**The use of simulations for teaching practical clinical skills to veterinary students – a review**

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**Abstract**

In the context of veterinary education, simulations are devices or sets of conditions aiming to imitate real patients and enable students to practice skills without the need for live animals. Simulation use in veterinary education has increased significantly in recent years and simulations allow consistent practical teaching without reliance on clinical cases. This review examines the available literature regarding the use of simulations for teaching practical day one competences to veterinary students. Scientific databases were searched and seventy three relevant articles were reviewed. The articles reviewed displayed that there are a number of simulations available to veterinary educators and that simulations can enhance student skills, provide an alternative learning environment without the need for live animals and/or cadavers, and usually receive positive feedback from students. There is a bias towards small animal simulations, however, some skills learned on small animal or table-top models will be transferrable to other species. The majority of large animal simulations focused on bovine rectal palpation and/or pregnancy diagnosis. Further research is required to increase the repertoire of available simulations for use in veterinary education in order to improve practical skills in veterinary students and reduce the use of live animals and cadaver material for teaching purposes.

**Key Words**

Teaching, clinical, veterinary, education, simulation, practical

**Introduction**

Simulations are, at their simplest definition, imitations of a situation or process. In the context of veterinary or medical education, a simulation is “a device or set of conditions that aims to imitate real patients, anatomic regions, or clinical tasks”.1 The use of simulations for teaching in healthcare professions has increased significantly in recent years 2 and is likely to continue increasing with the advent of new technologies and increasing drive of academic institutions and regulatory bodies to ensure a consistent level of competence in new graduates. Scalese, 2005,2 discusses a worldwide shift towards outcomes-based education and standard-setting by universities and professional regulators for quality assurance in order to produce consistency amongst graduates. According to Edwards, 2004, “there is a societal expectation that veterinarians everywhere will all have graduated at the same standard and have the same basic competencies”.3 In the United Kingdom (UK), veterinary curricula aim to ensure students graduate with all of the skills designated by the Royal College of Veterinary Surgeons (RCVS) in their List of Day One Competences and there is a drive to ensure that all students achieve a consistent learning experience during their time at University.4

Teaching of practical clinical skills is crucial for veterinary education in order to ensure graduates comply with the RCVS Day One Competences but also because confidence and proficiency in performing clinical procedures is important to veterinary students.5 The strongest predictor of skill level is the number of hours of deliberate practice,6 and this time can be limited in veterinary education due to the variable availability of practical teaching opportunities on live patients, as such opportunities are reliant on case exposure and consent from the animal’s owner (the client). Teaching simulations allow the development of practical skills in the absence of a live patient and can produce more confident graduates and greater proficiency in practical skills, in addition to protecting animal welfare and reducing the need of live patients for teaching. 2,5,7,8,9,10 It can also be postulated that the use of simulations provides a safe, low risk environment for students in which to practice their skills and not experience concerns regarding animal welfare or pressure from observing parties such as the client. A safe, low-stress environment may increase learning potential as student anxiety has been demonstrated to inhibit learning and stress in medical situations inhibits judgement.11,12 The availability of clinical skills laboratories at veterinary institutions is considered to be beneficial via enhancing student learning, complementing traditional training and benefitting animal welfare by reducing the requirement for live animals or cadaver materials in teaching sessions.13 It should be noted that the ability to practice skills on live animals is a crucial component of veterinary education and the use of simulations can not supersede this. However, simulations can aid the development of skills prior to practicing on a live animal and can improve student competence and confidence when students then perform certain procedures on live clinical cases requiring veterinary treatment or intervention. This in turn may improve animal welfare as tasks will be performed more skilfully with less stress and lower risk of harm to the patient. 2,5,7

A number of teaching simulations are already employed within veterinary schools, ranging from simulations teaching clinical skills such as clinical examinations, intramuscular and intravenous injections, rectal examinations, ophthalmic examinations and anaesthetic monitoring to more complex surgical simulations such as neutering and arthroscopy. 1,2,7,14,15 It is highly likely that there are additional smaller, less publicised simulations within veterinary schools that are unique to individual establishments.

