



The Effectiveness of Humane Teaching Methods in Veterinary Education

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Summary

Animal use resulting in harm or death has historically played an integral role in veterinary education, in disciplines such as surgery, physiology, biochemistry, anatomy, pharmacology, and parasitology. However, many non-harmful alternatives now exist, including computer simulations, high quality videos, "ethically-sourced cadavers," such as from animals euthanased for medical reasons, preserved specimens, models and surgical simulators, non-invasive self-experimentation, and supervised clinical experiences. Veterinary students seeking to use such methods often face strong opposition from faculty members, who usually cite concerns about their teaching efficacy. Consequently, studies of veterinary students were reviewed comparing learning outcomes generated by non-harmful teaching methods with those achieved by harmful animal use. Of eleven published from 1989 to 2006, nine assessed surgical training – historically the discipline involving greatest harmful animal use. 45.5% (5/11) demonstrated superior learning outcomes using more humane alternatives. Another 45.5% (5/11) demonstrated equivalent learning outcomes, and 9.1% (1/11) demonstrated inferior learning outcomes. Twenty one studies of non-veterinary students in related academic disciplines were also published from 1968 to 2004. 38.1% (8/21) demonstrated superior, 52.4% (11/21) demonstrated equivalent, and 9.5% (2/21) demonstrated inferior learning outcomes using humane alternatives. Twenty nine papers in which comparison with harmful animal use did not occur illustrated additional benefits of humane teaching methods in veterinary education, including: time and cost savings, enhanced potential for customisation and repeatability of the learning exercise, increased student confidence and satisfaction, increased compliance with animal use legislation, elimination of objections to the use of purpose-killed animals, and integration of clinical perspectives and ethics early in the curriculum. The evidence demonstrates that veterinary educators can best serve their students and animals, while minimising financial and time burdens, by introducing well-designed teaching methods not reliant on harmful animal use.

Zusammenfassung: Die Leistungsfähigkeit humaner Unterrichtsmethoden im Tiermedizinstudium

Die mit Leiden oder Tod verbundene Verwendung von Tieren spielte – historisch gesehen – eine integrale Rolle beim Studium der Tiermedizin, hauptsächlich in den Fächern Chirurgie, Physiologie, Biochemie, Anatomie, Pharmakologie und Parasitologie. Heute existieren viele nicht mit Leiden verbundene Alternativen, darunter Computersimulationen, hochwertige Videos, Tierkörper „ethisch unbedenklicher“ Herkunft, wie solche von aus medizinischen Gründen eingeschläferten Tieren, konservierte Tierkörper, Modelle und Chirurgesimulatoren, nicht-invasive Selbstversuche und klinisches Arbeiten unter Aufsicht. Studierende der Tiermedizin, die solche Methoden verwenden wollen, stossen oft auf harsche Ablehnung seitens der Hochschullehrer, welche üblicherweise den didaktischen Wert dieser Methoden infrage stellen. Infolgedessen wurden Studien von Tiermedizinstudenten geprüft, um den Erfolg einer Ausbildung ohne Leiden von Tieren mit solchen mit Tierleid zu vergleichen. Elf solche Studien wurden zwischen 1989 und 2006 publiziert, neun davon bewerten die chirurgische Ausbildung mit dem – historisch gesehen – grössten Leidensdruck für Tiere. Zu 45,5% (5/11) erwiesen sich die Ausbildungsgänge mit humaneren Methoden als überlegen, weitere 45,5% (5/11) waren in ihrer Effizienz gleichwertig und nur 9,1% (1/11) zeigten einen geringeren Ausbildungserfolg. Einundzwanzig Studien nicht-tiermedizinischer aber verwandter Studiengänge wurden zwischen 1968 und 2004 veröffentlicht. Dabei erwiesen sich humane Ausbildungsmethoden zu 38,1% (8/21) als überlegen, 52,4% (11/21) waren gleichwertig und 9,5% (2/21) waren weniger erfolgreich. Neunundzwanzig weitere Studien, in denen keine Vergleiche mit Leiden verursachenden Methoden angestellt wurden, belegten zusätzliche Vorteile humaner Ausbildungsmethoden, darunter Zeit- und Kostenersparnis, ein erhöhtes Potenzial zur Anpassung und Reproduzierbarkeit der Übungen, vermehrtes Vertrauen der Studenten und ihrer Zufriedenheit, erhöhte Verträglichkeit mit der Tierschutzgesetzgebung, Vermeidung der Ablehnung des Gebrauchs zu diesem Zweck getöteter Tiere und die Integration klinischer und ethischer Perspektiven schon früh im Studium. Es kann als erwiesen gelten, dass Hochschullehrer im Tiermedizinstudium sowohl zum Nutzen der Studierenden wie auch zum Vorteil der Tiere und zur Einsparung von Kosten- und Zeitressourcen, gut ausgesuchte Unterrichtsmethoden verwenden sollen, die sich nicht auf eine mit Leiden verbundene Nutzung von Tieren stützen.

Keywords: *alternative, animal experiment, education, training, veterinarian, veterinary surgery*

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1 Introduction

1.1 Harmful animal use in veterinary education

Animal use resulting in harm or death has traditionally played an integral role in veterinary education. Many thousands of animals have been killed worldwide during attempts to teach practical skills or to demonstrate scientific principles which have, in many cases, been established for decades. Animals are killed and dissected to demonstrate anatomical principles. Living animals or organs taken from them are subjected to invasive experiments in physiology, biochemistry, pharmacology and parasitology laboratories. Veterinary students in most countries learn surgery by practicing surgical procedures on healthy animals. Animals surviving these experiments or procedures are usually killed afterwards by students.

