Surgeons' Skills Training

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Adding Minimally Invasive Surgery to a Surgeon's Repertoire

Within the last decade, veterinary medicine has started to increasingly recognize the importance of skills development for surgeons who want to incorporate minimally invasive surgery (MIS) in their clinical practice.

Even for surgeons with considerable expertise in traditional open surgery, it often becomes readily apparent that some laparoscopic skills are distinctly different from those of open surgery. The challenges and differences include the use of long instruments, which magnifies any tremor and limits tactile sensation, often referred to as haptic feedback. When the instrument movement is limited by a portal into the body cavity, the surgeon needs to handle the resulting fulcrum effect and the loss of freedom to simply alter an approaching angle. But even more important, the normal binocular vision becomes monocular; as a result, the associated depth perception is lost. Other challenges include the loss of a readily accessible bird's eye view of the entire body cavity. The advantage of magnification may be perceived as offset by a reduced field of view, and any instrument activity outside the view becomes a liability.

Understandably, a surgery team with extensive experience of open procedures may initially be reluctant to take on some of the challenges of MIS. This may be especially conspicuous in small animal laparoscopy, in which the conventional surgical approach provides easy access to all intraabdominal organs. A budding small animal laparoscopic surgeon may meet resistance from referring veterinarians and even staff members when converting open procedures to laparoscopic because costs and surgery time, at least initially, tend to be higher. Educating the referral base, clients, and staff in the advantages of laparoscopy may alleviate but not completely remove the initial resistance.

The surgeon's transition from open to MIS surgery can be greatly facilitated by skills pretraining. The basic laparoscopic skills of ambidexterity, optimizing instrument interaction; observing cues for depth perception; and precise, deliberate movements need to be achieved early in the skills development for the benefit of patient safety and surgeon's confidence in the operating room (OR). Furthermore, for the surgeon interested in advancement from basic to advanced procedures, simulation pretraining becomes a necessity, especially if aspirations include MIS suturing.

Basic Laparoscopic Skills

The basic skills required for laparoscopic surgery include ambidexterity, hand-eye coordination, instrument targeting accuracy, and recognition of cues to provide a sense of depth [1, 2].

Although these skills are used, and therefore trained, in clinical practice, the surgeon should not rely on caseload for training, for reasons including patient safety and costs. The Institute of Medicine reported in "To Err Is Human" that approximately 100 000 humans die each year as a result of medical errors and that approximately 57% of these deaths are secondary to surgical mistakes [3]. More recent estimates suggest that these figures likely are severely underestimated [4]. The costs for medical errors in human medicine are staggering; up to \$29 billion has been estimated [3]. Costs for learning in the OR are likewise steep; the additional costs have been estimated to \$100 000 per resident in additional OR time alone [5].

Animal patient safety concerns and costs associated with errors and training time apply to veterinarians as well, albeit we do not have evidence of the exact costs. Veterinary training curricula are also faced with financial limitations, as well as increasing external and internal ethical concerns regarding the use of live animals for surgical training. Using cadavers for surgery training is also fraught with challenges because of problems with availability, storage, and limited usefulness because of decay. Finally, the tolerance for medical errors is declining, and the urgency to reduce errors made by inexperienced surgeons on actual patients has increased, in veterinary and human medicine alike [6]. For these reasons, both human and veterinary educators are being compelled to develop innovative teaching methods for surgical skill instruction.

Beside the ethical and cost issues, it is likely that a training program built solely on OR practice in live patients becomes limited, inefficient, and inconsistent. Conversely, a shift to simulation training outside the OR has been suggested to improve operative efficiency and quality [5]. For example, we have noticed in our work that even experienced veterinary laparoscopic surgeons tend to lag in efficient use of their nondominant hands, something easily rectified by simulation training [7]. In fact, the basic skills are most efficiently trained through simulation training [8]. This has been recognized for more than a decade among medical doctors. Since 2008, laparoscopic simulation training curricula have been a

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requirement for surgery residency programs in the United States [9]. Robust evidence has been presented to demonstrate that skills developed by simulation indeed transfer into improved OR performance [10–14]. Recently, a survey of ACVS residents demonstrated a widely held desire to include a MIS simulation training curriculum into the traditional surgical training programs [15].