Martinsen and Jukes, 2014,15 divided simulations into four categories:

1. Models, mannequins and simulators
2. Multimedia computer simulation
3. Virtual reality
4. Ethically sourced animal cadavers and tissues

The categories described above do not allow for the distinction between the different types of skills simulations may teach (for example, practical clinical skills versus anatomical knowledge or communication skills). The aim of this article is to summarise the available literature regarding the use of practical simulations for teaching practical clinical skills to veterinary studentsveterinary students. Therefore, simulations within this article are separated into the following broad categories:

* **Model-based practical simulations** - for teaching practical clinical skills via the use of non-cadaver model simulations.
* **Practical virtual simulations** – using virtual reality or augmented reality to deliver practical skills.
* **Non-practical virtual simulations** - using computer software or virtual reality programmes to deliver teaching material or example case scenarios, which is mainly theoretical.
* **Communication or scenario based simulations** – using actors, multimedia software or example communication scenarios to teach professional or communications skills.

It is acknowledged that non-practical virtual simulations, multimedia computer simulations and communication or scenario based simulations are of extremely high value to the veterinary curriculum and the former may indeed be an area of advancing research and technology in the near future with the advent of modern virtual reality technology. The focus of this review is on the use of practical simulations for teaching practical clinical skills and as such,the discussion of non-practical, virtual and communication based simulations will be limited.

**Materials and methods**

The research question set for this review was: What simulations are available for teaching practical day one competences to veterinary students and are they efficacious?

Sub-questions as part of the main research question included:

* Do simulations realistically mimic the task being performed when compared to a live animal?
* Do simulations improve student learning and skills?
* Do students provide positive feedback regarding simulations?
* Do students prefer training on live animals?
* Do simulations improve the welfare of animals?
* What challenges do educators face in simulation use and development?

*Search strategy*

Four databases (CAB Abstracts, Scopus, Science Direct and Wiley Online Library) were searched using the below terms and Boolean operators. Google Scholar was not included due to unmanageably high number of articles yielded on initial searching (71,400) and a lack of clear refining tools (as documented by Halevi et al., 2017)16. A total of seventy three relevant articles was yielded.

Search terms:

Search 1: Simulation OR Simulator AND Veterinary AND Education.

Search 2: Simulator OR Simulation AND Veterinary.

Search 3: Model AND Veterinary AND Education

Search 4: Simulation OR Simulator AND Veterinary AND Training

Search 5: Model AND Veterinary AND Training

Further searches: Simulation OR Model AND Veterinary AND (Education OR Training) AND <species> - bovine, ovine, porcine, feline, canine, equine, cattle, sheep, pigs, cats, dogs, horses.

Searches were also performed using the plural forms (simulations/simulators) and it was found that the search results were the same regardless of singular or plural form. Certain journals with a number of relevant articles were searched separately in addition to the main database searches (for example, Journal of Veterinary Medical Education, Alternatives to Laboratory Animals). Reference lists and bibliographies of discovered articles were examined to identify other relevant publications. The Wiley Online Library and Science Direct searches yielded high numbers of articles on initial searching, necessitating subject refinement to Veterinary Medicine/Science and original research articles.

Dates covered in database searches (latter date being the date the search was performed):

* CAB Abstracts – 1973 to 16th January 2022 bbbbbbbbbb
* PubMed – unknown to 16th January 2022
* ScienceDirect – Elsevier – unknown to 16th January 2022
* Scopus – unknown to 16th January 2022
* Wiley Online Library – unknown to 16th January 2022

Exclusion criteria: Non-English language, non-peer reviewed articles, full text unavailable, or articles not relevant to the research question.

Inclusion criteria: Peer reviewed articles written in the English language and relevant to the research question(s).

**Results**

*Small animal simulations*

Forty five of the seveny three articles reviewed (61.6%) focused on small animal simulators and the majority of these used canine models (73.3%, n=33/45), with four using feline models and two using lagomorph (rabbit) models. Six articles used a model that could be utilised for both canine and feline tasks. It must be noted, however, that the anatomy of mammalian species for the purposes of model clinical skills simulators is very similar and therefore certain skills learned on some canine models (for example, skin suturing or ligation of blood vessels) will be transferrable to other species.