The assertion that animals are harmed within veterinary education is controversial. However, invasive procedures – that is, those markedly interfering with bodily integrity, such as surgical and some experimental procedures – do normally incur harm, when conducted on healthy animals that do not benefit from the procedures. Harm accrues from any pain, discomfort or psychological distress associated with the procedure, and from the impediment of physical function and the disruption of the animal's normal life, both of which are likely to interfere with the achievement of interests important to the animal.

Animal shelter sterilisation programs – in which homeless animals are neutered by students under supervision – constitute a special case within veterinary education. While individual animals rarely experience immediate benefits from being neutered (although long-term health benefits may accrue), populations of animals may benefit, for example, through prevention of over-breeding and consequent suffering, due to lack of homes and living resources.

Some consider that the killing of a healthy animal, when conducted without the infliction of distress or other suffering, does not necessarily constitute harm (e.g. Luy, 1998). To varying degrees, deaths approaching such an idealised state are reasonably common within vet-

erinary education, for example, when animals are killed with minimal pain or distress prior to laboratory exercises, or following experiments or surgical procedures conducted under general anaesthesia. However, animals have a broad range of natural interests they seek to fulfil during their lives. The interest in achieving a state of positive physical and psychological wellbeing is but one example. Death prevents the achievement of almost all of the interests of any animal, and therefore constitutes one of the most profound harms that may, in fact, be inflicted (Balluch, 2006).

A very rare exception occurs when there is an overwhelming interest in avoiding severe and intractable suffering caused by illness or injury. In this case physical and psychological wellbeing is elevated from a profoundly negative to a “null” state, through death. This improvement constitutes genuine *euthanasia*, that is, a “good death” – one that is clearly in the animal's best interests.

1.2 Humane teaching methods

During the last two decades there has been a large increase in the development and availability of non-harmful teaching methods, such as computer simulations, high quality videos, ethically-sourced cadavers, preserved specimens, models and surgical simulators, non-invasive self-experimentation, and supervised clinical experiences (Rowan, 1991; Bauer, 1993; Knight, 1999; Gruber and Dewhurst, 2004; Martinsen and Jukes, 2006). Some of these deserve further explanation.

Ethically-sourced cadavers

Ethically-sourced cadavers are those obtained from animals that have been euthanased for medical reasons, or, less commonly, that have died naturally or in accidents. At least nine US veterinary schools (the University of California (Davis) School of Veterinary Medicine (SVM), University of Minnesota College of Veterinary Medicine (CVM), Mississippi State University CVM, University of Missouri-Columbia CVM, University of Pennsylvania SVM, Texas A&M CVM, Tufts University Cummings SVM, Western University of Health Sciences CVM and the University of Wisconsin (Madison) SVM) (Donley and

Stull, 2001; McCoy, 2003; AVAR, 2006; Duda, 2006), and some international veterinary schools, have established client donation programs in their teaching hospitals, to facilitate the use for teaching purposes of cadavers from animals euthanased for medical reasons.

The first cadaver donation program was implemented at the Tufts University SVM (now the Tufts University Cummings SVM) in 1996 (Kumar et al., 2001), and is perhaps the most successful. As is typical, clients and clinicians in the Tufts program make decisions to euthanase on normal medical grounds, but once the decision is made, the euthanasia fee is waived. Financial influences are therefore minimised. Humane euthanasia information leaflets assist clinicians while explaining body disposal options to clients; however, allocation of cadavers to specific teaching areas is not made until afterwards, and precise details of cadaver use – which may be sensitive – are generally not provided.

Kumar and colleagues reported that some reluctance of anatomy faculty members to initiate similar programs elsewhere appeared to be based on assumptions that such programs would be labour intensive, and that the high prevalence of neutered animals donated would impede the teaching of reproductive anatomy. However, the client donation program at Tufts is reportedly no more labour intensive than the procurement and embalming of animals from traditional sources. Furthermore, Kumar and colleagues reported the ease of recruiting and training students to perform the embalming, thereby saving faculty time. They also reported that a few sexually intact animals are donated each year, which are preserved and re-used, allowing sufficient study of reproductive anatomy at Tufts.

On the other hand, several advantages reportedly accrue from the use of ethically-sourced cadavers. These include financial savings, greater biological diversity between specimens, integration of clinical histories, pathological conditions and ethical considerations into the first year of the veterinary curriculum, and elimination of student and faculty objections to the use of purpose-killed animals (Kumar et al., 2001; Fearon, 2005).



In 2000, Tufts University SVM had a caseload of 21,484 dogs and cats. Approximately 240 animals per month (with a canine to feline ratio of about 2:1) were euthanased at the request of the clients, of which approximately 20 were donated to teaching programs (around 8%). This was sufficient to meet all cadaver needs for educational purposes, including the first year gross anatomy course, and the clinical skills and medical procedures laboratories. Kumar and colleagues consequently concluded that such a donor program should be logistically feasible at any normal veterinary teaching hospital (Kumar et al., 2001). By 2005 the Tufts annual caseload had risen to around 31,000 small animals (Fearon, 2005).

