Current concepts in simulation and other alternatives for veterinary education: a review

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ABSTRACT: Driven by a combination of pedagogical, ethical and economic factors, the use of simulation technology and other alternatives to traditional training methods has become increasingly common in veterinary education as a means to teach basic and advanced concepts along with technical skills. When paired with well-structured and supervised clinical training on animal patients, these modern methodologies help educators fill gaps left by conventional methods, reduce and replace the consumptive use of live animals, and ultimately result in the graduation of more confident and proficient veterinarians, veterinary technicians, and allied health personnel. This article surveys an array of the simulation methods currently available for veterinary education and how they integrate with and enhance standard curricula.

Keywords: instructional methods; animal welfare; curriculum; simulation; alternatives; manikins

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1. Introduction

Veterinary medicine has increasingly embraced simulation and other modern training methodologies as a result of scientific advances in the diagnosis and treatment of disease and injury, the development of new technologies, changes in the clinical landscape, increased specialization, and mounting concern for patient safety (Scalese and Issenberg 2005). Growing professional interest in animal welfare as both a guiding ethos and academic discipline over the last three decades (Lord and Walker 2009; Colonius and Swoboda 2010; American College of Animal Welfare. American Veterinary Medical Association 2012, http://www.avma.org/education/abvs/animal-welfare.asp), has also factored heavily into efforts to develop and implement veterinary training curricula that reduce reliance on and replace once-common exercises that may be harmful to animals, such as terminal surgery laboratories (Hart et al. 2005; Martinsen and Jukes 2005; Knight 2007; Smeak 2007).

Veterinary students, drawn to the profession most often by their strong affinity toward animal health and wellness, experience stress in the course of their education if they witness animal suffering or feel inadequate in their skills to identify and treat pain (Gelberg and Gelberg 2007). Procedures such as terminal surgery and practicing painful techniques on living animals can cause, distress and take a profound psychological toll on trainees, many of whom have objections to harming animals in the course of their education (Arluke 2004; Capaldo 2004; Gelberg and Gelberg 2007). Thus, when instructors make efforts to reduce or eliminate educational exercises in which the curriculum requires veterinarians in training to perform painful, unnecessary procedures on living animals, they are aiding in allowing students to engage more fully in their education and make optimal use of their talents and skills.

2. How simulation fits into the veterinary curriculum

In many veterinary programs around the world, combinations of computer software-based learning, haptic task trainers, video demonstrations, virtual reality systems, plastic models, full-body manikins, and plastinated specimens have been used to augment traditional didactic learning methods and substantially reduce and replace the consumptive use of animals (Hart et al. 2005; Martinsen and Jukes 2005; Knight 2007; Smeak 2007; Yushchenko et al. 2012). Drawing from this diversity of resources provides for increased flexibility that traditional training methods have often not permitted, thus making it possible to place greater emphasis on humane values in the curriculum without compromising the teaching and learning of hands-on skills.

The common advantages of simulation technology and the characteristics that make it successful, regardless of the field in which it is being employed or the particular skills being taught, have been clearly articulated by Scalese and Issenberg (2005). They determined that the most pedagogically effective simulators tended to offer several advantages, including:

– Feedback is provided during the learning experience
– Learners engage in repetitive practice
– The simulator is integrated into the medical curriculum
– Learners practice with increasing levels of difficulty
– The simulator is adaptable to multiple learning strategies
– The simulator provides clinical variation
– The simulator is embedded in a controlled environment
– The simulator allows individualized learning
– Outcome measures are expressed clearly
– The simulator is a valid (high-fidelity) approximation to clinical practice

Admittedly, few, if any, simulators score well on all of these criteria; however, by incorporating several of the features, highly effective simulations can be created. When combined with the ethical and conservative clinical use of animals for teaching purposes such simulators can actually enhance learning over the use of animals alone. Dr. Daniel Smeak, currently professor of surgery at Colorado State University (CSU) has said:

Use of simulators have (sic) distinct advantages over traditional laboratories that use cadavers or live animals. Ethical, cost-effective, and portable simulators are provided along with autotutorial lessons for each student to use when and where they choose. Thus, practice time can be tailored to the individual student. Some students without prior surgical experience or tuned psychomotor skills may require more time or repetitions to become adept at a skill. In most traditional surgery laboratories, only one animal is provided for three or more students, and the exercise is conducted only during specific supervised laboratory settings. Time restrictions and the laboratory environment may not be as conducive for learning for some students. Simulators allow repetitive practice and this helps strengthen motor skills and increase confidence and efficiency (Smeak 1999).

Developing simulators often requires focusing on meeting some of the above criteria at the expense of others; in the end, a combination of approaches is generally more effective and addresses multiple learning styles.