The topics with the most studies dedicated to them appeared to be laparoscopy, venepuncture and/or intravenous catheterisation and anaesthetic procedures and monitoring (four articles each), followed by neutering (orchiectomy and ovariohysterectomy), endotracheal intubation and endoscopy..

Most articles were experimental studies (n=42/45, 93.3%)), plus two cross-sectional surveys and one observational study via analysis of case records. Thirty of the experimental studies involved the creation of a simulation, then assessing the validity of the simulation by comparing the ability of simulation-trained participants when performing a task (either using the simulation, cadaver or a live animal) with a control group (non-simulation trained). The majority of the experimental studies obtained participant feedback on the perceived usefulness of the simulation or the perceptions of change in confidence and/or competence following use of the simulation (n= 36/45).

*Farm animal simulations*

Ten of the seventy three articles reviewed (13.7%) focused on farm animal simulators, all were experimental studies and all used bovine simulators. Nine out of the ten studies assessed bovine rectal palpation simulators such as the Haptic Cowα and/or Breed’n Betsyβ or a Bovine Trans-rectal Palpation Phantom created by the researchers. 14,17-22 One article focused on a calving simulator. 23

*Equine simulations*

Nine of the seventy three articles reviewed (12.3%) focused on equine simulators. All of the studies were experimental and the topics included intravenous and intramuscular injections,24 intra-articular (joint) injections,25 diagnostic regional anaesthesia (nerve blocks),26 endoscopy of the upper respiratory tract,27 gynaecological examination,28,29 laparoscopic ovariectomy,30 and cardiac dissection.31 Cardiac dissection was included as a clinical skill for the purposes of this article due to the RCVS listing ability to perform a post-mortem examination in their Day One Competences and the assumption that this will be required as part of a thorough post mortem examination.4

*Simulations applicable to all species*

Ten articles focused on skills which were not species-specific or used multiple species in their methodology, eight of which were experimental, one descriptive and one cross-sectional survey. In addition, as aforementioned, some of the small animal specific models are transferrable to other species (e.g., ligation) so this categorisation is not absolute. Topics in the non-species specific articles included student perceptions of alternative teaching methods,32 table-top simulators for basic surgical skills training (venepuncture, placement of peripheral venous catheters),33 laparoscopic surgery,34 enterotomy skills,35 ligation (haemostasis),36 suturing,37 and one study assessed the ability of a commercial human patient simulator to educate veterinary students.38 Table 1 details a summary of all available simulations in the reviewed literature.

[Table 1 placeholder as per SAGE guidelines]

**Discussion**

The use of simulations for teaching in veterinary and medical education has been extensively studied and the literature reviewed shows that simulations are being developed and implemented into veterinary curricula across the globe, with the overall aim of improving practical skills in students (and therefore new graduates) and reducing the use of live animals and cadavers in veterinary education.

From the literature reviewed, there appears to be a notable species discrepancy within the field of simulators, with small animal simulations appearing over-represented compared with other species. Simulation development for large animal species may be inhibited by costs or availability of materials, as large simulation models are more expensive and more difficult to obtain than table-top simulations using everyday materials; this may therefore be a contributory factor to the apparent bias towards small animal simulations documented in the reviewed literature. It must be noted, however, that the anatomy of mammalian species for the purposes of model clinical skills simulators is very similar and therefore skills learned on some models (for example, skin suturing or ligation of blood vessels) will be transferrable to other species. However, there is a paucity of literature regarding simulations in large animals when compared to small animals; for example, although simulations for venepuncture appear to be available for small animals and horses, there do not appear to be any specifically designed for farm animals described in the literature. The procedure for jugular venepuncture in horses is very similar to that of cattle, though phlebotomy (bleeding) of cattle is often performed via venepuncture of the tail vein (median ventral coccygeal vein, Figure 1) as this is considered to be quicker and easier to perform in cattle when restrained in a race, cattle crush or when free-standing in cattle stalls and provides little disturbance to the animal. 86 The lack of peer-reviewed literature detailing such simulations does not necessarily preclude their existence, however, as it is possible that clinical skills laboratories within veterinary schools contain a large number of simulations which have not been described in the published literature.