Humane surgical training

Humane veterinary surgical courses ideally comprise several stages. Students may commence by learning basic manual skills such as suturing and instrument handling, using knot-tying boards, plastic organs, and similar models. They may then progress to simulated surgery on ethically-sourced cadavers. Finally students observe, assist with, and then perform necessary surgery under close supervision on real patients that actually benefit from the surgery – as distinct from on healthy animals that are later killed – similar to the manner in which physicians are trained (Knight, 1999; Hart et al., 2005).

On the face of it, traditional terminal surgical laboratories appear to offer the advantages of guaranteed access to and consistency of practical training. However, well-designed alternative surgical programs appear to consistently achieve the necessary depth and breadth of surgical experience through a combination of internal and external rotations within veterinary school teaching hospitals, private clinics and animal shelters. Pavletic and colleagues (1994), for example, described an alternative small animal medical and surgical procedures course developed at the Tufts University SVM. The use of ethically-sourced cadavers during the third year laboratory program was supplemented with additional clinical training during the fourth and final year, comprising four supplemental weeks in the

small animal surgery rotation, and one week in each of the small animal medicine and intensive care rotations. The positive educational outcomes of this and several other alternative surgical programs are reviewed in the following.

Hart and colleagues (2005) described the trend for greater clinical and surgical exposure in alternative veterinary surgical curricula. The recently-modernised curriculum at the Faculty of Veterinary Medicine, University College Dublin, for example, requires students to complete at least 24 weeks of extramural practice (external rotations) during the third, fourth, and fifth years of the course, provided at various branches of the practicing profession, including state veterinary research and diagnostic institutes (Doherty and Boyd, 2006). The curricula at The Cambridge University Clinical Veterinary School, the University of Glasgow Faculty of Veterinary Medicine, the University of London Royal Veterinary College, and the University of Sydney Faculty of Veterinary Science, are a few of a growing of veterinary schools number that have recently implemented lecture free final years, to allow students full time experience within clinical environments, such as university teaching hospitals and selected private veterinary practices (Dale et al., 2003; Jefferies, 2003; May, 2003; Canfield and Taylor, 2005). Clinical exposure may also begin earlier. At the University of California (Davis), for example, clinical exposure now commences in the first year of the curriculum (Hart et al., 2005).

The increased clinical exposure common within alternative surgical programs provides more realistic learning experiences (Gruber and Dewhurst, 2004), offering a myriad of learning opportunities not found outside clinical settings (Smith and Walsh, 2003). In particular, external rotations are more likely to expose students to a higher volume of commonly-encountered conditions than teaching hospitals, with their invariably higher proportion of referral cases (Kopcha et al., 2005). Resultant benefits include greater exposure to the clinical histories, examinations, and presenting signs of cases more directly relevant to new graduates, and to the diagnostic workups and post-operative management of such cas-

es. Surgical participation is normally conducted under close individual supervision, as distinct from the group supervision normally provided during veterinary school surgical laboratories. On the other hand, surgical supervision within veterinary schools is provided by specialists.

Participating external practices are chosen on the basis of factors such as geographic proximity, sufficient case load, interest in teaching senior veterinary students, willingness to liaise with veterinary faculty, and compatibility of the species caseload, practitioner personalities and practice facilities with the needs and interests of particular students. Placements are arranged by faculty coordinators or by students. Assessment of experiences typically occurs via a combination of practitioner performance evaluations, and student written assignments, such as clinical case logs, case reports and practice management assessments. Published experiences demonstrate that sufficient participating practices may be successfully located under normal circumstances to service the needs of major veterinary schools (e.g. Kopcha et al., 2005).

An important part of humane veterinary surgical courses worldwide are animal shelter sterilisation programs, in which homeless animals are neutered by students under supervision and returned to shelters. The popularity of these programs stems in part from the fact that all parties benefit from them. The animals have their adoption rates increased by neutering (Clevenger and Kass, 2003), the numbers of unwanted animals subsequently killed due to uncontrolled breeding is decreased, the students gain invaluable experience at some of the most common procedures they will later perform in practice (Richardson et al., 1994; Howe and Slater, 1997), and their veterinary school experiences the public relations benefits of providing a valued community service (Knight 1999).

1.3 Faculty opposition to humane teaching methods

Australian veterinary opposition

Despite their potential benefits, however, since at least 1986 to the present time (2007), it has been the experience of this author and veterinary student and faculty colleagues around the world that many



veterinary academics remain opposed to the introduction of more humane teaching methods.

As a veterinary student in 1998 at Western Australia's Murdoch University Division of Veterinary and Biomedical Sciences, I was forced to initiate legal action and media exposure of curricular animal killing, before Murdoch allowed me to use humane teaching methods (Knight, 2007). To its considerable credit, Murdoch then responded affirmatively by introducing Australia's first formal university-wide policy allowing conscientious objection by students, agreeing to provide them with alternatives to harmful animal use during teaching or assessment activities, on request. Similar policies have since been adopted by at least two other Australian universities (University of Sydney Faculty of Veterinary Science, University of Woollongong), and several US universities (e.g., the University of California (Berkeley), Cornell University, University of Illinois and Virginia Commonwealth University).