It is important to have realistic expectations for the effective application of each of the learning tools being utilised in any curriculum. Unrealistic expectations on either the part of students or instructors will to lead to disappointment and an unrealistic assessment of the value/efficacy of the simulation or animal-based experience.

Examining the criteria of Scalese and Issenberg (2005) makes it clear what simulation technology offers and what its limitations are. For example, simple suturing and knot-tying boards do not offer a wide range of experiences and are not adaptable to different learning styles but they do allow for repetitive practice by individual students in their own time and are very cost-effective.

Similarly, experience performing procedures on live animals and learning anatomy and pathology through cadaver dissection are as vital in veterinary medicine as they are in human medicine, but neither method alone can provide for sufficient repetition to instil the requisite proficiency and confidence in trainees without using unacceptably large numbers of animals. Clinical experience with live animals often does not provide the range of experiences that simulators can be designed to provide, as students may never have the opportunity to witness certain conditions or perform certain procedures during their clinical experience (Scalese and Issenberg 2005).

Ideally, simulation technology and other alternatives can be used to prepare students for clinical experience with live patients so as to ensure the maximum educational value of hands-on training for students, minimise the risk involved for animal patients and obviate the need for consumptive use of live and dead animals to prepare students for their initial clinical experience. Training exercises employing live animals and cadavers can also be structured in such a way as to alleviate animal welfare concerns by establishing willed body donation programs through which to obtain ethically-sourced cadavers (Kumar et al. 2001; Educational Memorial Programs. Humane Society Veterinary Medical Association 2012, http://www.hsvma.org/educational_memorial_programs) and developing relationships with local animal shelters and veterinary clinics in lieu of obtaining healthy, purpose-bred animals on whom to conduct medically unnecessary or harmful procedures (Smeak 2008).

It is by taking advantage of this diversity and not entirely relying on any one method that makes the goals of harnessing the particular strengths of the various training tools available and leads to the elimination of the unnecessary use of animals when possible. For example, Smeak (2007) developed an undergraduate veterinary surgical training curriculum that made optimal use of simulation methods. Students begin training on cadavers and gradually advance to supervised clinical experiences. This largely supplants the need for unnecessary or terminal surgery laboratories while increasing the time devoted to pre-clinical skills training.

As in all areas of veterinary medicine, an evidence-based approach should guide decisions regarding the utilisation of pedagogical methods whether they be old standards or novel technologies (Scalese and Issenberg, 2005). With new teaching methods, extensive research has been and continues to be conducted to establish their validity and efficacy. When compared to traditional methods, systematic reviews of comparative studies have found that simulation methods exhibit overall favourable results (Knight 2007; Patronek and Rauch 2007). Often, the learning outcomes and skill proficiency of veterinary students taught using alternatives have been found to be equivalent or greater than that of their peers who were taught using traditional learning methods.

This article builds on previous work examining innovations in veterinary education (Hart et al. 2005; Martinsen and Jukes 2005; Scalese and Issenberg 2005; Knight 2007; Smeak 2007) by surveying some of the recently developed and commercialised methods available for teaching veterinary students. In addition to a survey of available simulation technologies, we examine some of the most commonly advanced concerns regarding the adoption of such technologies and their effect on the curriculum, teaching, and student learning.

3. Overview of simulation methods for veterinary education

Veterinary training programs are well-positioned to more widely incorporate already existing technologies and methods that have proven to be effective in human and veterinary medical education into their curricula. These teaching technologies span a wide range of essential skills and vary from the relatively simple to the highly sophisticated. Extensive databases of these alternative methods for veterinary education and other biomedical fields, as well as libraries of studies that have evaluated the efficacy of these methods, are publicly accessible on the website of the International Network for Humane Education InterNICHE (www.interniche.org) and at veterinarian Andrew Knight's Humane Learning website (www.humanelearning.info). There exists a multitude of websites and search strategies to help educators identify alternatives to refine, reduce and replace animal use in their training programs (Nesdill and Adams 2011).

3.1. Anatomy

Traditionally, live animals and cadavers have played a large role in teaching and learning anatomy both in human and veterinary medicine. Dissection has often been thought of as the most rigorous method of teaching anatomy and its defenders continue to point to the fact that it remains a unique experience that simulation technology does not entirely replicate (Korf et al. 2008). However, the question need not become "cadaver versus cadaverless" anatomy instruction, but rather a matter of investigating the comparative effectiveness of each method alone and then in combination. Indeed, pedagogical research may reveal that dissection alternatives are not only pedagogically sound but, in fact, preferable and produce better learners (Balcombe 2001). As the focus of veterinary school faculties on patient safety and evidence-based medical education increases, their incorporation and reliance on simulators and virtual reality training methods will likely follow, as has happened in human medicine (Lovquist et al. 2012).

