice

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1 Training in Endoscopy: A Historical Background

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Introduction

Gastrointestinal endoscopy has grown increasingly more complex as the field has evolved over the past several decades, now requiring the practitioner to become proficient at many techniques. To perform high-quality care, endoscopists often have had to devote time to learn new techniques as well as take care to continually maintain existing skills. As the technology and applications have progressed, so too have the methods by which individuals have learned to perform these procedures. In this chapter, we will trace the evolution in training from the self-taught pioneers of the early days to the advent of formal proctored tutelage that remains the mainstay of training in this field. The chapter will also relate the emergence of numerous innovative learning tools that have already served to further transform training in gastrointestinal endoscopy. In particular, we will describe the development of simulator-based instruction from the creation of realistic models to their validation and growing importance in endoscopic training. Lastly, we will address a number of novel principles of education in endoscopy that have paralleled the growing availability of these new teaching tools.

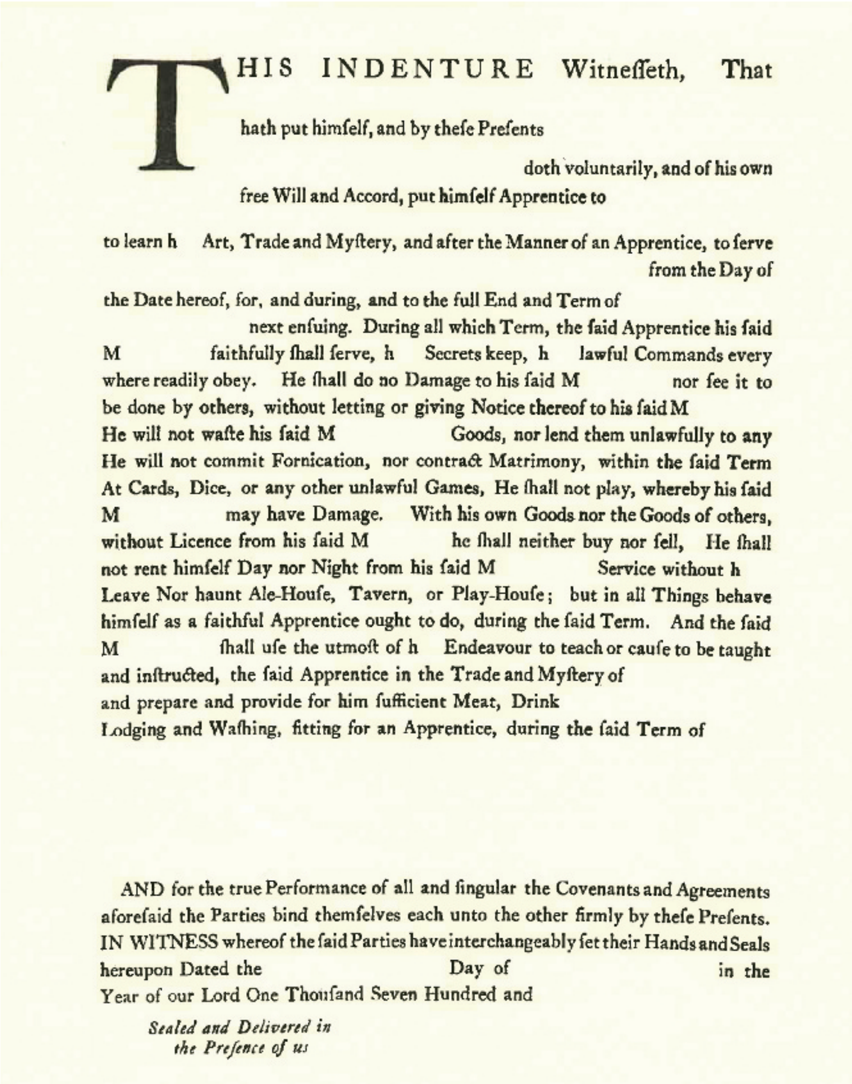
Standard training in endoscopy: then and now

Self-training for gastrointestinal procedures was the mode by which many of the early endoscopists progressed, largely because devices and equipment became available for which there was no "expert" instruction. In general, this method is not appropriate any longer for training in standard procedures (i.e., colonoscopy, upper endoscopy) where sufficient proctoring is readily available. However, as newer techniques are introduced (i.e., endoscopic suturing, endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), stent placement, transluminal surgery), the question of how to satisfactorily teach these new skills becomes relevant [1]. In fact, "short courses" have been developed to review the cognitive and technical aspects associated with such procedures. American Society for Gastrointestinal Endoscopy (ASGE) guidelines concerning such "short courses" exist, and suggest them as a possible way for experienced endoscopists to acquire new skills, but reject such methods for initial training for "standard" endoscopic techniques such as colonoscopy, upper endoscopy, ERCP, and EUS [2].

The need to impart the wisdom from the growing expertise with endoscopes was readily apparent to the pioneer generation of flexible fiberoptic endoscopy. As early as 1962, the then recently renamed ASGE conducted a symposium entitled "Teaching Methods in Gastrointestinal Endoscopy" in New York City [3]. Two years later, the ASGE formed a committee to examine the requirements for training endoscopists; the conclusions established training as a priority and created a framework that guided formal endoscopy training for many years to follow. Three items were required: (1) full training in medicine or surgery, (2) special training specifically in GI endoscopy under the supervision of an appropriately skilled teacher, and (3) performance of an adequate number of procedures. Soon to follow was the first annual postgraduate training course.

These efforts at a national level have been complemented by a proliferation of local and regional efforts to promote training with local courses and lectures aimed to supplement the one-on-one supervised instruction of trainees in the endoscopy laboratory as well as keep practicing endoscopists up on all of the latest techniques and advances. In 1973, Jim Eddy, Jerry Waye, Hiromi Shinya, Sid Winawer, Paul Sherlock, Henry Colcher, David Zimmon, and Richard Mc Cray met at the Yale Club to discuss how they might disseminate their knowledge and excitement about colonoscopy and polypectomy to practicing gastroenterologists. The result was the formation of the New York Society for Gastrointestinal Endoscopy (NYSGE) and shortly thereafter, an annual endoscopy course initially designated "A Day in the Colon." In this case, a regional society was founded for the sole purpose of promoting training. The evolving role of societies in training is the subject of a subsequent chapter in this book. However, it is important to recognize that from the national to the local level, the endoscopic societies have provided the dedication, organization, and resources to innovate and advance the field of training.

Successful Training in Gastrointestinal Endoscopy, First Edition. Edited by Jonathan Cohen.