Veterinary students at two of Australia's three other established veterinary schools have experienced similar difficulties when seeking to use humane teaching methods. The University of Sydney Faculty of Veterinary Science adopted very progressive policies with respect to humane alternatives in 2000 (elimination of all terminal surgical laboratories, implementation of a pound dog sterilisation program, adoption of a policy allowing student conscientious objection), but even there students still faced difficulties when requesting humane teaching methods, as recently as 2003 (Anon., 2006). Since 1999 this author has also corresponded with students seeking to overcome considerable faculty opposition to requests for humane teaching methods at the University of Melbourne Faculty of Veterinary Science and the University of Queensland School of Veterinary Science. However, all of these students were ultimately successful, with the result that by 2005 the first students had graduated from all four established Australian veterinary schools without killing animals during their surgical training.

International veterinary opposition

Reports from veterinary students within the US and elsewhere indicate that although a

growing number of veterinary schools worldwide have implemented humane teaching methods, to varying degrees, such opposition to their implementation remains common. Veterinary students requesting humane teaching methods have faced strong faculty opposition in at least the following veterinary schools:

- University of California (Davis) including the SVM: 1986-1992 (Rasmussen, 1998);
- University of Florida CVM: 2000 (Poehost, 2001);
- University of Illinois CVM: 1999-2000 (Stull, 2003);
- Massey University Institute of Veterinary and Biomedical Sciences (New Zealand): 2001 (Beer, 2002);
- Norwegian School of Veterinary Science: 1997-2002 (Martinsen, 1998, 2002);
- Ohio State University CVM: 1992 (Anon., 1997);
- Ontario Veterinary College, University of Guelph (Canada): 2002-2006 (Thompson, 2003; Papp, 2006);
- Oregon State University CVM: 2000-2001 (McNamara, 2001);
- Virginia-Maryland Regional CVM: 2001 (Chaves, 2001); and,
- Washington State University CVM: 2002 (Anon., 2002);

Additionally, from 1998 to 2007 this author has corresponded with students facing faculty opposition to their requests for humane alternatives in at least another 10 veterinary schools, and at least 10 non-veterinary faculties, with the majority of those being located in the US.

Although not a definitive survey, and possibly biased internationally by varying student capacities to communicate their experiences by email or other means, these results nevertheless indicate that faculty opposition to student requests for humane teaching methods is an international, rather than an isolated problem, and that it is evident in some of the world's leading veterinary schools.

On rare occasion, this opposition is described in veterinary journals. Fearon (2005), for example, describes an interview with Professor Kumar, head of veterinary gross anatomy at the Tufts University Cummings SVM. Kumar established Tufts' pet body donation program in 1996 (Kumar et al., 2001) to

facilitate the ethical sourcing of the cadavers of animals euthanased for medical reasons, to replace the use of purpose-killed animals in anatomy dissection and clinical skills training. Kumar described the opposition of almost all of his academic peers at other veterinary schools to student requests for the establishment of similar programmes as "arrogant", and stated that the general attitude to requests of this sort is that "you don't let the inmates run the asylum." (Fearon, 2005).

In 2002 a "*Petition for Rulemaking and Enforcement Under the Animal Welfare Act to Eliminate Violations of the Review of Alternatives Provision*" was filed by the US Association of Veterinarians for Animal Rights and several veterinary students, with the United States Department of Agriculture, who have jurisdiction for enforcing this federal Act. All US veterinary schools were subsequently inspected, and nearly every school was cited for non-compliance with the Act. Most citations were issued for failing to search for alternatives to harmful or lethal animal use, or for failing to provide an adequate explanation as to why non-harmful alternatives were not being used. Many schools were also cited for duplicative use of animals and for the number of animals used, as well as for inappropriate species choice. Some were cited for lack of personnel training and animal identification, for conducting multiple potentially painful procedures, and for lack of information regarding anaesthetics and methods used to kill animals (Anon., 2004).

International non-veterinary opposition

Such opposition to the use of humane teaching methods is not unique to veterinary educators. Non-veterinary students requesting humane teaching methods have similarly faced strong faculty opposition in at least the following institutions:

- University of Colorado School of Medicine: 1992-1995 (McCaffrey, 1995);
- University of Frankfurt Faculty of Medicine: 1986-1990 (Völlm, 1998);
- University of New Mexico in the Bachelor of Science (Biology) course: 1989-1991 (Hepner, 2002);

- Portland Community College (Oregon) Science Department: 1997-1998 (Powell, 1998);
- University of Santa Catarina, Biological Sciences (Brazil): 1998-1999 (Tréz, 2002); and,
- University of Wales in the Bachelor of Science (Zoology) course: 1991 (Humphries, 1998).

Again, this survey is far from definitive, and it is likely that many additional institutions have also opposed student requests for humane teaching methods. Such opposition was demonstrated by the prestigious US National Association of Biology Teachers, which at first endorsed the use of humane alternatives in education, but which later rescinded this policy because of opposition from biology teachers. Commenting on this reversal, van der Valk and colleagues (1999) stated: "Often, they are not interested in the ethics of using animals. Textbooks, laboratories and equipment are still oriented toward animal experimentation. Convincing these teachers of the advantages and ethics of using alternatives is difficult, the situation being very much polarised. Incorporating the principles of the Three Rs into teachers' initial training and post-qualification professional development would help to overcome some of these difficulties."