Simulation Training Models

A number of simulation models have been presented and can currently be divided into three main categories: physical task trainers; virtual reality (VR); and hybrid, or augmented reality (AR), models combining VR with synthetic tissue models.

Another terminology for simulation is to denote how life-like or "real" the model is perceived. Low fidelity tasks are often simple task trainers utilizing low cost materials. Cadaver training has been denoted to vary from medium fidelity to high [5], depending on species, surgery type practiced, and cadaver condition. Live animal models, if utilizing the patient species, is an example of a high fidelity model. Recently, higher fidelity synthetic models are being developed for small animal use [16], but they currently have limited availability. However, some models developed for use in human surgery may be of value also for veterinary training.

Physical Simulation Models: Box Trainers

Box trainers have in common that tasks are performed using regular laparoscopic instruments in a box containing a camera, which projects onto a computer, mobile device, or TV screen. A number of box trainers are commercially available (Figure 1.1) and carry the advantages of being portable and highly versatile. Utilizing a variety of video-capable devices, homemade trainers can be a very cost-effective alternative [17, 18]. An example of a homemade trainer used in the author's Veterinary Applied Laparoscopic Training (VALT) laboratory is presented in Figures 1.2–1.4. Homemade versions are used solely for practice and not for skills assessments.



Figure 1.1 A number of laparoscopic skills training boxes are commercially available. Most are portable, and many have cameras that connect to a computer by USB connections. Some, including the official box for Veterinary Assessment of Laparoscopic Skills (VALS; small inlay), require a TV screen. *Source*: Photo courtesy of Henry Moore, Jr., Washington State University, College of Veterinary Medicine.



Figure 1.2 Commonly used dimensions in laparoscopic training boxes.



Figure 1.3 An example of a homemade training box.

A number of practice drills have been developed and validated. In the 1990s, several structured training tasks were described, including the Dr. Rosser's station tasks developed at Yale University, which are part of the popular "Top-Gun Laparoscopic Skills Shoot-Out" resident competition. The physical task training system with the most solid validation to date is the McGill Inanimate Simulator for Training and Evaluation of Laparoscopic Skills (MISTELS) [8, 19-21]. MISTELS was the foundation for the task training included in the Veterinary Assessment of Laparoscopic Skills (VALS) program (Figure 1.5), which launched in 2017 (www.valsprogram.org). VALS intends to provide veterinarians with a validated curriculum with tutorials for independent skills practice and certification available for specialty trained surgeons [22]. Our group has trained and assessed veterinarians in our simulation training and research facility, the VALT laboratory at Washington State University since 2008. This experience was instrumental in the development of VALS [7, 23].







Figure 1.5 Logotype for the Veterinary Assessment of Laparoscopic Skills (VALS) training and assessment program. *Source*: Veterinary Assessment of Laparoscopic Skills.

Tasks included in VALS include peg transfer, pattern cutting, ligature loop placement, and intra- and extracorporeal suturing.

- **1 Pegboard transfer:** Laparoscopic grasping forceps in the nondominant hand are used to lift each of six pegs from a pegboard, transfer them to a grasper in the dominant hand, place them on a second pegboard, and finally reverse the exercise (Figure 1.6).
- 2 **Pattern cutting:** This task involves cutting a 4-cm diameter circular pattern out of a 10×15 -cm piece of a gauze suspended between clips (Figure 1.7).
- **3 Ligature loop placement:** The task involves placing a ligature loop pretied with a laparoscopic slip knot over a mark placed on a foam model and cinching it down with a disposable-type knot pusher (Figure 1.8).
- **4 Extracorporeal suturing:** A simple interrupted suture using long (90-cm) suture on a taper point needle is placed through marked needle entry and exit points in a slitted Penrose drain



Figure 1.6 Peg transfer task. Six objects are lifted from the left-sided pegs with the nondominant (usually left hand) grasper, transferred mid-air to the dominant hand grasper, and then placed on a right-sided peg. The exercise is then reversed.



Figure 1.7 Pattern cut task. A 4-cm circle is cut, with a penalty applied if the cut is outside the mark.



Figure 1.8 Ligature loop application task.

segment. The first throw in the knot is tied extracorporeally with a slip knot and cinched down by use of a knot pusher. Thereafter, three single square throws are placed by use of laparoscopic needle holders and the suture is cut (Figure 1.9).