THIS INDENTURE Witneſſeth, That
hath put himſelf, and by theſe Preſents
doth voluntarily, and of his own
free Will and Accord, put himſelf Apprentice to

to learn h Art, Trade and Myſtery, and after the Manner of an Apprentice, to ſerve
from the Day of
the Date hereof, for, and during, and to the full End and Term of
next enſuing. During all which Term, the ſaid Apprentice his ſaid
M faithfully ſhall ſerve, h Secrets keep, h lawful Commands every
where readily obey. He ſhall do no Damage to his ſaid M nor ſee it to
be done by others, without letting or giving Notice thereof to his ſaid M
He will not waſte his ſaid M Goods, nor lend them unlawfully to any
He will not commit Fornication, nor contract Matrimony, within the ſaid Term
At Cards, Dice, or any other unlawful Games, He ſhall not play, whereby his ſaid
M may have Damage. With his own Goods nor the Goods of others,
without Licence from his ſaid M he ſhall neither buy nor ſell, He ſhall
not rent himſelf Day nor Night from his ſaid M Service without h
Leave Nor haunt Ale-Houſe, Tavern, or Play-Houſe; but in all Things behave
himſelf as a faithful Apprentice ought to do, during the ſaid Term. And the ſaid
M ſhall uſe the utmoſt of h Endeavour to teach or cauſe to be taught
and inſtructed, the ſaid Apprentice in the Trade and Myſtery of
and prepare and provide for him ſufficient Meat, Drink
Lodging and Waſhing, fitting for an Apprentice, during the ſaid Term of

AND for the true Performance of all and ſingular the Covenants and Agreements
aforeſaid the Parties bind themſelves each unto the other firmly by theſe Preſents.
IN WITNESS whereof the ſaid Parties have interchangeably ſet their Hands and Seals
hereupon Dated the Day of in the
Year of our Lord One Thouſand Seven Hundred and

*Sealed and Delivered in
the Preſence of us*

Figure 1.1 An example of a typical apprenticeship contract in colonial America, circa 1750.

Supervised performance of actual endoscopies remains the predominant mode of endoscopy education today. Such apprenticeship-type relationships between mentor and mentee have evolved greatly from the autocratic and unidirectional flow of information characteristic of similar learning environments dating back to the Middle Ages (Figure 1.1). Recognition and adoption of key concepts such as the benefits of learning in a reduced stress environment, the need for constructive feedback and interactive dialog, and the importance of gradually increasing autonomy of the trainee as skills progress are among the concepts that would make current trainee learning environments quite foreign to medical apprentices of earlier eras.

In the United States today, most instruction in the techniques of gastrointestinal endoscopy are accomplished in the setting of formalized training programs of 3 years duration, with additional training available for selected "advanced" procedures such as ERCP and EUS. Proctored teaching of endoscopic techniques within such highly structured environments has been the "traditional" training method in gastrointestinal endoscopy. Endoscopic skills are developed concurrently with the immersion of the trainee in a complete curriculum that encompasses the range of normal and abnormal functioning of the digestive system, GI anatomy, and pathology. Trainees learn the indications for endoscopy, diagnostic and therapeutic capabilities of endoscopy, technical endoscopic skills, and application of therapeutic endoscopic intervention all in the context of intensive active supervised participation in consultative gastroenterology, for both outpatients and hospitalized individuals. While many physical aspects of endoscope manipulation and even lesion recognition can be taught to individuals not versed in the science and art of caring for patients with gastrointestinal complaints and disorders, to date, patients and practitioners alike have recognized the value and requirement that endoscopy be performed by individuals trained in such a comprehensive fashion, something that in this day can only be achieved in formal gastroenterology and surgical training programs. For this reason, this remains a first principle of published ASGE training guidelines [4,5].

Within these training programs, didactic information about endoscopy is included in the curriculum to an extent, but much of the actual endoscopic training remains directly imparted from instructor to student in the course of the performance of actual procedures on actual patients. Such hands-on supervision allows for increasing independence on the part of the trainee, as the teacher constantly assesses both technical and cognitive progress [6,7]. In this process, the endoscopy teacher must give the trainee sufficient time to develop skills while protecting the patient's safety at all times, and must be able to give appropriate feedback [8,9]. This process is both time and labor intensive. Additionally, sufficient case volume is necessary to allow for development of necessary skills through repetition, and enough variation in pathology needs to be present to allow the development of cognitive skills to go along with advances in technical expertise [10,11]. Mere possession of clinical judgment and endoscopic proficiency do not guarantee that an individual is qualified to be a good endoscopic teacher. The importance of having instructors who know how to teach and the constraints that limit the time such mentors have to devote to teaching can pose significant challenges for this "traditional method" of endoscopy training–challenges which some of the newer complementary teaching tools discussed later in this chapter were developed to address. While many of the chapters in this book refer to the importance and characteristics of good mentors, very little investigation has yet been conducted to understand how to best train the trainers to teach endoscopy.

What must be learned?

Guidelines for training in gastrointestinal endoscopy have been published and widely disseminated [4,5]. Skill sets that trainees must acquire to successfully perform endoscopic procedures have been outlined [12–16] and include the following:

1 Understanding of the indications and contraindications for endoscopic procedures and risk factors for complications.
2 Knowledge of the endoscopic equipment and accessories and how to set up this equipment for use.
3 Familiarity with the endoscope control dials and buttons.
4 Dexterity in controlling the scope range of motion using the dials and torque applied to the endoscope shaft.
5 Hand–eye coordination to produce deliberate, precise manipulation of the endoscope within the lumen and of accessories.
6 Communication with nursing and technical staff regarding required assistance during the procedure.
7 Knowledge of normal anatomic landmarks and possible abnormal pathologies that might be encountered.
8 Interpretive skills to correctly identify abnormalities that are detected.
9 Judgment of how to manage appropriately those lesions that are encountered.
10 Familiarity with patient monitoring and the administration of conscious sedation.
11 Awareness of how to recognize and manage adverse events.
12 Understanding of risks and benefits of intended procedures and the ability to obtain informed consent.
13 Documentation of findings.
14 Communication of results to patients and other physicians.

Standards and endpoints of current endoscopic training

Since the early establishment that training in endoscopy was a high-priority activity among academic endoscopy centers and GI societies, a great deal of effort has been devoted to assess the efficacy of training, determine learning curves for various procedures, and explore new methods for imparting proficiency. A number of important guidelines on the subject have incorporated much of this data and expert opinion on the subject [5]. One large recent review delves into the data for each procedure in great detail [16]. Specific chapters in this volume address training as it relates to quality in endoscopy and to specific standards for each of the major endoscopic procedures that are performed. Apart from the specific recommendations about learning particular procedures, a number of themes have emerged throughout all current guidelines, which reflect the evolution of the concepts of optimal training in endoscopy. Key principles include the following:

- *Specificity of training and privileging*: Individuals must be trained for each particular procedure they wish to perform.
- *Threshold numbers for competency*: Guidelines have steered away from earlier emphasis that trainees gain competence after independently performing a certain minimum number of procedures. It has been increasingly accepted that numbers do not guarantee competency; individuals develop proficiency at different rates; and accordingly, the best way to assess competency is to do so on the basis of some objective measures. Threshold numbers have been derived from evidence-based studies in which objective competency for a particular procedure is achieved after a particular amount of training; however, these numbers are now viewed merely as a minimum amount of training that must be performed before competency can even be assessed. The endpoint of successful endoscopic training should be objective demonstration of competency.