1.4 Causes of faculty opposition

Psychological factors

There may be some interesting psychological phenomena underlying the resistance demonstrated by some faculty members to the use of humane teaching methods, including the need to personally justify the large-scale killing of animals for courses within their responsibility. Gruber and Dewhurst (2004) further asserted that: "Human vanity ... should not be underestimated. For many university teachers it is not acceptable to diverge from the methods one was taught and which one has always used in a life of teaching. Aversion towards accepting alternatives that were not developed in one's own country also plays a role."

Appeals to academic freedom to support opposition to humane teaching methods were rebutted in detail by Rutgers University (New Jersey) law professors Francione and Charlton (1992), who

described the legal bases for student conscientious objection. Although important, academic freedom is not unlimited, they asserted. Instructors may require students to consider and discuss academically relevant material with which they are uncomfortable, but they may not normally require students to actually participate in acts to which they have sincere and conscientiously held objections. Although Francione and Charlton referred to US constitutional and legislative provisions, the general legal principles described are also applicable in many other countries.

Concerns about resource constraints

The freedom to exercise such conscientiously held beliefs is considered sufficiently important under the US constitution, that exceptions may only be permissible if it can be proven that accommodating such beliefs, such as through the provision of humane teaching methods, would impose financial or administrative burdens so severe as to seriously threaten the continued operation of the school (Francione and Charlton, 1992). Unsurprisingly, such arguments have not been successfully proposed at any school. Concerns have been raised about the time and costs burdens humane teaching methods might incur. However, existing studies demonstrate time and cost benefits, rather than disadvantages, associated with these methods (e.g. Rudas et al., 1993; Dewhurst and Jenkinson, 1995; Dhein and Memon, 2003).

Concerns about teaching efficacy

The only argument that might successfully allow the denial of humane teaching methods in a legal or similarly rational forum would be that harmful animal use was truly essential for the acquisition of the skills or knowledge required for the practice of the profession in question. And indeed, in the experiences of this author and veterinary and non-veterinary student colleagues worldwide, the reasons most commonly cited by faculty members opposed to the introduction of humane teaching methods are concerns about their educational efficacy. Given the prevalence of such concerns, reviews of relevant educational studies are warranted.

Patronek and Rauch (2007) systematically reviewed learning outcomes achieved via humane teaching methods in comparison to those achieved by terminal live animal use. Seventeen studies were retrieved, of which five examined veterinary students, three examined medical students, six examined other undergraduate students and three examined high school biology students. For two of these studies of medical students, equivalent learning outcomes were achieved using alternatives to the dissection of human cadavers, and harmful animal use may not have occurred (Jones et al., 1978; Guy and Frisby, 1992). Of the remaining 15 studies clearly involving comparisons with harmful animal use, four resulted in superior, and eleven resulted in equivalent learning outcomes, when humane teaching methods were used. Of the five veterinary student studies, two resulted in superior surgical skill acquisition when alternatives to terminal live animal use were employed, and three resulted in equivalent learning outcomes when alternatives to harmful animal use were employed in surgical and physiology courses. Consequently, Patronek and Rauch concluded that "alternatives are a viable method of instruction in the field of biomedical education". They encouraged "biomedical educators to consider how adopting alternative teaching methods could be of benefit to their teaching programs, students, and faculty members".

By publishing one of the first such systematic reviews, Patronek and Rauch made a major contribution to this field. However, they only examined terminal live animal use, for example, associated with animal dissection, live animal surgery and live animal physiology demonstrations. Other potentially harmful procedures, such as equine or bovine nasogastric intubation when conducted by novice practitioners, repetitive equine or bovine rectal palpation, or even potentially stressful confinement and observation of non-domesticated species, were excluded from consideration. Additionally, only one bibliographic biomedical database (Pubmed) was searched for papers published from 1996 and 2004, and the search terms used were somewhat limited. Additional relevant comparative



studies of student learning outcomes exist. Consequently I conducted a more comprehensive systematic review of student learning outcomes achieved via humane teaching methods, in comparison to those achieved by harmful animal use.

2 Materials and methods

The peer-reviewed biomedical literature was searched to locate studies of the learning outcomes achieved by veterinary students trained using non-harmful teaching methods, in comparison to those achieved by traditional harmful animal use. To ensure comprehensive coverage, the following six biomedical bibliographic databases were searched:

1. CAB Abstracts, which is the most comprehensive bibliographic database for the applied life sciences, covering veterinary medicine and many other disciplines. It contains over five million records from 1973 onwards, sourced from over 6,000 biomedical journals and more than 3,500 other documents from over 140 countries (CABI, n.d. a-b).
2. The Cochrane Central Register of Controlled Trials (CENTRAL or CCTR), which is a bibliographic database of definitive controlled trials produced by the Cochrane Collaboration (www.cochrane.us), in cooperation with the National Library of Medicine in Washington, DC, who produce MEDLINE (see following), and Reed Elsevier of Amsterdam (The Netherlands), who produce EMBASE (see following). Over 350,000 bibliographic references to controlled trials in health care were included by 2003 (United States Cochrane Center, n.d.).
3. The Cochrane Database of Systematic Reviews (COCH) is the main component of The Cochrane Library and includes regularly updated systematic reviews of the effects of healthcare prepared by the Cochrane Collaboration (United States Cochrane Center, n.d.).
4. The Cumulative Index to Nursing & Allied Health (CINAHL) database, which provides authoritative coverage of the literature related to nursing and allied health. More than 1,600 journals and many related documents are regu-

larly indexed (CINAHL information systems, 2005).