3.1.2. Simulation software

For example, Colorado State University has successfully incorporated a *Virtual Canine Anatomy* (VCA) DVD to teach canine anatomy in addition to cadaver dissection (Virtual Canine Anatomy. Colorado State University 2005, http://www.cvmbs.colostate.edu/vetneuro/index2.htm). Linton et al found that students and faculty expressed positive attitudes toward the program. They also found that it increased dissection efficiency (Linton et al. 2005). Prior to its implementation, instructors overseeing dissection spent most of their time identifying basic structures for students and students spent a significant amount of time waiting for instructor assistance and relying on textbooks. Students who miss this class time are even further hampered in learning the material as the lesson cannot be repeated for individual students. VCA, a computer-assisted program, overcomes these problems. After its incorporation into the anatomy laboratories, students became self-directed in their dissections and their questions became more substantive and functionally related.

VCA guides students through a virtual dissection by identifying and describing key structures. It can be used by students studying alone or in groups, whether in the classroom or elsewhere. Perhaps most importantly, VCA allows students to repeat the virtual dissection to reinforce the material; this is not an option when using animal cadavers. Linton found that students and faculty alike expressed a strong degree of satisfaction with the program: "Faculty praised the program as a strong visual aid and self-paced study guide for students. Some instructors indicated that the application gave them more opportunities to discuss higher-level issues with the students such as structure functions and relationships" (Linton et al. 2005). Students gave the application high ratings on all seven criteria that were employed in the study: general attitude toward the program, educational needs met, dissection assistance provided, increase in overall confidence, appropriate content for academic level, efficient use of laboratory time, and how user-friendly the program was.

While *Virtual Canine Anatomy* is specific to canine anatomy, there exist a large number of similar applications for various other species. One such program is ScienceWorks's (1760 Jonestown Rd., Suite 200, Winston-Salem, NC 27103 USA; 800.478.8476, www.scienceclass.com) DissectionWorks Delux software package, which includes interactive virtual dissections of a frog, foetal pig, earthworm, crayfish, and perch. The software contains detailed schematics of the major body systems, information on organ function and structure, and review questions. ScienceWorks also makes cat anatomy software, CatWorks, which allows students to perform virtual dissections of the cat and watch videos of selected portions of actual dissections along with voice descriptions of the procedures being performed. Also included in this software are laboratory practical examinations, quizzes, and in-depth comparative histology.

3.1.3. Models and manikins

Anatomy can be taught with realistic models and manikins that reproduce a whole animal. While these are most readily available with common species such as cats, dogs, and mice, it is possible to obtain whole body manikins of a vast number of other animals ranging from a flea to a horse. When whole body manikins are not necessary, models of specific and highly detailed parts of animal bodies and biological systems are also available.

Ward's Natural Science (P.O. Box 92912, Rochester, NY 14692, USA; 800-962-2660, http://wardsci.com) offers a life-size one-piece pregnant cat model cast from an actual specimen and featuring over one hundred accurate anatomical details. The accompanying key identifies 136 relevant structures. Ward's sells a wide range of plastic models of amphibians, mammals, fish, invertebrates and birds.

Anatomy in Clay (Zahourek Systems, 2198 W. 15th St., Loveland, CO 80538, USA; 970-667-9047, http://www.anatomyinclay.com), offers clay models for students to assemble, effectively performing dissection in reverse. Instead of taking apart a specimen, Anatomy in Clay models ask student to build one. This allows for a more intuitive approach to learning anatomy whereby layers are added instead of removed. Models come in human, cat, dog and horse species; as well as full body and forelimb and hind limb models. These models allow anatomy to be learned with a start-to-finish "hands-on" approach accommodating different learning styles. In the area of human anatomy education, several recent studies have found the Anatomy In Clay system to be a highly effective method with which to teach students when compared to animal dissection (Waters et al. 2005: Motoike et al. 2009; DeHoff et al. 2011; Waters et al. 2011).

3.1.4. Plastination

Perhaps the most significant recent innovation in the teaching of anatomy of humans and animals has been plastination. Plastination is a method of preserving biological specimens for later study. "The results [of plastination] are clean, dry, odourless, and durable real biological specimens that can be handled without gloves and do not require any special storage conditions or care" (Latorre et al. 2007). Furthermore, by replacing dissection, plastination eliminates student and instructor exposure to toxic substances such as formaldehyde. While the usual form of cadaver dissection requires a significant time input for the learning process to take hold, this investment need not be made with plastinated specimens and therefore can be redirected toward other learning objectives. Larger educational institutions have begun establishing their own plastination laboratories to develop their own specimens and/or offer services to other institutions who lack the equipment required (Melanson 2008).