Emergence of complementary teaching modalities

Why use simulators?

Simulators have been proposed as a way to facilitate endoscopic training from the time of the earliest development of the field. In fact, Rudolf Schindler described using a model stomach for practice in orientation [17]. Many of the items in the "skill sets" listed above, and particularly those that involve dexterity, hand–eye coordination, and recognition of normal anatomy and abnormal pathology, can be addressed through the use of various endoscopic simulators.

Endoscopy simulators, including *ex vivo* artificial tissue, animal tissue, and virtual reality computer-based models, provide

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a unique method for endoscopic teaching. These devices allow for teaching which is free from the possibility of patient discomfort or injury. This factor alone confers several benefits to the learning process. First, the stress of the learning environment is reduced for the trainee and the trainer alike. There is more time for questions and feedback than available when an actual patient is involved. The issue of reduced trainee endoscope time due to critical clinical exigencies is eliminated, and there is ample opportunity for repetition. In fact, the sequence of demonstration of proper technique, repetitive practice of skills with expert feedback, and assessment of skill are all possible in this environment. Creative teaching exercises such as demonstrating common errors and what constitute poor technique are also uniquely possible using such alternative means of instruction to the traditional proctored human endoscopy setting for instruction (Video 1.1). In this way, simulators can confer excellent opportunities for "standard" techniques to be practiced by trainees and allow for new procedures to be taught to experienced clinicians [1]. To the extent that certain models might be used independently by trainees without real-time instructor feedback, and to the extent that simulator work might hasten the time in which trainees can perform unsupervised procedures on their own, simulators also have the potential to address the time constraints facing endoscopy instructors with substantial nonteaching clinical responsibilities of their own to fulfill. However, as we will relate below, much of the actual effective learning using endoscopy simulators does require fairly labor-intensive expert instruction, and to date, the potential for freeing up time spent mentoring trainees has not yet been realized.

Figure 1.2 Roller demonstration model (1971): Homemade model showing alpha loop and mobile transverse colon. (Courtesy: Dr Christopher Williams.)

Evolution and types of endoscopy simulators

Static models

The initial attempts to complement endoscope training with simulators utilized static models. Such "phantoms" were intended to teach basic hand–eye coordination, the use of the endoscope dials, and even the recognition of basic pathology. In the 1970s, as upper endoscopy and colonoscopy were becoming established as important modalities, other models were developed. These included the Heinkel hemispheric anatomical model [18] and the upper GI plastic dummy introduced by Classen [19].

In the early 1970s, homemade demonstration models of the colon, featuring a mobile transverse colon and the ability to demonstrate an "N" or alpha loop, were devised (Figure 1.2). In 1972, a colonoscopy model fashioned from the spiral metal-reinforced tubing of a hair dryer was introduced, with the ability to demonstrate corkscrewing movements (Figure 1.3). This early simulator featured the ability for the colonoscope to "become stuck" and then to be "straightened out." Christopher Williams' St. Marks/KeyMed colonoscopy model of 1975, shown in Figure 1.4, had an improved feeling of realism and was made commercially available. Twisting movements were required to negotiate the lumen, and endoscopists found it challenging [20].

Simultaneously, hand–eye coordination models were developed. These included an electronic targeting model (Figure 1.5), which had a photocell at the center, tested two-handed coordination, and allowed for "scoring" of results. An endoscopic version of the popular game "Pong" was even developed in 1977 (Figure 1.6), allowing for reinforcement of left/right coordination maneuvers in an enjoyable and motivating "game."

The Imperial College/St Mark's College Simulator was introduced in 1980 (Figure 1.7) and allowed for insertion of a limited

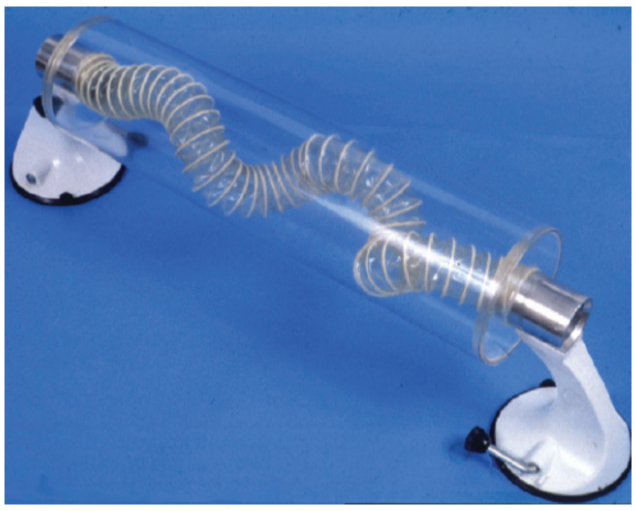

Figure 1.3 Hair dryer tube model (1972). (Courtesy: Dr. Christopher Williams.)

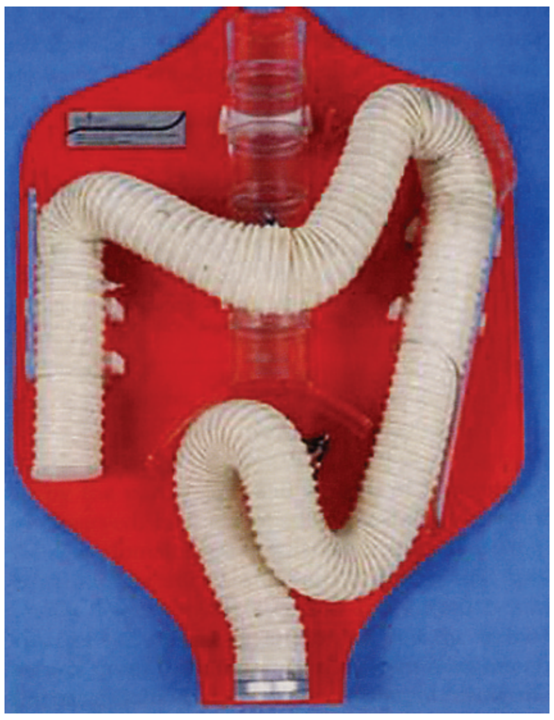

Figure 1.4 St Mark's/KeyMed model (1975): Commercially available with semirealistic feel. (Courtesy: Dr. Christopher Williams.)

amount of the shaft of an endoscope into the computer model, with real-time video feedback. This model demonstrated that such devices were feasible, although the particular model was limited by the fragility of the microswitches. Improvements were made over the ensuing 5 years, and by 1985, an updated and substantially more robust version of that simulator existed. The MK2 simulator allowed full "shaft" insertion, a sensation of resistance during looping, and audio tracks to simulate patient "complaints" (Figure 1.8). The computer allowed for a database and record