5. EMBASE, the Excerpta Medica database, which is a biomedical and pharmacological database containing over 11 million records from 1974 onwards, covering veterinary medicine and many other disciplines, particularly those with relevance to pharmacology, sourced from over 5,000 biomedical journals from 70 countries (EMBASE, 2007).
6. MEDLINE, the United States National Library of Medicine's premier bibliographic database, covering veterinary medicine and many other medical and related disciplines. Medline contains over 15 million citations from the mid 1950s onwards, sourced from more than 5,000 biomedical journals from over 80 countries (NCBI, 2006).

All titles, abstracts, subject headings, and other key fields were searched for: "endoscopic simulation" or "endoscopy simulation" or "endoscopic simulator" or "endoscopy simulator" or "surgery simulation" or "surgical simulation" or "surgery simulator" or "surgical simulator" or "veterinary curriculum" or "veterinary education" or "veterinary physiology" or "veterinary student" or "veterinary surgery".

These search terms were chosen partly because endoscopic simulators comprise a large and important sub-category within the field of surgical simulators, and because both historically and contemporarily veterinary physiology and surgery have been the disciplines in which the greatest harmful use occurs, and consequently the greatest efforts to introduce humane alternatives have also occurred in these disciplines.

The abstracts, and, on occasion, complete papers, were examined to locate studies of veterinary and non-veterinary student performance achieved using humane alternatives, in comparison to harmful animal use. Cited references of retrieved papers were also reviewed to identify additional relevant papers.

Additionally, the main reference books within this field were searched (Balcombe, 2000b; Knight, 2002; Jukes and Chiui, 2003).

For the purposes of this review, animal use considered harmful included:

- invasive procedures, or those reasonably likely to be significantly stressful, such as:
 - equine nasogastric intubation (when conducted by novice practitioners);
 - most physiology, pharmacology and biochemistry demonstration laboratories using live animal subjects or living tissue from recently killed animals;
 - surgical procedures other than those described below; and,
- any use of animals resulting in death, other than genuine euthanasia performed solely for medical or severe and intractable behavioural reasons; and,
- the dissection of purpose killed animals.

Animal use considered non-harmful included:

- observation of wild, feral or companion animals in field studies;
- minimally-invasive or stressful procedures conducted on living animals, such as bovine rectal palpation (although repeated use in some veterinary practical classes can become stressful and/or harmful);
- invasive procedures conducted for the benefit of genuine animal patients or populations, such as neutering operations and similarly beneficial elective surgeries performed on healthy animals, and emergency surgeries conducted on injured or unwell animals; and,
- dissection, clinical or surgical procedures performed on cadavers obtained from animals that had been euthanased for medical reasons, or that had died naturally or in accidents (ethically-sourced cadavers), including the cadavers of humans donated for use in medical education.

With respect to studies of veterinary surgical training, in which surgery performed on living animals was compared with that conducted on cadavers or inanimate models, the source of the cadavers was unspecified in most studies. However, cadavers are usually obtained from ethically-questionable sources, such as the greyhound racing industry and animal control agencies ("pounds"). Consequently, when compared with a non-an-

mal alternative (e.g., Griffon et al., 2000), the latter was considered the more “humane” option for the purposes of this review.

However, cadavers may also be ethically-sourced, and growing minority of veterinary schools have established client donation programs in their teaching hospitals, as described previously. Given their potential for ethical-sourcing when compared with “terminal” (lethal) live animal use (the norm in veterinary surgical training), a cadaver was considered the more “humane” option.

3 Results

Biomedical bibliographic databases are constantly updated. As of 22 Dec. 2006, 3,954 records were located using the specified search terms. These were examined to identify studies of veterinary and non-veterinary student learning outcomes comparing harmful animal use with humane teaching methods.

Increasing numbers of veterinary schools around the world have introduced non-harmful teaching methods, which have sometimes been accompanied by educational evaluations. Twelve papers published from 1989 to 2006 described studies of veterinary students comparing learning outcomes generated

by humane alternatives with those achieved by traditional harmful animal use (Tab. 1).

Greenfield and colleagues (1994, 1995) described the same study; hence 11 distinct studies of veterinary student learning outcomes were retrieved. Nine of these veterinary student studies assessed surgical training – historically the area of greatest harmful animal use.

In 45.5% (5/11) of cases, superior learning outcomes (superior skill or knowledge, or equivalent performance with reduced activity times) resulted from the use of the humane option; equivalent learning outcomes also resulted in 45.5% (5/11) of cases; and in one case (9.1%) the humane option resulted in inferior learning outcomes.

Twenty one papers published from 1968 to 2004 described studies of non-veterinary students in related academic disciplines, similarly comparing learning outcomes generated by humane alternatives with those achieved by traditional harmful animal use (Tab. 2).

Seven of these studies of related non-veterinary disciplines examined high school biology students, while 14 examined undergraduate biology, medical, nursing, pharmacology, physiology and psychology students. The seven studies of high school biology students published from 1968 to 2004 examined

anatomical knowledge using alternatives to the dissection of purpose killed animals. Three studies demonstrated superior, three studies demonstrated equivalent, and one study demonstrated inferior knowledge acquisition, when humane alternatives were used.

Of the 14 studies examining undergraduate students published from 1983 to 2001, 35.7% (5/14) demonstrated that alternative students achieved superior learning outcomes, or achieved equivalent results more quickly, allowing time for additional learning. 57.1% percent (8/14) demonstrated equivalent educational efficacy, and only one study (7.1%) demonstrated inferior educational efficacy of humane alternatives.