[Figure 1 placeholder as per SAGE guidelines]

The studies reviewed appear to document that simulations can improve student skill for a particular task and do therefore seem to be efficacious methods of teaching certain practical skills.24-26,29,33-35,37,45,47,53,62,66,69,71,75-79,81,83)

Student surgical times and performance scores using simulators have been correlated with live surgical performance and times 10,86 and training on models can provide learning outcomes equivocal 81 or superior 66,67,73,77 to those of cadaver or live animal practicals. Training using simulations can increase student confidence in performing a task, 51,66,68,75-78 and can increase student confidence in identifying anatomical structures or landmarks, even if they did not increase competence in performing the practical task itself. 60,79 Simulations have also been shown to decrease student anxiety prior to performing a task on a live animal. 51,66,77

Positive feedback was received by students for the majority of the simulations documented in the reviewed literature, but some students provided feedback in some studies stating that they would prefer more live animals to be used for teaching purposes.39.49

A small number of the papers reviewed monitored procedural success of simulator training by then observing students performing the task on live animals, with some studies using live animals obtained specifically for research purposes and others using animals obtained for teaching purposes on undergraduate or postgraduate courses. It must be noted that the use of live animals for invasive procedures (e.g., surgical procedures) in such studies would be considered unethical in some veterinary schools and such studies would not pass the stringent ethical review process in some institutions and schools. The use of live animals obtained specifically for the purposes of teaching surgery is prohibited by some institutions, and at the author’s institution, all surgical teaching is performed under direct and continuous supervision from a qualified veterinary surgeon registered with the Royal College of Veterinary Surgeons (MRCVS) on clinical cases undergoing surgery for medical reasons, with full informed consent from the animal’s owner. At no point in the veterinary course at the author’s institution are live animals obtained, anaesthetised, used for the purposes of teaching and then euthanised; such practices are forbidden in accordance with the institution’s ethical framework and guidelines. It is understood that the studies using live animals aimed to ensure the simulations developed could mimic a real-life situation and therefore, if validated, could replace the use of live animals for teaching certain skills and therefore reduce the number of live animals used in teaching in the long-term. However, alternative methods of validation not necessitating the use of live animals obtained solely for this purpose would be preferred from an ethical standpoint, for example, observing students performing a certain task on clinical cases requiring veterinary intervention rather than obtaining animals and performing the task without clinical need solely for research purposes.

According to the National Centre for the Replacement, Refinement and Reduction of Animals in Research (NC3Rs84) guidelines on the responsibility for the use of animals in bioscience research, “All experimental work should seek where possible to avoid the use of animals if the work has the potential to cause animals pain, suffering, distress or lasting harm. Where use of animals is considered necessary, the researcher should advance sound scientific reasons for their use, explaining in proposals for support why no realistic alternative exists”.84 It could be argued, therefore, that if researchers were to follow those guidelines, the obtainment and use of animals purely to validate teaching simulations would be prohibited as there is no justifiable reason why veterinary students could not be observed performing such tasks on real clinical cases during their training or on live cases following graduation; the logistics of data obtainment for such a study would be lengthier and more complex, but this would not necessarily preclude data from being obtained.

Knight, 2007, documented that certain veterinary academics were opposed to the introduction of more humane methods of teaching and listed a number of institutions in which veterinary students had requested more humane methods and had met with opposition from their faculties, the majority of which were in the United States of America (USA). 88 Knight, 2007 also documented the introduction of a conscientious objection policy for practicals involving the use of live animals or cadaver materials. A number of reasons for academics objecting to the introduction of more humane methods were postulated, however, the aforementioned article is dated over fifteen years prior to this review, and it is hoped that advancements in the field of veterinary education, quality improvement and enhancement, simulator use and the advancement in virtual and augmented reality technologies would lead to veterinary students no longer facing such opposition in the present day.

According to Sachana et al.,32 students would like traditional training methods to be paired with alternative approaches such as simulations, with 68.8% of students expressing a desire for alternative classes. Students did express desire to be exposed to as many humane models for teaching as possible, however, 52.1% of students would not refuse a live animal class even if an alternative was offered. The study appeared to show that simulations can be an effective supplement to traditional teaching methods, but it seems that alongside some academics as documented by Knight, 2007, some students still prefer live-animal or cadaver practical classes. 51 The preference for live-animal classes amongst some students could be due to increased realism and the perception that simulators cannot provide a true representation of performing tasks on live patients, even if outcomes from simulators have been documented to be equivocal to or superior to using live animals. More research is required on this topic, particularly in light of recent advancements and growth in the area of simulations within veterinary education.