5 Intracorporeal suturing: A simple interrupted suture is placed using short (12- to 15 cm long) suture on a taper point needle through marked needle entry and exit points in a slitted Penrose drain segment. Three throws are placed, the first being a surgeon's (double) throw, by use of laparoscopic needle holders. The exercise is completed when the suture is cut (Figure 1.10).



Figure 1.9 Extracorporeal suture task. (A). A suture is placed in a Penrose drain segment. (B). The suture is exteriorized and a slip knot tied outside the box. (C). A knot pusher is used to cinch the knot. (D). Three intracorporeally tied suture throws are placed on top of the slip knot.



Figure 1.10 Intracorporeal suture task.

The one major disadvantage with box training is the lack of instant feedback. Without automated feedback, an experienced surgeon needs to be available to critique the performance of the trainee, which becomes an important limitation because of the busy schedules of most surgeons. However, proficiency goals have been defined for MISTELS and VALS such that the trainee can monitor his or her progress by simple metrics such as time and errors [22, 24] With these goals in mind, the trainee can practice independently for the basic tasks of peg transfer, pattern cutting, and ligature loop placement. Laparoscopic suturing may require instructive sessions with an experienced surgeon. When suturing techniques have been learned, the trainee can continue to practice independently to reach an expert level of performance, as defined by the proficiency goals [22].

Another disadvantage of box training is the current lack of veterinary higher fidelity synthetic models for practicing surgical procedures. Physical models for cholecystectomy, appendectomy, and so on are commercially available, but they are all fairly expensive and most are based on human anatomy and physiology. A physical model, which can often be used only once, may not be feasible for most residency training programs if the cost is more than \$100/each. Hopefully, cost-effective medium and high fidelity synthetic models for veterinary MIS training will become more available in the future.

Virtual Reality Simulation

Highly realistic VR simulation (Figure 1.11) is commercially available for both basic skills as well as entire simulated surgical procedures. In fact, one of the main advantages with VR training is realistic simulation of surgical procedures, which is hard to achieve to a reasonable cost in box training. For veterinarians, this advantage is somewhat limited, though, because anatomy and surgical procedures are all based on human anatomy.

Basic task simulations give the trainee opportunity to experience a variety of surgical complications, such as bleeding, dropping clips, and repercussion from rough tissue handling while benefiting from instant and more objective motion metrics feedback and suggestions on how to proceed. Other advantages of VR simulation are that modules contain detailed instruction for performance of all tasks and summative feedback comparing the overall performance with an expert level. The summative performance is also broken down into a number of performance metrics, such as time, instrument path length for the dominant and nondominant hands, and errors, giving objective information about the performance. Therefore, the provided feedback of VR gives the trainee opportunity to practice without the need for an instructor. We have found that this instant feedback also serves as motivation because most surgeons and residents have competitive personalities and enjoy the comparison with expert level.

At present, a number of VR simulators are commercially available, but they all carry the disadvantage of being expensive. Costs range from \$28 000 (LapSim Essence) to over \$90 000 for units with haptic feedback (LapSim haptic, Surgical Science, Minneapolis, MN) (personal communication, Martin Jansson, GM, Surgical Science, Inc., June 2020), and software updates are also expensive. Another disadvantage is that, as mentioned, all VR simulation is



Figure 1.11 The LapSimHaptic system virtual reality trainer is combining high-technological virtual reality exercises with haptic feedback. *Source:* © Surgical Science Inc. Reproduced with permission from Surgical Science Inc.

based on human anatomy, and developing software for veterinary simulation is expensive; such models may not become available, at least not in the near future.

Because of the high cost of VR training, investigations have tried to determine if VR training can be justified by being more effective than box training. A systematic review through the Cochrane Institute found that VR procedural training shows some advantage over box training in operating time and performance [25]. Similar results were reported in another recent meta-analysis, showing that VR was associated with higher performance score during MIS, and faster completion of peg transfer task [26]. No differences were, however, demonstrated in any of 6 other outcomes parameters [26]. Some controversy seems to exist: a similar review concluded that VR and box training both are valid teaching models and that both methods are recommended in surgical curricula but with no definitive superiority of VR [27]. Important for veterinary conditions, VR procedural training may not be superior unless it is procedure specific [28], and thus it likely needs to be species specific.