Twenty nine papers published from 1983 to 2006 not involving comparisons with harmful animal use were also identified, illustrating additional benefits of humane teaching methods when used veterinary in education (Tab. 3).

Nb: “Hypermedia” (s. Tab.3, p. 99, last line) refers to interactive information media in which graphics, audio, video, plain text and hyperlinks intertwine in a structure that is generally non-linear. In contrast, the broader term ‘multimedia’ may also be used to describe non-interactive linear presentations reliant on a variety of media, as well as hypermedia (Nelson, 1965).

Tab. 1: Veterinary student learning outcomes: humane teaching methods compared to harmful animal use

	Study	Veterinary discipline	Humane option	Total students (humane option)	Humane method superior	Equivalent learning outcomes	Humane method inferior
1	Abutarbush et al. 2006	clinical skills (equine)	CD-ROM	52 (27)	√		
2	Bauer et al. 1992	surgery	cadavers			√	
3	Carpenter et al. 1991	surgery	cadavers	24		√	
4	Fawver et al. 1990	physiology	interactive videodisc	85	√		
5	Greenfield et al. 1994	surgery	soft tissue organ models	36		√	
6	Greenfield et al. 1995	surgery	soft tissue organ models	36		√	
7	Griffon et al. 2000	surgery	plastic models	40 (20)	√		
8	Johnson & Farmer 1989	surgery	models		√		
9	Olsen et al. 1996	surgery	fluid haemostasis models	40 (20)	√		
10	Pavletic et al. 1994	surgery	cadavers	48 (12)		√	
11	Smeak et al. 1994	surgery	hollow organ simulators	40 (20)			√
12	White et al. 1992	surgery	unspecified “alternative surgical program”			√	
	Totals				5	6	1



4 Discussion

4.1 Efficacy of humane teaching methods in comparison to harmful animal use

Veterinary surgical training

Humane surgical teaching methods compared with traditional harmful animal use have included models or surgical simulators (Greenfield et al., 1994, 1995; Griffon et al., 2000; Johnson and Farmer, 1989; Olsen et al., 1996; Smeak et al., 1994) and cadavers (Carpenter et al., 1991; Bauer et al., 1992; Pavletic et al., 1994).

Skills assessed in surgical laboratories included psychomotor (all), ligation

(Griffon et al., 2000; Olsen et al., 1996), intestinal anastomoses and celiotomy closures (Carpenter et al., 1991), gastro-tomy closures (Smeak et al., 1994) and ovariohysterectomies (Griffon et al., 2000).

Overall, the surgical skills generated by these humane alternatives were at least equivalent to those achieved via traditional harmful animal use. Three surgical studies demonstrated superior surgical skills when humane alternatives were used. Johnson and Farmer (1989) found that inanimate models were superior to live animals in teaching basic psychomotor skills. Olsen and colleagues (1996) demonstrated that a fluid haemostasis

model was at least as effective as a live dog splenectomy for teaching blood vessel ligation and division. In fact, students using the model completed their ligatures more quickly, with fewer errors. They successfully tied more square knots, their ligatures were tighter, and their instrument grip was superior. These students' initial scepticism regarding the use of properly designed inanimate models for teaching these surgical skills was dramatically altered. Griffon and colleagues (2000) found that 20 veterinary surgical students trained using plastic surgical simulators performed ovariohysterectomies on live dogs with greater skill than 20 classmates trained via cadavers. In all cases the abili-

Tab. 2: Non-veterinary student learning outcomes: humane teaching methods compared to harmful animal use

	Study	Discipline	Humane option	Total students (humane option)	Humane method superior	Equivalent learning outcomes	Humane method inferior
1	Cohen & Block 1991	psychology	field study (feral pigeons)			√	
2	Clark 1987	physiology	computer simulation			√	
3	Cross & Cross 2004	biology (high school)	computer simulation	74 (38)			√
4	Dewhurst et al. 1988	physiology	computer simulation	~80 (~40)		√	
5	Dewhurst & Meehan 1993	physiology	computer simulations	65 (~33)		√	
6	Dewhurst et al. 1994	physiology	computer simulation	14 (6)		√	
7	Downie & Meadows 1995	biology (undergraduate)	models (rats)	2913 (308)		√	
8	Fowler & Brosius 1968	biology (high school)	video	156	√		
9	Henman & Leach 1983	pharmacology	biovideograph videotape recordings	50	√		
10	Hughes 2001	pharmacology	computer simulations			√	
11	Kinzie et al. 1993	biology (high school)	interactive videodisc	61		√	
12	Leathard & Dewhurst 1995	physiology (medicine)	computer simulation	156		√	
13	Leonard 1992	biology (undergraduate)	interactive videodisc	142	√		
14	Lieb 1985	biology (high school)	lecture			√	
15	Matthews 1998	biology (undergraduate)	computer simulation	20 (12)			√
16	McCollum 1987	biology (high school)	lecture	350 (175)	√		
17	More & Ralph 1992	biology (undergraduate)	computer courseware	184 (92)	√		
18	Phelps et al. 1992	physiology (nursing)	interactive videodisc		√		
19	Samsel et al. 1994	physiology (medicine)	computer simulations	110	√		
20	Strauss & Kinzie 1994	biology (high school)	interactive videodisc	34 (17)		√	
21	Velle & Hal 2004	biology (high school)	computer simulation	64	√		
	Totals				8	11	2