Latorre et al. (2007) has demonstrated that students welcomed the inclusion of plastinated specimens in their learning of anatomy and that veterinary surgery students voiced the most positive opinions. Plastinated specimens can include particular organs, organ systems and even whole figures. Alternatively, plastinated specimens can be created from cross-sectional slices designed to foster student understanding of imaging techniques such as ultrasound, computerised tomography, and magnetic resonance imaging.

Publications on plastination illustrate the diversity of applications for these specimens as well as their efficacy for medical education and related disciplines (Douglass and Glover 2003; Hoffmann et al. 2010; Fruhstorfer et al. 2011; Caperton and Lopresti-Goodman 2012; The New Plastination Index. International Society for Plastination 2012, http://www.uqtr.ca/plastination). In a study looking at human anatomy education, medical students using plastinated specimens learned as well as those who dissected human cadavers (Hoffmann et al. 2010). Much of this literature (through 2006) has been catalogued and made available by the International Society for Plastination in their New Plastination Index (The New Plastination Index. International Society for Plastination 2012, http://www.uqtr.ca/plastination). Like many simulation technologies, incorporating plastinated specimens into the curricula can conserve financial resources as well as limited class time. In addition to its clear value in education, plastination and plastinated specimens have begun serving the interests of researchers as well; many of these aspects apply to the veterinary field (Nel 1997). Possible applications include comparative investigations of human and veterinary developmental anatomy; soft tissue injuries in forensic science, applicable to abuse investigation; orthopaedic research regarding functional relationships, alterations in articular cartilage, and the vascularisation of bone with multiple clinical implications, and trauma research.

3.2. Animal handling

It is essential that veterinarians and technicians be taught to properly handle a variety of animal species. Handling skills are often neglected but are vital not only for proper care but also for clients to have confidence in their medical providers (Cawdell-Smith et al. 2007). Proper animal handling education has commonly involved live animals. This has often resulted in programs maintaining animals on site and risks subjecting those animals to improper handling and possible injury by students who have yet to acquire a sufficient level of skill.

Affordable animal manikins with life-like ranges of motion are available to teach students animal handling skills, thereby allowing students to gain a comfort level and a familiarity with animal anatomies prior to handling live patients. Practice with these procedures on inanimate models may help to reduce student anxiety, allow skills to be repeated and mastered, and ultimately prevent injury to animals and students. It also eliminates the need for veterinary programs to house some animals on site for this purpose and is consequently cost-effective.

Rescue Critters (15635 Saticoy St., Unit D, Van Nuys, CA 91406 USA; 1-818-780-7860, http://www.rescuecritters.com) currently offers two manikins designed specifically for this purpose: the "Emily" K9 Positioning Manikin and the "Rufus" Bandaging and First Aid Manikin. The "Emily" K9 Positioning Manikin allows students to practice positioning dogs for a variety of procedures such as abdominal surgery, spay and neutering, radiographs, and advanced spinal stabilization amongst others. All joints have a realistic range of motion and accurately mimic the degree of resistance typical of a live animal. The "Rufus" Bandaging and First Aid Manikin offers a similar life-like range of motion and is ideal for practice in different bandaging techniques. This manikin is also designed for various first aid procedures such as mouth to snout resuscitation.

Like many simulation technologies, positioning manikins provide students with the opportunity to develop psychomotor skills prior to handling live animals. These skills will be reinforced when a student handles live animals in the course of clinical experience.

3.3. Anaesthesia and critical care

Administering anaesthesia is an essential skill for veterinary students. It is becoming increasingly important as procedures that in the past were done without anaesthesia are now more frequently being recognised as requiring anaesthesia as society's concern for animal welfare and awareness of animal pain increases (American College of Veterinary Anesthesiologists' Position Paper on the Treatment of Pain in Animals 2006, http://www.acva.org/docs/Pain_Treatment; Hellyer et al. 2007). Furthermore, anaesthesia is a skill that is inherently risky because if performed incorrectly it can lead to injury or death. It is skills such as this that simulation technology is vital for because simulation can allow for risk-free learning and can allow students to make mistakes and learn from those mistakes without causing harm.

In a very explicit instance of borrowing from human medicine, Modell et al. (2002) sought to determine if the Human Patient Simulator available from Medical Education Technologies, Inc (102 Cattlemen Rd., Sarasota, FL 34232, USA; 1-941-377-5562, http://www.meti.com), a manikin designed for medical students, could be successfully used to train veterinary students. Despite its human form, the simulator proved to be successful in creating a realistic scenario in which students were able to practice administering anaesthesia. The simulator works with a real anaesthesia machine and vital signs respond whenever drugs are administered. Drugs may be administered intravenously or by inhalation. In addition to anaesthesia, the simulator can also exhibit various pulmonary states such as hypoventilation, apnoea, pneumonia, bronchospasm, and tension pneumothorax. By using a simulator rather than a live animal, the instructor can at various points decide to stop the particular intervention and discuss the decision making process with students before continuing. Cornell University faculty recently reported on their success in fabricating a high-fidelity canine patient simulator using components from a human patient simulator and a low-fidelity canine CPR manikin (Critical Care Jerry mentioned below). Student evaluations of the system were exceedingly favourable and most reported that they felt it improved their emergency response skills (Fletcher et al. 2012).