In veterinary medicine, there is limited accessibility to the VR trainer. A recent study conducted by the VALT laboratory failed to demonstrate the construct validation on VR trainer [29]. Based on our experience, using VR simulator does not provide superior results compared to traditional box trainers.

Hybrid Training Models: Augmented Reality

VR simulation has been criticized for the lack of realistic haptic feedback [30]; therefore, hybrid, or AR, simulators were developed that combine a live and a virtual environment. A number of AR



Figure 1.12 The ProMis augmented reality trainer is a combination of a physical box trainer and a virtual reality overlay used in many surgical exercises. *Source*: Photo courtesy of CAE Healthcare, © 2014 CAE Healthcare.

simulators are commercially available [31]. To date, the most validated system is the ProMIS simulator (CAE Healthcare, Montreal, Quebec; Figure 1.12), which has been used in the VALT laboratory since 2010. Tasks are performed in a box trainer using real instruments, but a virtual interface can be placed over the image of the camera. Three cameras are used for motion tracking of the physical instruments in three planes. Therefore, objective metrics such as instrument path and economy of movement (i.e., velocity and directional changes over time, also expressed as motion smoothness) are provided. The metrics used have showed construct validity in suturing tasks and in the ability to separate expert colorectal surgeons from experienced laparoscopic, but novice colorectal, surgeons [32, 33].

In our experience, the use of surgical instruments adds realism to the simulation, which is in agreement with studies comparing AR with VR simulation [29, 33, 34]. However, an even bigger advantage for veterinary surgery is the ability to use novel physical models for simulation. Species-specific models can be custom made and used in the ProMIS, obtaining motion metrics feedback. The VALT laboratory has recently developed a simulated canine laparoscopic ovariectomy model and is currently working to incorporating this model into AR training. Unfortunately, the ProMIS simulator is currently unavailable because the manufacturing company has changed and the previous model is discontinued. With the advancement of technology, similar products are, however, available with different companies, in combination with VR or 3D technology.

Robotic Surgery Simulation Training

Robotic-assisted surgery is the most recent technological platform in MIS. Robotic surgical procedures are currently in the adoption phase, or approaching the standard of care phase, of surgical progression in people. The associated training is currently developing and being validated [35, 36]. Due to the very high expense associated with robotic surgical systems, it is less likely that they could be widely adopted into veterinary medicine within the near future. The detail of robotic surgical training is therefore considered beyond the scope of this chapter, and we refer the interested reader to other texts for information.

How to Train MIS Surgeons Safely; The Optimal Training Program

In the early days of veterinary MIS, surgeons had few options other than progressing rapidly into live surgery on patients, after a short introductory course. Such an approach to training is becoming less and less acceptable, due to increasing patient safety concerns, especially as training options outside the OR are becoming more available. If veterinary MIS is to expand unimpeded, effective simulation training may become necessary.

Extensive amounts of research have provided comprehensive information on training program design. What follows is a discussion of current evidence-based information, with comparative aspects to our experience of veterinary training in the VALT laboratory.

Basic Skills

Ideally, training initially focuses on basic skills task training before progressing to specific surgical procedure training. Skills training such as the VALS program should be considered only the starting point of MIS training. Currently, our institution train all first-year residents in a VALS-like curricula in the VALT lab and test competency before proceeding to primary surgeon's role. The resulting improvement in OR performance is not only often dramatic but also highly individually variable. Preliminary data show that inexperienced surgeons are able to perform the highly complex procedure of suture-ligated ovariectomy, immediately after the training [37].

Life-like-High Fidelity- Training

In addition to the fundamental psychomotor skills, the complex skills of MIS surgery require an additional variety of training; in lifelike scenarios such as fresh cadavers, live animal models, and apprentice training in surgery. (Figure 1.13) In particular, surgery training programs who lack experienced MIS surgeons on staff, may have problems providing a broad and varied training program to their residents. Also, surgery practitioners wanting to develop MIS skills are limited in options. Currently, industry-supported commercial short courses, utilizing live models, provide training opportunities for veterinarians. Limited live training opportunities using ovariectomy as a model surgery is also available for ACVS residents. Hopefully the future brings a concerted effort to combine similar efforts into a comprehensive and effective training program for all veterinary surgeons.