It should be noted that students raised concerns regarding the use of live animals in teaching in some studies,39,43,74 but similarly some students provided feedback stating that they would prefer more live animals to be used for teaching purposes,39,49 or that they did not consider the welfare of the animals used to be a concern due to the significant educational value provided by the practical class43 According to Verrinder & Phillips (2014), “veterinary students are sensitive to animal ethics issues and are motivated to prioritize the interests of animals but have little experience in taking action to address these issues”,85 which could be interpreted such that veterinary students are aware of ethical guidelines surrounding the use of animals but perhaps do not know how to act in response to them. It therefore remains the responsibility of the educational establishment to ensure the use of animals adheres to their own ethical framework or guidelines and is in line with national ethical guidelines, and to teach veterinary students the importance of animal welfare and the ethical use of animals in teaching and/or research. This includes providing access to a conscientious objection policy if appropriate for the particular task being performed and providing this does not interfere with compulsory aspects of the curriculum at the individual institution. 88

It is the author’s sincere hope that any future simulation studies performed adhere to more modern ethical guidelines in order to protect animal welfare and reduce the need to obtain live animals solely for teaching or pedagogic research purposes , in addition to providing veterinary students with opportunities to learn practical skills in a safe, low-risk environment. As aforementioned, it is not envisioned that simulations supersede the use of live animals in teaching, as this is a crucial aspect of veterinary training. It is hoped that the use of live animals in teaching, particularly for the teaching of invasive skills such as surgical techniques, will be restricted to clinical cases requiring veterinary intervention rather than animals obtained solely for the purpose of teaching those skills, and in those cases, the use of simulations will increase student competence and confidence prior to their exposure to clinical cases.

**Conclusion**

The articles reviewed displayed that there are a number of simulations available to veterinary educators and that simulations enhance student skill acquisition, provide a suitable alternative teaching method to live animal or cadaver practicals and that simulations are usually well-received by students. There is a bias towards small animal simulations, however, some skills learned on small animal or table-top models will be transferrable to other species. The farm animal simulations reviewed were biased towards bovine rectal palpation and/or pregnancy diagnosis and there is scope for further research into large animal simulations, both for farm animals and horses. The use of live animals to validate simulations in certain studies was not considered to be in adherence of current ethical guidelines in the United Kingdom. Further research is required to develop an increased repertoire of available simulations for use in veterinary education in order to improve practical skills in veterinary students and reduce the use of live animals and cadaver material in veterinary education, with the long-term aim of both improving animal welfare and the competence and confidence of veterinary graduates.

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**Manufacturers**

α. Haptic Cow, Virtalis Ltd, Cheshire, UK, <https://www.virtalis.com/haptic-cow/>

β. Breed’n Betsy, Brad Pickford, Australia, <http://www.breednbetsy.com.au/>

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*Table 1. Simulations detailed within the reviewed literature categorised by simulation type, including author, date and species.* # Species key: [C] = canine, [F] = feline, [L] = lagomorph (rabbit), [B] = bovine, [E] = equine, [A] = all