A significant number of simulators and task trainers are commercially available that replicate the airway anatomy of both cats and dogs. Two of the most widely adopted simulators are both produced by Rescue Critters: the canine version is Critical Care Jerry and the feline version is Critical Care Fluffy. These are full body manikins, which allow for extensive airway training. Critical Care Jerry replicates a sixty to seventy pound dog with a pulse and offers a realistic airway anatomy including trachea, oesophagus, epiglottis, and functional lungs. Skills trained include endotracheal intubation, compressions, mouth-to-snout resuscitation, and splinting and bandaging. Critical Care Fluffy affords the opportunity to train students in a similar set of skills on a feline patient. Rescue Critters also offers Advanced Airway Jerry and CeePeR Dog, which are manikins that can be employed for instruction in a similar set of skills.

Life/form also offers an Advanced Sanitary CPR Dog manikin (Nasco, 901 Janesville Avenue, P.O. Box 901, Fort Atkinson, WI 53538-0901, USA; 1-800-558-9595, http://www.enasco.com). This manikin allows students to practice assisted breathing on a canine model as well as learning the appropriate rate, pressure, and position of cardiac massage. Objective feedback is provided during the learning session; a box connected to the manikin displays various lights to indicate when proper ventilation volume is achieved, when the correct position for cardiac massage has been found, and when the correct compression depth is being applied. If excessive pressure is applied, a light and sound indicate this to the trainee who can then make the necessary accommodation. In the absence of this kind of feedback, either by instructor or simulator, repetitive practice may not always be beneficial if it allows improper techniques to become habitual.

Task trainers are available that focus exclusively on airway anatomy and training. The Rescue Critters K-9 Intubation Simulator consists of a model of a canine head along with trachea, oesophagus, epiglottis, and lung. The model produces a variety of life-like breath sounds during the procedure for a student to become familiar with. Since this is not a full body manikin and is more limited in its uses, it is consequently more affordable.

A model also exists for thoracentesis training – the K9 Thoracentesis Training Model also by Rescue Critters. The model replicates a sixty to seventy pound dog and allows students to practice placing a cannula so as to remove air and fluid from the pleural cavity in a trauma situation. The model has all of the relevant anatomical landmarks necessary for learning this skill.

3.4. Intravenous catheterisation

Vascular access or venipuncture training models are available in varieties that simulate several different species and with different access points. The full body manikins discussed above generally allow for venipuncture but there are also considerably smaller devices that focus exclusively on venipuncture.

The University of California, Davis, School of Veterinary Medicine (University of California, Davis School of Veterinary Medicine, One Shields Avenue, Davis, CA 95616, http://www.vetmed.ucdavis.edu/products/vatm.cfm, svmacadprog@ucdavis.edu) offers Vascular Access Training Models (VATMs) in the form of a canine head and neck to simulate the jugular vein or a canine forelimb to simulate the cephalic vein. Both models feature identifiable and palpable anatomical landmarks and replaceable vessels and skin for repeated, long-term use.

Koken (Koken Company Ltd., 3-14-3 Mejiro, Toshima-ku, Tokyo, Japan, http://www.kokenmpc.co.jp, customer@kokenmpc.co.jp) has produced a rat full-body manikin which can be used to teach a number of skills such intubation, venipuncture, oral dosage and proper handling technique. The tail of the Koken rat can be used for up to one thousand injections before replacement is necessary making it highly cost-effective compared to keeping live rats on site (Conarello and Shepherd 2007).

For programs that instruct students on large animal procedures, an Alpaca venipuncture and catheterization model is available from Alternavitae (2415 Northwest Blvd., Columbus, OH 43221, USA; 1-614-486-9150, alternavitae@wowway.com) which replicates the unique anatomy of camelids. Additionally, Rescue Critters is developing a life-size model of an equine head and neck for the purposes of jugular vascular access.