Very few high-fidelity veterinary simulation models are commercially available. Ideally, such analog models should be low cost, physiologically and anatomically similar to dogs and cats, and with inherent means of objective assessment of the skills. For training of M.D. surgeons, a number of procedures have been identified for which simulator models have been developed. Hopefully, the future will see a similar development on the veterinary side. Until then, some of the models used for M.D. surgeons may have value. However, prior to training programs investing in costly tools, the models need validation. Validation evidence is a complex



Figure 1.13 Graphic representation of an ideal training program, balanced with concern for patient safety. Training starts with simulation task training such as a VALS-like curriculum until passing competency assessment. Thereafter high-fidelity models such as training in fresh cadavers takes place, prior to training on a live animal model. After these steps, the trainee should be ready to perform basic MIS procedures on patients, under supervision of an experienced MIS surgeon. Advancing the level of surgeries would ideally start with fresh cadaver exercises followed by practice in a live model, before attempting advanced procedures on animal patients. It is likely that training of a fully competent MIS surgeon, able to safely do advanced procedures on patients, is beyond the goal of ACVS resident training. Training such as ACVS Fellowship may be required to reach that level.

subject [38, 39], but as a concept aims to show that the model represents the intended skills and is clinically relevant. This often starts with face and content validation. If a veterinary expert, with ample experience of successfully performing the particular surgery, is not able to do the simulated procedure effectively, the model content may be faulty ("too hard"). The model anatomy or physiology may be different enough to not effectively simulate veterinary conditions. Conversely, if a novice seems to perform the procedure more effectively than a laparoscopic expert, the model content may not be of appropriate challenge level ("too easy"). Even if the content of the model is validated, simply having the model available for trainees will not reach educational goals. Use of such models does not circumvent the need for principles of deliberate practice. The trainee needs to be at the appropriate training level for the modeled procedure, know the training goals and objectives, and will need individual feedback to truly benefit.

Starting a Simulation Skills Training Curriculum

For a program director interested to develop a simulation skills training program, there is vast evidence on best practices. More important than the type of simulation model one has access to is that the practice is deliberate [40]. Expertise is not gained by simply spending time practicing but by engaging in a specific type of practice. The concept of deliberate practice [40] outlines the critical elements of optimal learning, that is, tasks with (i) well-defined goals, (ii) motivation to learn, (iii) feedback, and (iv) opportunities for repetition and refinement.

Tasks and Goals

Training tasks can be selected based on construct validity (i.e., tasks in which performance has been demonstrated to correlate with higher skill levels). However, face value is also important (i.e., experienced surgeons confirming that a training task is using the same skill sets as those required in clinical practice). All tasks need to be demonstrated clearly and effectively for superior learning. Ideally, trainees have unlimited access to high-quality video tutorials and demonstrations, complementing and significantly decreasing the need for expert instructor involvement [41].

Training goals in the form of performance targets are generally accepted as superior to time-based training because individuals may differ considerably in how fast the target is reached. For MISTELS-based training, performance goals have been clearly defined [24]. For other practice tasks, speed, accuracy, or even motion metrics have shown severe limitations, and appropriate training goals for trainees at different levels of training remain work in progress [41]. A training study in the VALT laboratory failed to document advantages of proficiency goals compared with time control [7], and this observation has also been made by others [42]. Perhaps as the medical field learns more about simulation training, we will become increasingly successful in setting appropriate goals. Despite our experiences in the VALT laboratory, we consider proficiency goals valuable because we have noted that training goals appear to add motivation to practice.

Motivation

Internal motivation is a prerequisite for learning but cannot be relied on as the sole driving source for a successful training program. Surgical residents and practicing surgeons are affected by long working hours, limited free time, and seemingly endless clinical responsibilities. Not surprisingly, studies on voluntary participation of skills training in a busy residency showed the participation rate as between 6 and 14% [41, 43]. Also, 82% of ACVS residents reported that lack of time was the main barrier to practice [15].