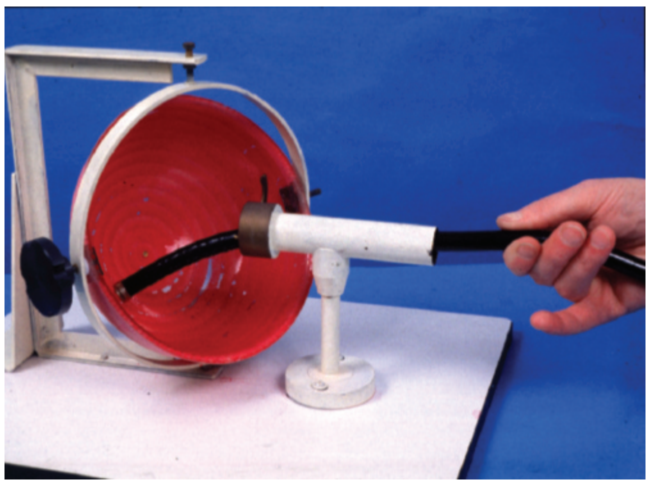

Figure 1.5 Electronic targeting model (1975): Tested hand–eye coordination. (Courtesy: Dr. Christopher Williams.)

Figure 1.6 Endoscopic Pong Game (1977): Tested hand–eye coordination. (Courtesy: Dr. Christopher Williams.)

keeping. Still, the simulator was felt to be crude and somewhat unrealistic.

In 1992, Leung and Chung developed a static model and described its use in teaching ERCP [21]. Unfortunately, the utility of each of these models has been limited by their inability to truly simulate realistic conditions. To date, while these static learning devices can be useful in instruction and learning of appropriate manipulation of the endoscope within the bowel lumen, they offer little in the way of simulated pathology. The lack of motility, the "feel" of actual compliant tissue, and the inability to practice

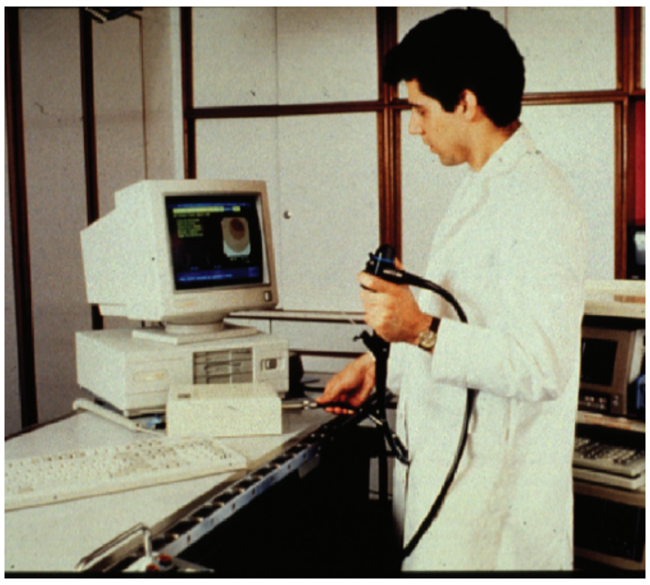

Figure 1.7 Imperial College/St Mark's simulator (1980): Limited shaft insertion, but feasibility of simulator demonstrated. (Courtesy: Dr. Christopher Williams.)

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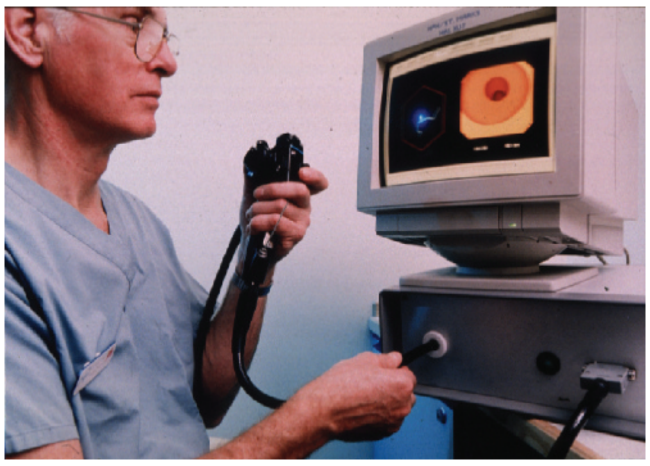


Figure 1.8 Imperial College/St Mark's simulator MK2 (1985): Full shaft insertion and audible "complaints." (Courtesy: Dr. Christopher Williams.)

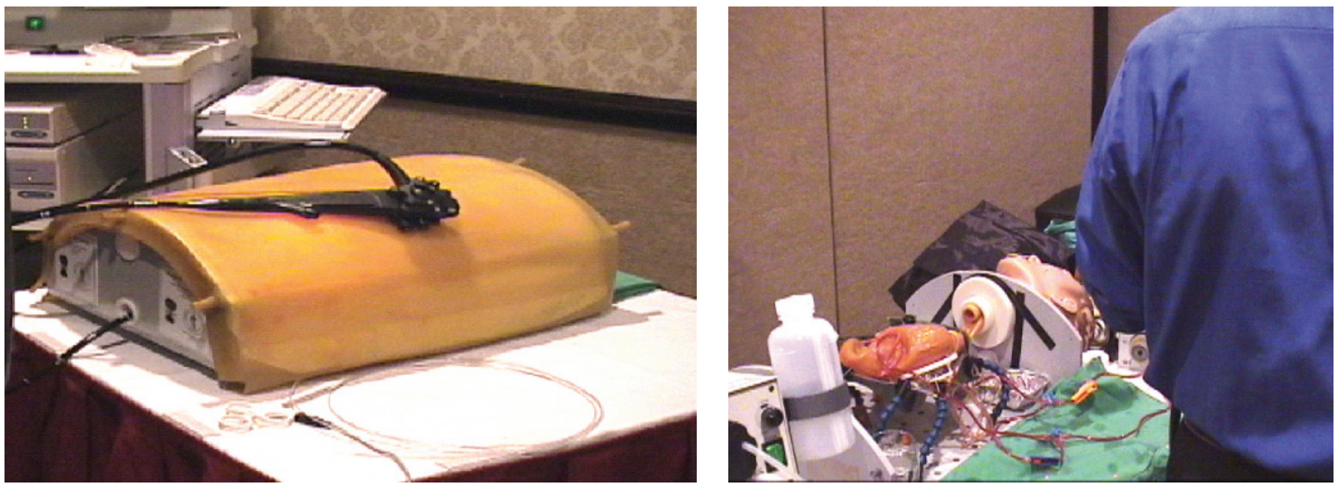
therapeutic maneuvers have largely limited the use of static models to introductory training.