3.5. Urethral catheterisation

Urethral catheterisation is an essential skill for veterinary practitioners to acquire; it is also a skill that if performed improperly can harm an animal and disturb a student. Even when adroitly performed it has been found to be among the most painful procedures commonly performed on humans in the emergency department; it is therefore reasonable to conclude that it is quite painful for nonhuman patients as well (Singer et al. 1999). Fortunately, given these facts, urinary catheterisation is a skill that manikins are well suited for. Rescue Critters produces a Female K-9 Urinary Catheterisation manikin. The model replicates the relevant internal and external structures that a student will have to be familiar with in order to successfully catheterise a female dog. The vulva, clitoral fossa, vaginal vault, urethral papilla, and urethral orifice are all reproduced. This allows a student to benefit by experiencing visual and tactile feedback similar to when performing the procedure on a live animal.

The Female K-9 Urinary Catheterisation model allows students to practice the skills needed to perform the procedure aseptically on a live animal patient who genuinely needs the procedure performed during the student's clinical experience.

3.6. Dental care

A large number of dental models are currently available for instruction in animal dental care.

Columbia Dentoform (Columbia Dentoform Corporation, 34-24 Hunters Point Ave, Long Island City, NY 11101, USA; 1-800-688-0662, info@columbiadentoform.com; http://www.columbiadentoform.com) offers canine and feline dental models. These can be ordered with or without soft gingiva in place. In addition to learning the dental anatomy of various species these models can also be used to demonstrate various dental conditions and procedures by applying available materials that simulate tartar build-up, which can then be removed by students. This not only familiarises students with dental procedures but also allows them to practice their instrument handling skills and develop a greater dexterity.

Saw Bones (Pacific Research Laboratories, Inc., 10221 SW 188th St., PO Box 409, Vashon, WA 98070, USA; 1-206-463-5551, http://www.sawbones.com) also offers models of both the canine and feline jaw that can be used for instruction in dental care. These models are divided into halves with one representing a completely healthy state and the other representing various dental problems such as periodontal disease, tartar accumulation, plaque, gingivitis, worn incisors, retained deciduous tooth, fractured canine tooth, and a missing premolar.

Harlton's Equine Specialties (792 Olenhurst Court, Columbus, OH 43235 USA; 1-800-2473901, http://www.harltons.com, mail@harltons.com) offers equine skull and dental models that replicate a fifteen-year-old Quarter Horse. The teeth are made from a composite material that is commonly used for dental restorations in human patients and are removable. The teeth and skull model can be used to demonstrate a variety of dental conditions. Teeth can also be purchased with or without the skull.

3.7. Radiography

For the purposes of radiography, many of the aforementioned manikins from Rescue Critters can be used to teach radiographic positioning. In addition to these fully body positioning and handling manikins, Saw Bones has over 200 canine, bovine, and equine bone models available for anatomical instruction. Bone models are available that simulate a healthy condition as well as ones exhibiting various pathologies.

Bristol Medical Pro (Henry Wellcome Laboratories for Integrative Neuroscience and Endocrinology, University of Bristol, Dorothy Hodgkin Building, Whitson St., Bristol BS1 3NY, England, UK; +44 (0)117-331-3115, http://www.bristolmedicalpro.com, alevy@bristol.ac.uk) offers a Dog Skeleton Simulator. The Dog Skeleton Simulator is approximately the size, shape, and weight of the skeleton of medium sized dog; its joints exhibit the same range of motion as the joints of a healthy dog. This model can be used to train students in positioning for various veterinary procedures as well as bandaging and radiology. The model can also be used to teach difficult techniques such as the lateral shoulder joint and oblique views.

SYNBONE (Neugutstrasse 4, CH-7208 Malans, Switzerland; +41 81 300 02 80, www.synbone.ch) produces teaching models for canine, feline and equine orthopaedic anatomy and fracture repair as well as custom applications for laparoscopic and open surgical training. SYNBONE sells single and multi-bone models that are fractured or intact and these can be purchased with and without rubber ligaments and a flesh-like foam cover.

3.8. Surgical procedures

Previous reviews (Hart et al. 2005; Martinsen and Jukes 2005; Knight 2007; Smeak 2007) have discussed some of the surgical simulators available for veterinary training, but a number of high-quality products have been developed and released since and will be reviewed here.

Rescue Critters has recently announced the development of three new manikins: the Whelping Assistant Manikin and the Male and Female Spay and Neutering Surgical Training Manikins.

The Whelping Assistant Manikin can be obtained in various canine and feline models and allows for proper training in skills that can reduce mortality rates. All models come with functioning lungs for airway training, as well as realistic features, and umbilical cords.

The Spay and Neuter K9 Manikins represent six-month-old male and female puppies. Each model features realistic skin, organs, fat tissue and blood, and allows for the practice of all necessary surgical skills associated with spaying and neutering. Replaceable parts allow the same manikin to be used by many students.