|  |  |  |
| --- | --- | --- |
| **Category** | **Simulation(s)** | **Author(s) & [Species]#** |
| Examination | Canine prostate examination | * Capilé et al., 2015 39 [C]
 |
| Cardiac dissection | * Allavena et al., 2017 31 [E]
 |
| Feline abdominal palpation | * Williamson et al., 2015 40 [F]
 |
| Gynaecological examination | * Nagel et al., 2015 28 [E]
* Nagel et al., 2015 29 [E]
 |
| Ophthalmic examination | * Banse et al., 2021 [C]41
* Nibblett et al., 2015 42 [C]
* Williams et al., 2016 43[C]
 |
| Orthopaedic examination  | * Troy & Bergh, 2015 44 [C]
 |
| Otoscopy | * Nibblett et al., 2017 45 [C]
 |
| Clinical procedure | Anaesthetic procedures & monitoring | * Jones et al., 2017 46 [C]
* Jones et al., 2019 47 [C/F]
* Lewis et al., 2017 48 [A]
* Modell et al., 2002 38 [A]
* Musk et al., 2017 49 [A]
 |
| Calving | * French et al., 2018 23 [B]
 |
| Cardiopulmonary resuscitation (CPR) | * Fletcher et al., 2012 50 [C]
 |
| Cerebrospinal fluid (CSF) sampling | * Langebaek et al. 2021 51 [C]
 |
| Dentistry - cleaning | * Hunt et al., 2021 52 [C]
* Lumbis et al., 2012 53 [C/F]
 |
| Diagnostic ultrasound | * Mariano Beraldo et al., 2017 54 [C]
 |
| Endoscopy | * Elnady et al., 2015 27 [E]
* McCool et al., 2020 55 [C]
* Pérez-Merino et al., 2018 56 [C]
* Usón-Gargallo et al., 2014 57 [C]
 |
| Endotracheal intubation | * Aulmann et al., 2015 58 [C]
* Clausse et al., 2020 59 [F]
* Musk et al., 2017 51 [C]
 |
| Female urinary catheterisation | * Aulmann et al., 2015 58 [C]
 |
| Intra-articular injection | * Fox et al., 2013 25 [E]
 |
| Rectal palpation and/or pregnancy diagnosis | * Annandale et al., 2018 17 [B]
* Baillie et al., 2003 18 [B]
* Baillie et al., 2005 19 [B]
* Baillie et al., 2010 14 [B]
* Bossaert et al., 2009 20 [B]
* Kinnison et al., 2009 21 [B]
* Zolhavarieh et al., 2016 22 [B]
 |
| Regional anaesthesia | * Gunning et al., 2013 26 [E]
* Neves et al. 2020 60 [C]
 |
| Thoracocentesis | * Williamson, 2014 61 [C/F]
* Williamson & Rito, 2014 62 [C/F]
 |
| Ultrasound guided invasive procedures | * Hage et al., 2016 63 [C]
 |
| Venepuncture and/or intravenous catheterisation | * Hunt et al., 2020 10 [F]
* Lee et a., 2013 64 [C/F]
* Musk et al., 2017 49 [C]
* Pérez-Rivero & Rendón-Franco, 2011 65 [L]
* Silva et al., 2021 66 [C]
* Williamson et al., 2016 24 [E]
 |
| Surgical procedure | Biopsy | * Grimes et al., 2021 67 [A]
 |
| Orchiectomy (castration) | * Griffon et al., 2000 68 [C]
* Hunt et al., 2020 9 [C]
* Motta et al., 2018 69 [C]
 |
| Enterotomy | * Grimes et al., 2019 35 [A]
 |
| Laparoscopy | * Balsa et al., 2020 70 [C/F]
* Chen et al., 2017 71 [C]
* Elarbi et al., 2018 30 [E]
* Kilkenny et al., 2019 34 [A]
* Tapia-Araya et al., 2016 72 [C]
* Usón-Gargallo et al., 2014 73 [C]
 |
| Ligation | * Giusto et al., 2015 36 [A]
* Olsen et al. 1996 74 [A]
* Smeak et al., 1991 75 [C]
 |
| Ovariohysterectomy (OVH/spay) | * Annandale et al., 2020 76 [C]
* Au Yong et al., 2019 77 [C]
* Badman et al., 2016 78 [F]
* Elarbi et al., 2018 30 [E]
* Langebæk et al., 2015 79 [C]
* MacArthur et al. 2020 80 [C]
* Read et al., 2016 81 [C]
 |
| Suturing | * Baillie et al., 2020 37 [A]
* Caston et al., 2016 82 [A]
* Pérez-Rivero et al., 2015 83 [L]
 |

It should be noted that some articles, such asPérez-Rivero & Rendón-Franco, 2012 33 and Sachana et al., 2014 32 were descriptive surveys of veterinary student and faculty staff opinions on the use of simulations and therefore are not included in Table 1.

**Figures**



*Figure 1. Venepuncture from the tail of a cow (from Kramer, 196286)*