Perhaps the most comprehensive application of static models in endoscopic teaching was described by Lucero et al. in 1995 [22]. This group designed a psychomotor training program called SimPrac-EDF y VEE (simulator for the practice of fiberoptic digestive endoscopy and electronic video endoscopy). Moreover, they described a series of courses in which they included static models and superimposed painted pictures to recreate frequently seen endoscopic abnormalities. These courses featured didactic lessons, slides, tapes, and supervised hands-on training on models. In addition to the Lucero model, those of Classen and Heinkel were also used. A specific Billroth II model was designed to demonstrate the unique features of this altered anatomy. Participants were offered sessions with increasingly challenging manual and cognitive tasks; faculty at the course assessed objective skills of the participants [22].

In Lucero's courses, 8–25 individuals were included in each particular workshop, and trainees had a mean duration of hands-on practice of 28 hours. In all, 422 trainees in over 22 such courses were described, and the authors noted that 95% of trainees demonstrated an "acceptable level of skill" by the end of the training [22]. However, the authors failed to describe other details of the possible benefits of such training. Such courses would appear to be difficult logistically to conduct and hugely labor intensive. Perhaps the most important contribution of this work was the concept of intergrating various hands-on training tools into a comprehensive training program that combined didactic lesions, cognitive training, and specific hands-on exercise geared to develop particular skill sets. Lucero's use of a patterned lesson plan integrated into multimodality workshops using expert faculty, a blend of manual training and cognitive skills, and immediate feedback and evaluation served as a model for subsequent efforts using more realistic and sophisticated simulators. As such, it remains an important example for future endeavors in endoscopic training.

Ex vivo artificial tissue models: the "Phantom" Tübingen models

A further advance in endoscopic simulation was developed by Grund et al. at the University of Tübingen in Germany [23]. In this "Interphant" or "Phantom" model, artificial electrically conductive tissue called Artitex is used to fashion abnormalities such as polyps and strictures and incorporate this into static models. These "pathologies" are in place of the painted-on abnormalities used in some of the pure static models mentioned above. Grund's "Artitex" abnormalities are sewn directly into a three-dimensional latex anatomical model (Figure 1.9a). While these models generally lack a realistic representation of bowel wall compliance and motility, the integrated pathology appears realistic and allows practice in electrosurgical techniques.



(a) (b)

Figure 1.9 (a) Artificial tissue colonoscopy "Phantom" simulator, U. of Tübingen. (b) Combined artificial tissue "Phantom" upper GI simulator with integrated chicken heart tissue papilla for ERCP simulation.

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In order to simulate the resistance to endoscope passage in an actual procedure, this colon model uses a semiflexible series of coils. In addition, to allow for a still wider possibility of simulated techniques, Grund's model can incorporate real animal tissue into the existing framework. For example, using a chicken heart, they can fashion an ampulla of Vater replete with separate pancreatic and biliary orifices and insert this into their upper endoscopy simulator (Figure 1.9b). The advantage of using this type of system is that several "polyp-laden" colons and "chicken-heart papillae" can be prepared in advance and quickly inserted into the chassis of the model during a training session, after the initially prepared material has been depleted.

The Tübingen simulators made possible the teaching of polypectomy and provided an excellent means of teaching therapeutic procedures such as argon plasma coagulation and simple therapeutic ERCP. In particular, the orientation of the man-made papilla more closely resembled that of humans than the porcine papilla found in the Erlangen models described below. Pancreatic cannulation and endotherapy was possible, in contrast to the porcine tissue models in which the pancreatic orifice was not readily accessible. However, procedures that required submucosal injection were still not feasible.

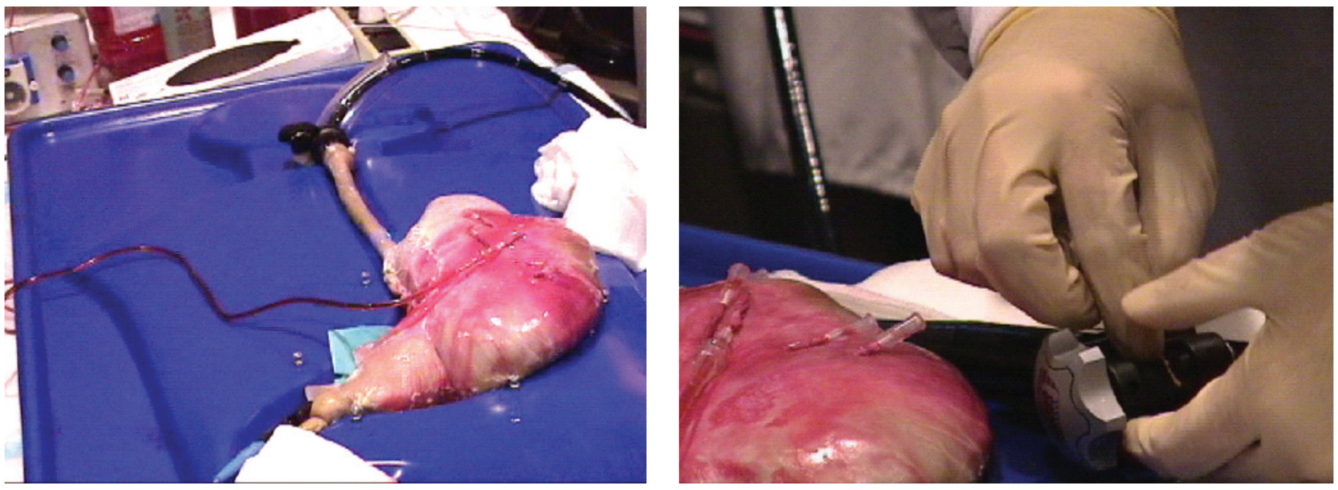
While this model represented a technological advance over prior static models and added many new capabilities, there remained several limitations that hindered its more widespread use in training. The main drawbacks were that the pathology remained hand-prepared and that the models were not mass-produced. Therefore, the "Phantoms" have not been readily available and have required the presence of the Tübingen team if the device was to be used at a training course. The trade-off for increased realism and the ability to start practicing therapeutic manipulations were significant increases in the logistical and cost obstacles to widespread use. Furthermore, models combining the real tissue abnormalities of the Tübingen model with the more accessible ex vivo animal tissue simulators described below now exist.

Ex vivo animal tissue simulators: Erlanger and EASIE models

In 1996, Hochberger and Neuman created an innovative simulator using pig organs obtained from a slaughterhouse and fastened to a plastic platform [24,25]. In order to create a model that would allow training and practice in therapeutic techniques, Hochberger then created a highly realistic simulation of pulsatile arterial bleeding (Figures 1.10a,b). This was accomplished by inserting tubes through the stomach, and sewing real arteries attached to a roller pump capable of pulsatile perfusion with a cherry-colored saline solution. Following this, Hochberger developed representations of other pathologies for this model, including polyps, varices, and strictures [26,27].