For training and assessment in more advanced procedures, Saw Bones offers a canine abdominal virtual reality system called the Mayo Endoscopy Simulated Image (MESI) model. This model can be used for diagnostic techniques including gastroscopy, colonoscopy, cystoscopy and operative laparoscopic procedures such as exploration, liver biopsy, renal biopsy, gastropexy, cystoscopic calculi removal and ovariohysterectomy. A study by researchers at Washington State University's College of Veterinary Medicine found that training on this model increased laparoscopic skills scores of novice surgeons (Fransson and Ragle 2010).

A large number of the full body, multi-use manikins allow for practice of suture and wound closing skills. Alternatively, smaller task trainers can be obtained that are designed specifically and exclusively for this purpose.

Suture training is an ideal example of the kind of skill that can be effectively taught with fairly simple task trainers. While more elaborate, multi-use manikins often allow for suture training, there are also fairly simple, low-cost technologies that allow for practicing this skill. Furthermore, suture training highlights the fact that many skills that need to be learned by veterinary professionals require psychomotor and dexterity training as opposed to rote learning of scientific facts and principles. High- and low-fidelity simulation technology can give students the opportunity to develop the necessary dexterity and the psychomotor skills in a safe environment with no risk to a live patient.

Rescue Critters offers a Suturing Arm, which can be used repeatedly with minimal wear. The dermis, adipose tissue, and muscle tissue are all replicated making the product useful for both internal and external sutures. Smeak (1999) has also developed a Skin/Suture Pattern Simulator. This allows students to practice instrument handling, various suture patterns, as well as intradermal suturing techniques. While relatively simple in their technology, both of these products exemplify many of the virtues described by Scalese and Issenberg (2005) as being important for successful simulation technology. A recent study examined veterinary students' perceptions of the usefulness of low-fidelity models for surgical skills training and explored what psychomotor and psychological features – including the look and feel of the model and nature of the training environment – contributed to the students' perceived usefulness of the session (Langebaek et al 2012).

3.9. Large animals

The focus thus far of simulation technology has largely been on companion animals such as dogs and cats but this has not exclusively been the case. For skills that are specific to large animals, simulation technology is also available, as aforementioned with the camelid venipuncture simulator.

The Haptic Cow (Royal Veterinary College, Hawkshead Lane, North Mymms Hatfield, Hertfordshire, AL9 7TA, UK; +44 (0) 1707 666657, http://www.live.ac.uk/index.html), a bovine rectal palpation simulator, takes advantage of sophisticated haptic technology to provide the user with the tactile sensation of actually performing the procedure. Haptic technology aims to provide users with information by reproducing the tactile sensations that would be experienced if a particular experience, in this case a bovine rectal exam, were actually being undertaken. The Haptic Cow has been proven effective when compared with traditional teaching methods (Baillie et al. 2005b). When two groups of students were compared, one receiving traditional training while the other had their training supplemented with the bovine rectal palpation simulator, the students who had the benefit of the simulation performed better when actually performing this task (Baillie et al. 2005a). Another study found that students consider the Haptic Cow to be a useful and enjoyable mode of learning bovine anatomy (Kinnison et al. 2009). An automated version of the program that guides the students' hands along a pre-recorded path has been developed and validated eliminating the need for instructor supervision during the training (Baillie et al. 2010). The Royal Veterinary College has also developed the Haptic Cat, a feline abdominal palpation simulator (Parkes et al. 2009).

Haptic technology has been employed for the purposes of other procedural simulations including the SimPooch simulator for canine acupuncture, (SimPooch: Canine Medical Acupuncture Trainer and Simulator. Colorado State University Department of Electrical & Computer Engineering and College of Veterinary Medicine and Biomedical Sciences 2009, http://www.engr.colostate.edu/ece-sr-design/AY08/SIMPooch/index.shtml), the Horse Ovary Palpation Simulator, a simulator for the rectal examination of horses, and the Equine Colic Simulator (Crossan et al. 2000). These procedures are difficult to learn and equine ovary palpation can even be fatal if performed incorrectly making this skill an ideal candidate for simulation that can be learned in a risk-free environment.

4. Simulation in perspective

Simulation technology has proven capable of being put to use to teach a wide range of psychomotor skills and thereby has contributed to making the once common harmful and consumptive use of animals unnecessary. Advocates of simulation technology do not claim that veterinary professionals will ever be graduating without "hands-on" experience with live animals. In fact, many advocates of simulation technology also advocate for *more* "hands-on" experience in the form of more substantial clinical experience for students. Such experience currently is most often gained by students through internships in shelters, teaching hospitals or veterinary practices (Smeak 2008).

Building new relationships with other animal-related businesses or organizations can create diverse educational opportunities for veterinary technology students and can provide actual live animal patients to teach skills that simulation technology cannot adequately address. Many technologies are most effective at setting the stage for subsequent learning experiences involving live animals. Simulation technology provides the opportunity for students to gain the hand-eye coordination and dexterity necessary to perform certain skills and attain a level of comfort so that their eventual encounters with live animals will be most beneficial for them and their patients. It is the harmful use of animals and the pedagogically ineffective use of animals that simulation technology aims to replace.