These studies showed that providing dedicated regular time for mandatory training, known ahead of time to trainees and their faculty, greatly improved participation. For a laboratory with limited resources, this may be hard to accomplish. In the VALT laboratory, we have had success with mandatory training sessions but with timing flexibility through an online sign-up policy, so each trainee can choose the time that works best for him or her without affecting the clinic or crowding the laboratory. The importance of dedicated laboratory personnel, keeping track of the trainees' sessions, and the commitment from faculty in supporting the training cannot be stressed enough. In addition, external motivation can be gained from training feedback and scheduled skills assessments. Further external motivation may be gained by performance requirements on simulators before OR participation [41], Importantly, we have found an inverse relationship between motivation for simulation training and clinical experience [7], regardless of skill level, underscoring the importance of initiating simulation training early in a laparoscopic surgeon's career.

Feedback

Regular feedback during simulation training is not only a tool for motivation but is also essential for skills acquisition and retention. As already discussed, motion metrics serve as instant feedback during VR training and are likely one of the most important advantages to that type of simulation training. However, verbal feedback from experts has been shown more effective than motion metrics [44]. Specific and individualized feedback and subsequent training tailored to address that feedback have been shown to greatly improve OR performance [45].

Opportunity to Practice

Currently, the opportunity for simulation training is severely limited for veterinary surgeons and residents. Hopefully, veterinary surgery will show a similar development to that occurring over the past decade among MD surgeons. In 2006, only 55% of residency programs had training laboratories [12], but by 2008, such laboratories became a requirement [9]. In 2019, approximately 36% of ACVS resident training programs had access to a simulator [15]. Unfortunately, as many as 48% of residents perceived that training was not encouraged by senior faculty [15]. Despite lacking support from senior faculty, 88% of ACVS residents thought that simulation training increases OR performance [15].

Ideally, all trainees should have easy access to simulation training at their practices. This preference is based on the fact that distributed practice leads to better skills acquisition and retention compared with intense extended practice [41, 46]. The optimal distribution is presently considered to be one-hour sessions with a maximum of two sessions per day interspersed by a rest period, allowing the brain the opportunity to internalize the learning [47]. Approximately 10 hours of practice has been demonstrated to lead to fundamentals of laparoscopic surgery (FLS) competency [24]. Skill decay will ensue after rigorous training, but with ongoing practice in small amounts at six months intervals, performance has been shown to be maintained at a high level [47].

Self-Directed Training

Most veterinarians in practice do not and will not have easy access to simulation training curricula. Fortunately, MISTELS-type exercises lend themselves well to self-study because there are welldefined training goals that are easy to monitor. Self-study guidelines based on performance time have been demonstrated, showing that reliable achievement of 53-s peg transfer, 50-s pattern cut, 87-s ligature loop, 99-s extracorporeal suturing, and 96-s intracorporeal suturing times are associated with a 84% chance of passing the FLS test [48], thus demonstrating basic skills competency. Laparoscopic suturing may require training proctored by experienced surgeons, and we encourage self-study trainees to seek instruction for those exercises. Examples of available training are listed on the VALS website (www.valsprogram.org). Independent training on fresh cadavers may also be highly valuable, prior to or after commercially available live animal model courses. The self-trained surgeon is encouraged to start with basic surgeries until ample experience of laparoscopic entry and instrument manipulation has been gained.

Miscellaneous Training; Video and Serious Games

Video gaming ability has frequently been shown to be associated with various laparoscopic skills in both human [49–51] and veterinary medicine [52–54]. There are important similarities between MIS and video gaming in the two-dimensional visual and observation of hand movements' effects on a screen, which can explain this association. However, other studies have not been able to demonstrate such associations [29, 55]. A recent meta-analysis found inconsistent results and concluded that there was limited evidence that video gaming enhances surgical simulation performance [51]. It is possible that video games designed with the added objective to educate may become more consistently beneficial. The concept of interactive computer applications with the goal to educate in an entertaining fashion is known as "serious games." A systematic review concluded that serious gaming can be beneficial for training both technical and decision-making skills [56]. To our knowledge, no serious games have been developed for MIS training of veterinarians yet.

A few nonsurgical psychomotor skills have been associated with improved laparoscopic skills. Chopstick use and handicraft experience have been demonstrated to be associated with higher scores on laparoscopic task simulators [54, 55]. A causative relationship has, however, not been demonstrated, so training programs may need more evidence before adding these activities into a training curriculum.

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