Currently, there are two basic model types based on these principles. The original Erlanger model features pig organs inserted into a dummy mannequin. This model has been used in the simulation of various laparoscopic surgical procedures [28]. Hochberger then created the compact-EASIE model, a smaller portable, lightweight version using a tabletop platform. There are now several commercially available versions of this type of simulator in which only the organs needed for endoscopy simulation are secured to the platform plastic tray (Figures 1.10a,b). For example, only the esophagus to the duodenal bulb may be needed for a specific training session, but the model has the flexibility to allow the liver and hepatobiliary tree for an ERCP simulation involving fluoroscopy. Multiple therapeutic procedures may be demonstrated, taught, and evaluated on both of these animal tissue-based simulators. With the advent of portable, compact tabletop *ex vivo* models that can easily be shipped to a location along with pre-prepared frozen organ packages, some of the obstacles to simulator availability have diminished.

While the most common application of the Hochberger model has been for hemostasis training, this group has conducted a number of training courses using the EASIE model in other areas, including EMR, stricture management, vital staining,



(a) (b)

Figure 1.10 (a) Compact-EASIE porcine model hemostasis simulator. (b) Close-up view of porcine stomach with arteries sutured in attached to catheters for hook-up to tubing connecting vessels to pump. The trainee puts together a band ligation device for varices treatment simulation.

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polypectomy, and ERCP [27,29–31]. A wide range of techniques can be demonstrated, including basic biliary cannulation, plastic stent insertion, choledochoscopy, laser lithotripsy, and placement of bilateral hilar metal stents (Video 1.2). EASIE training has been shown to significantly improve technical skill in endoscopic hemostasis in gastroenterology trainees as compared to clinical endoscopy training alone [32]. As will be discussed in detail in other chapters in this book, further adaptations of the *ex vivo* simulator have extended the use of this modality for training in colonoscopy, balloon-assisted small bowel endoscopy, improved simulation of bile duct and pancreatic duct manipulation, EUS with FNA, and even NOTES® [33–36].

Just as in the Lucero et al. experience described above, training sessions using the Erlanger or EASIE models are labor-intensive, with high faculty-to-trainee ratios. Moreover, the advance work to organize and staff workshops using this technology is extensive. Since the compact EASIE is relatively portable, its use may allow easier access to animal simulator training at local sites, but this is counterbalanced by the need to have the required expertise to prepare the animal tissues and "load" the models. For this training technique to be applied widely, many expert teachers will still need to be trained; the feasibility of 1 day "train-the trainer" courses has now been demonstrated [37].

On the other hand, like the static models before it, the EASIE model allows trainees to perform multiple repetitions of the same technique. The use of real tissue and the capability of performing advanced therapeutic procedures make this an attractive simulator for practitioners hoping to learn new techniques and for advanced fellows to practice and improve their skills, as well as to acquire new abilities [38].

By devising a way to allow realistic simulation of diagnostic and therapeutic techniques using a model that is portable, Hochberger set in motion a rapid expansion in the use of hands-on training for GI fellows in the United States and Europe. Workshops at courses such as the annual NYSGE course and at national and regional endoscopy meetings proliferated. Around 2000, under the leadership of Christopher Gostout, the ASGE launched a major initiative to create opportunities for *ex vivo* model training in a central freestanding location. This effort culminated in the creation of the Integrated Technology and Training (ITT) center of the ASGE in Oak Brook, Illinois, and the development of standardized first year fellows' course curriculum, integrating a day of intensive hands-on work in the *ex vivo* laboratory with interactive didactic lectures. The ongoing ASGE and industry support for these courses has led to over 300 fellows each year since 2005 attending the ITT workshop in the summer of their first year of fellowship. Through this effort, *ex vivo* hands-on training to some degree has become part of the standard endoscopy training for US GI fellows. Efforts to extend such opportunities for advanced endoscopy trainees and to individuals in practice have begun, but so far to a more limited extent. Creative solutions to expanding such opportunities are addressed in detail in a later chapter in this book.

Just as important as his role in the development and popularization of the *ex vivo* model, Hochberger made several other key contributions to the evolution of endoscopy training. Expanding on the course concept of Lucero, he embedded the simulator work into rigorous training programs, which deconstructed instruction according to specific targeted skill sets. Regardless of the endoscopic procedure being taught, each learning station was assigned separate specific learning objectives. Manual hand–eye skills were taught using specially designed coordination exercises. Communication skills between endoscopist and assistant were emphasized. Assessment of skills was broken down by specific procedure steps to ensure that all details received specific attention and instruction. The structure of the workshops he designed in collaboration with his German colleagues and his colleagues from the NYSGE incorporated expert demonstration of proper technique, repetitive practice with sufficient endoscope time per trainee per skill station to do so, self-assessment, and instructor feedback. These components have remained the essential backbone of all subsequent *ex vivo* model-based training. In addition, Hochberger first promoted the concept of "team training", focusing on the importance of coordinating training among the endoscopist and his staff.

Live animal courses

Both research and training courses have employed endoscopy performed on live anesthetized pigs and dogs [38–41]. Using live animals provides the best possible tactile "feel" of real tissue and endoscope movements with conditions most closely resembling those that occur during human endoscopy. Specifically, this includes the presence of luminal fluid, motility, and the ability to cause real bleeding and perforation (Video 1.3). Such courses have been conducted to teach therapeutic techniques, most notably ERCP and EUS [40]. At present, live animal courses are the only means of nonhuman simulation of sphincter of Oddi manometry [41].

Although clearly advantageous for the above reasons, live animal courses also present some substantial drawbacks. Among these are that animals are very expensive to maintain and there are significant ethical considerations in using animals for training. These ethical considerations are magnified by the fact that *ex vivo* alternatives now exist for teaching most techniques and do not require sacrificing any animals solely for this purpose. In contrast to the multiple uses possible on other simulator types, once certain procedures, such as sphincterotomy, are performed, it is difficult or impossible for others to practice the same techniques on the same animal.

For these and other reasons, training on live animals, while potentially more realistic than on inanimate simulators, appears now to be on the wane in the evolution of endoscopic training techniques. It appears likely that live animal courses will be limited to advanced procedures such as sphincter of Oddi manometry, for which no comparable inanimate model exists, and advanced training in ESD and NOTES®. For the latter techniques, many of the skill sets would still be best taught in inanimate tissue models, saving the live animal work for later training in which real physiological conditions and the potential for complication management is required. Live animal endoscopy laboratories remain well suited for clinical investigation. Finally, testing of new accessories and development of new techniques on live animals will likely continue, but much of the groundwork for these tests will have been already completed on inanimate simulators.