5. CONCLUSION

A wealth of effective teaching technologies and methods exist and continue to be developed. Veterinary students, animals and the profession as a whole will likely benefit as they become more widely adopted.

Ideally, newly discovered educational tools will capture all that is most valuable and expand on it by providing additional benefits. It must be noted that even if a new method does not provide every benefit that the old method provided it may still be superior overall. This is the case when benefits lost are few and relatively nonessential whereas benefits gained are significant enough to outweigh what is lost. That old methods are entrenched and familiar is no reason for retaining them when other methods are shown to be more effective. Furthermore, we should not expect new methods to replace old methods in a strict one-to-one correspondence where each new method can replace an old method while leaving the rest of the curriculum untouched. New methods will allow educators to re-conceptualize curricula and meet their learning objectives while placing greater emphasis on humane values.

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7. Links used in text

Advanced Sanitary CPR Dog manikin (Nasco, 901 Janesville Avenue, P.O. Box 901, Fort Atkinson, WI 53538-0901, USA; 1-800-558-9595, http://www.enasco.com

Alternavitae (2415 Northwest Blvd., Columbus, OH 43221, USA; 1-614-486-9150, alternavitae@wowway.com

American College of Animal Welfare. American Veterinary Medical Association (2012), http://www.avma.org/education/abvs/animal-welfare.asp

American College of Veterinary Anesthesiologists' Position Paper on the Treatment of Pain in Animals, http://www.acva.org/docs/Pain_Treatment

Andrew Knight's Humane Learning website, www.humanelearning.info

Colorado State University, Department of Electrical & Computer Engineering and College of Veterinary

Medicine and Biomedical Sciences, http://www.engr.colostate.edu/ece-sr-design/AY08/SIMPooch/index.shtml

Columbia Dentoform (Columbia Dentoform Corporation, 34-24 Hunters Point Ave, Long Island City, NY 11101, USA; 1-800-688-0662, info@columbiadentoform.com; http://www.columbiadentoform.com

Educational Memorial Programs. Humane Society Veterinary Medical Association (2012), http://www.hsvma.org/educational_memorial_programs

Harlton's Equine Specialties (792 Olenhurst Court, Columbus, OH 43235 USA; 1-800-2473901, mail@harltons.com; http://www.harltons.com

Henry Wellcome Laboratories for Integrative Neuroscience and Endocrinology, University of Bristol, Dorothy Hodgkin Building, Whitson St., Bristol BS1 3NY, England, UK; +44 (0)117-331-3115, alevy@bristol.ac.uk; http://www.bristolmedicalpro.com

International Network for Humane Education InterNICHE, http://www.interniche.org

Koken (Koken Company Ltd., 3-14-3 Mejiro, Toshimaku, Tokyo, Japan, customer@kokenmpc.co.jp; http://www.kokenmpc.co.jp

Medical Education Technologies, Inc (102 Cattlemen Rd., Sarasota, FL 34232, USA; 1-941-377-5562, http://www.meti.com

Rescue Critters (15635 Saticoy St., Unit D, Van Nuys, CA 91406 USA; 1-818-780-7860, http://www.rescuecritters.com

Royal Veterinary College, Hawkshead Lane, North Mymms, Hatfield, Hertfordshire, AL9 7TA, UK; +44 (0) 1707 666657, http://www.live.ac.uk/index.html

Saw Bones (Pacific Research Laboratories, Inc., 10221 SW 188th St., PO Box 409, Vashon, WA 98070, USA; 1-206-463-5551, http://www.sawbones.com

ScienceWorks's (1760 Jonestown Rd., Suite 200, Winston-Salem, NC 27103 USA; 800.478.8476, http://www.scienceclass.com

SYNBONE (Neugutstrasse 4, CH-7208 Malans, Switzerland; +41 81 300 02 80, http://www.synbone.ch

The New Plastination Index. International Society for Plastination, http://www.uqtr.ca/plastination)

University of California, Davis School of Veterinary Medicine , One Shields Avenue, Davis, CA 95616; svmacadprog@ucdavis.edu; http://www.vetmed.ucdavis.edu/products/vatm.cfm

Virtual Canine Anatomy. Colorado State University, http://www.cvmbs.colostate.edu/vetneuro/index2.htm

Ward's Natural Science (P.O. Box 92912, Rochester, NY 14692, USA; 800-962-2660; http://wardsci.com

Zahourek Systems, 2198 W. 15th St., Loveland, CO 80538, USA; 970-667-9047; http://www.anatomyinclay.com

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