Computer simulation

Parallel to the introduction and adoption of *ex vivo* animal tissue models has been the development of increasingly sophisticated computer simulators. The technology has evolved to incorporate two main features, the ability to vary the pathology encountered and refinements of forced feedback or "haptics" to improve the realism of the earlier static models.

A number of investigators have pioneered efforts to produce computer models, which can allow realistic experience handling the endoscope, and are also able to incorporate broad exposure to pathologic images [20,42–52]. Because so many diverse images can be stored, computer simulation offers the best opportunity to expose trainees to a wide range of pathology. Computer-based learning can take place either independently or as part of larger training courses, and progressive tutorials of increasing difficulty can be constructed. Unlimited repetition and drilling in specific infrequently encountered procedures is possible. Moreover, progress during training can be recorded and opportunities for feedback exist.

Computer simulators typically utilize a "real" endoscope passed into a dummy mannequin. Tactile feedback capability, generated by sensors on the endoscope tip, is a key feature. The experience is enhanced by incorporation of real video images. Moreover, insufflation, suction, and bowel wall motility can be reproduced. An ASGE technology assessment statement on simulators describes in detail the innovative technological developments in this field [42]. The images on the display can be derived from interactive video stored on the computer or external storage devices, computer-generated images, or a combination of both.

Two commercially available computer simulators exist for EGD, colonoscopy, bronchoscopy, EUS and ERCP, and a colonoscopy-specific simulator is also in development (Video 1.4).

The AccuTouch® endoscopy simulator (Immersion Medical) system (Figure 1.11) (http://www.immersion.com/products/medical/endoscopy.html) allows training in a number of procedures, including flexible sigmoidoscopy and colonoscopy, as well as bronchoscopy. It is possible to practice mucosal biopsy on this model. The simulator provides direct performance feedback to the trainee. A number of validation studies have been conducted using this simulator [52–55], which will be covered in detail in subsequent chapters in this book.

The GI Mentor II (Simbionix) (Figure 1.12) (http://www.simbionix.com/GI_Mentor.html) offers several diagnostic and therapeutic modules [48]. Upper and lower endoscopy and ERCP are all performed on the same mannequin using a special endoscope for each procedure type. An accessory channel allows the endoscopist to perform a variety of therapeutic techniques, including biopsy, polypectomy, sclerotherapy, and electrocoagulation to control active bleeding, ERCP cannulation, and sphincterotomy. This simulator also includes some manual dexterity training exercises ideal for beginners to develop skills controlling the endoscope dials and using torque. The logical descendent of the Lucero model and progressive training program, the simulator incorporates a series of cases of varying pathology and technical difficulty. Instructors may delineate specific training programs. Trainees can get immediate feedback during and after completing each simulated procedure. In fact, the computer will even generate an expression of pain for overinsufflation or excessive looping of the instrument. Performance is recorded, including numbers and types of errors made. The instructor can review the progress of each trainee and the written procedure reports to determine whether abnormalities were correctly detected and identified; feedback messages may be sent back to the trainee.

Figure 1.11 Immersion AccuTouch® colonoscopy simulator.

The GI Mentor II computer simulator has been incorporated into a number of European endoscopy courses, most notably in Scandinavia [56–58]. Respondents to questionnaires have expressed great satisfaction with the limited experience on the GI Mentor II simulator. As with the AccuTouch® simulator, a number of objective validation studies have been carried out for

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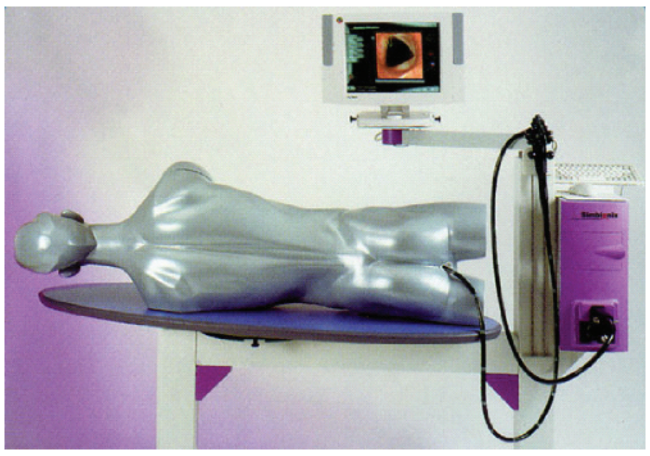

Figure 1.12 GI Mentor II (Simbionix) colonoscopy virtual reality simulator.

the GI Mentor II, and these data are presented in detail elsewhere in this book.

The Olympus colonoscopy simulator is a colonoscopy-specific simulator based on advanced mathematical models and is presently completing development and undergoing rigorous validation evaluation [59,60]. Among its features, this model attempts to better simulate more difficult colonoscope passage and perhaps allows for an accurate enough skills assessment on the model to predict performance on actual procedures. To date, none of the computer simulators have been able to achieve this degree of realism.

If computer simulators are to have a role in credentialing in addition to training, they must be able to distinguish between a novice and an accomplished endoscopist. A study from the Mayo Clinic demonstrated that performance parameters on the simulator vary according to real colonoscopy experience [55]. To date, however, no investigator has shown that a particular performance level measured on a computer or any other simulator is predictive of competent performance on subsequent real endoscopy.

At present, computer simulators appear to have much to offer trainees in terms of showing diverse pathology and teaching beginners hand–eye coordination and endoscope handling. Unique aspects of this type of training are simulation of contractions, feedback on comfort, opportunity for self-instruction without constant expert supervision, quantification of skills, and offsite skills assessment by instructors. Current available models appear less useful for more experienced endoscopists, although capabilities are expanding rapidly. At present, the therapeutic modules for the GI Mentor II simulator are best suited for introductory orientation only to polypectomy, hemostasis, and ERCP.

Computerized technology offers the potential to incorporate didactic lessons, specific questions for the endoscopist concerning accessory setup and generator settings, and opportunities for self-assessment quizzes to complement the hands-on technical experience. However, to date, such potential advances have not yet been incorporated into the existing simulators.

The major obstacle to expanded use of these simulators remains the cost and logistics of making them accessible to trainees. At costs ranging from $50,000 to $70,000, most individual departments cannot afford to purchase computer simulators.

The future of simulators in endoscopy training

Ongoing evolution of endoscopic training

The past two decades have been characterized by rapid expansion of the training modalities at our disposal and the general acceptance of their use. Much work remains to clarify the optimal way to integrate these tools into standard training, training in advanced procedures, and in the uncharted waters of maintaining skills. What will be the next steps in the evolution of endoscopy simulators? A number of scenarios can be envisioned. Some potential developments are described in Table 1.1. Regardless of exactly how this field evolves in the coming years, it is fairly certain that simulators will play an increasing role in teaching and training in gastrointestinal endoscopy.

Several challenges exist as endoscopic training continues to evolve. To date, the vast capacity to incorporate the trove of stored video and photographic content covering endoscopically encountered pathology and how to manage it has been greatly underutilized. The DAVE project [61] has been a significant advance in allowing for free and easy access to view much of this kind of material (Video 1.5). However, there is still very limited incorporation of this material into Web-based interactive learning opportunities. By taking advantage of broadband transmission and Web-based learning, cognitive training might undergo as great a transformation in the coming years as *ex vivo* models have provided for technical skills development.

A second major area for progress is in the area of creation and validation of simulator-based skills assessments that predict performance level and competency on actual procedures. Simulator investigators have long realized that a key milestone would be the development of reliable simulator-based assessments of competency.

A third area that will need to be addressed in coming years is the further integration of some of these new teaching modalities into local programs. For example, the ideal follow-up of the national first year's fellows hands-on training experience at the ITT would be a follow-up hands-on workshop at various intervals run and funded locally with support of local physicians and industry. Funding and logistic issues need to be addressed, but adoption will first require increased acknowledgment by local program directors of the importance of such activities. Expansion of hands-on *ex vivo* simulator training at the local level will also require a considerable effort to train a broader group of trainers on how best to utilize these simulators to teach endoscopy [62].

One other area of real promise is the growing role of simulators and specific training program development in the process of the introduction of new endoscopic technology and techniques. On the part of industry, this begins with the use of models to test early devices and procedures prior to more costly animal studies. Next is the growing recognition that innovative techniques require

Table 1.1 Potential next generation applications of endoscopy simulators.

1. Computer simulators may be used to test innate hand–eye coordination skills of fellowship applicants.
2. More training programs may offer static mannequins to allow novices to practice rudimentary maneuvers with controls on endoscopes and for manual dexterity training prior to handling endoscopes on real patients.
3. GI training programs with sufficient resources may provide access to hospital-based virtual reality simulators, designed to offer training in many GI and non-GI procedures. Hospitals can purchase these for training and credentialing of practitioners in many fields and training of technical assistants for these procedures. Multiuse simulators could justify the cost.
4. The large capital outlay for these simulators could be obviated by regional Web-based virtual reality servers. These might allow hospitals and training programs to subscribe and then "perform" specific procedures on "dummy" terminals at remote sites via cloud computing without purchasing the entire computer and software packages.
5. Interactive quizzes of pathology recognition and correct management decisions based on findings may be integrated into future simulator training along with the hands-on practice of technical skills. Alternatively, an Internet-based tutorial could serve as an introduction to pathology.
6. Simulators and simulator-based workshops might allow skill assessments, which would indicate when trainees were ready to proceed to perform supervised real cases and ultimately independent endoscopic procedures.
7. With validated simulator-based skills assessment, it is conceivable that no procedures would be allowed on human subjects until simulated training has occurred and satisfactory performance measured.
8. Therapeutic workshops using *ex vivo* animal models will proliferate further and become increasingly available at multiple regional locations for trainees and practicing gastroenterologists hoping to learn new skills or polish old ones.
9. GI trainees will be required to attend one such workshop during the first year of fellowship and recommended to attend another early in the third year.
10. A cadre of endoscopy instructors could be trained to run such workshops, including individuals from every region of the country.
11. Possibly, practicing endoscopists will be required in the future to attend such workshops at defined intervals, possibly every 5 years, to maintain privileges for therapeutic endoscopy.

specific training programs to ensure both proper execution of the new procedures and acceptance of the innovation by practitioners. Busy clinicians will not adopt new skills unless an efficient and preferably validated training program is available to ensure that they can develop the proficiency to safely and effectively do the procedure. In contrast to the past when efforts to determine the best ways to train for techniques often came long after the procedure was adopted, in the future, there will be increasing pressure to address training upfront. One hopes that with this additional attention to training in parallel with technology development will come increasing avenues of support for simulator-based training in general. This may be of particular importance as a partial solution to the problem of creating more opportunities for practicing endoscopists who desire to and will need to learn new techniques. The innovators will need to support those they hope will adopt the innovation; simulators are likely to facilitate this growing interdependence.

Conclusion

Training in endoscopy began with a pioneering spirit of self-taught innovators and quickly transitioned to a traditional apprenticeship model of learning during one-on-one proctored clinical experiences. Over the last 10 years, the advent of simulator-based teaching tools and a heightened scrutiny of the optimal methods, components, and endpoints of training have sparked a transformation in the way endoscopy is taught.

On the technology of training, there are now an array of realistic simulators that in sum allow for an excellent training experience in most of the therapeutic procedures comprising current endoscopic practice. There is growing evidence that training using these models is of benefit. These hands-on complementary methods are certainly popular, and thanks to the vision of the leadership of endoscopic societies and the support of the industry, opportunities to use them are increasingly available. The area of simulator-based skills assessment remains a relatively undeveloped field, awaiting increased realism, and the development and validation of proper tests. Still, the combination of static models, *ex vivo* artificial models, *ex vivo* animal models, and computer simulators, collectively represent a substantial and powerful tool for education and training in gastrointestinal endoscopy. It is easy to see the day when there will be ready availability of hands-on training via simulators beyond the gastroenterology fellowship setting. Paralleling the progression of technology and the continuous introduction of new devices and procedures will be a compelling need for hands-on experience on simulators for all such new tools and techniques.

Parallel to this transformation in the methods of training have been key new concepts about how this process ought to occur. Realizing that simulator work is generally costly and labor intensive, attention is being paid to learn how to best time simulator experience during training; for example, work with static models might be more cost-effective for novices than hands-on *ex vivo* workshops. The benefit from such workshops is intuitively greater for trainees who already have attained some basic skills. The growing experience with simulator-based training has taught the value of concepts such as team training of assistants along with the endoscopists, deconstructing complex procedures into their component skills, and increasing emphasis on self-assessment and feedback within the training process.

At the same time, the growing emphasis on maximizing quality in endoscopy has also affected guidelines and attitudes about endoscopic training. From the early days of endoscopy, thought leaders have aimed to train new endoscopists who were competent to perform procedures independently. But recently, the question they have asked has changed from "How many procedures are required for a trainee to become competent?" to "What are the objective measures of competency for a particular procedure and has a trainee reached that level of skill?" There is increasing recognition of the importance of objective measurement of success both during training and beyond. The process of keeping track of outcomes during training has the potential not only to ensure that benchmark end points of training are attained before endoscopists perform procedures independently on patients but also to facilitate that training process itself, by virtue of the feedback this information provides.

Videos

Video 1.1 The EASIE hemostasis *ex vivo* training workshop
Video 1.2 Tips for teaching using *ex vivo* models
Video 1.3 Use of simulator to teach what not to do: improper submucosal lift in EMR leads to perforation on purpose
Video 1.4 Virtual reality colonoscopy simulator training
Video 1.5 A tour of the DAVE project: a free versatile multimedia resource for endoscopy education

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