**Table 3: Additional benefits of humane teaching methods in veterinary education**

	Study	Veterinary discipline	Humane option	Benefits of humane option (other than decreased harmful animal use)
1	Allen & Chambers 1997	surgery	computerised tutorial	increased surgical skill
2	Baillie et al. 2003	clinical skills (bovine)	virtual reality simulator	customisation of learning experience, repeatability, superior skill acquisition and development
3	Baillie et al. 2005a	clinical skills (bovine)	virtual reality simulator	customisation of learning experience, repeatability, superior skill acquisition and development
4	Baillie et al. 2005b	clinical skills (bovine)	virtual reality simulator	customisation of learning experience, repeatability, superior skill acquisition and development
5	Buchanan et al. 2005	biochemistry	3D animations	superior understanding of complex biological processes
6	Dhein & Memon 2003	continuing education	internet based curriculum	overcomes obstacles of time and distance, decreased costs, facilitates lifelong learning
7	Dyson 2003	anaesthesia	CD-ROM	increased anaesthetic knowledge
8	Ellaway et al. 2005	unspecified	virtual learning environment	increased flexibility of use
9	Erickson & Clegg 1993	physiology	computer simulations	greatest student satisfaction
10	Galle U & Bubna-Littitz 1983	clinical skills (canine)	cadaver	repeatability
11	Greenfield et al. 1994	surgery	models	decreased student and faculty objections to harmful animal use
12	Hawkins et al. 2003	clinical skills (small animal)	video	increased diagnostic skills
13	Hines et al. 2005	pathology (systemic)	virtual learning environment	greater understanding, student satisfaction, increased flexibility of use
14	Holmberg et al. 1993	surgery	model	decreased student stress, repeatability
15	Howe & Slater 1997	surgery	sterilisation program	increased surgical and anaesthetic skills including atraumatic tissue handling, increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it, increased awareness of the activities of humane organisations
16	Howe et al. 2005	surgery	CD-ROM	increased practice of techniques, enhanced preparedness for laboratories, greater student satisfaction
17	Josephon & Moore 2006	anatomy	DVD	customisation of learning experience to individual needs, possibly increased examination results
18	Kumar et al. 2001	anatomy	ethically-sourced cadavers	compliance with animal use regulations, elimination of student and faculty objections to the use of purpose-killed animals, integration of clinical perspectives and ethics early in the curriculum
19	Linton et al. 2005	anatomy	computer simulation	rapid access to anatomically related views such as radiographs, increased learning efficiency and student confidence
20	Modell et al. 2002	anaesthesia	human patient simulator	realism, increased confidence coping with complex clinical problems, increased examination results
21	Mori et al. 2006	surgery	model	repeatability, increased surgical skill
22	Pinkney et al. 2001	parasitology	computer tutorial	increased examination scores
23	Richardson et al. 1994	surgery	sterilisation program	increased surgical and anaesthetic skills including atraumatic tissue handling, increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it, increased awareness of the activities of humane organisations
24	Rudas et al. 1993	unspecified	hypermedia	increased teaching efficiency, decreased cost
25	Silva et al. 2003	surgery	cadavers	increased surgical skill
26	Simpson & Meuten 1992	clinical skills	pathology specimens	repeatability
27	Smeak et al. 1991	surgery	haemostasis model	superior surgical skill acquisition
28	Waldhalm & Bushby 1996	unspecified	personal computer	enhanced information retrieval and communication, improved student attitudes towards computers, increased employer perception of computer literacy
29	Whithear et al. 1994	microbiology	hypermedia database	greater autonomy and more active learning, facilitation of postgraduate learning



ty to use the models repeatably contributed to the superior surgical skills of the students who used them.

Five studies demonstrated equivalent surgical skills when humane alternatives were compared to harmful animal use (Carpenter et al., 1991; Bauer et al., 1992; White et al., 1992; Pavletic et al., 1994; Greenfield et al., 1994, 1995). Carpenter and colleagues (1991) and Bauer and colleagues (1992) demonstrated equivalent surgical skill acquisition using cadavers as the humane option, while Greenfield et al. (1994, 1995) demonstrated a similar result using soft tissue organ models. White and colleagues (1992) found that veterinary students from an alternative surgical laboratory program had surgical skills equivalent to those with a standard laboratory experience, after some initial hesitancy of the alternative students during their first live animal surgery.

One study demonstrated inferior surgical skill acquisition using the humane option. Smeak and colleagues (1994) compared live animal gastrotomy skills of two groups of 20 students, one of which had practiced the procedure using a hollow organ model, and the other of which had practiced using a live animal. While they found no significant difference in overall gastrotomy closure technique, the students performing the procedure for a second time on a live animal were significantly quicker. Anaesthetic time is an important surgical consideration; hence this was considered a superior learning outcome. However, the plastic model used in this study was deficient, being more fragile and stiff than living gastric tissue, with suture pull-through occurring despite appropriate technique and tension; even though the model was found to be effective for teaching instrument use, needle placement, atraumatic tissue handling and tissue inversion.

Learning outcomes were compared both in the short-term (Johnson and Farmer, 1989; Carpenter et al., 1991; Bauer et al., 1992; White et al., 1992; Smeak et al., 1994; Greenfield et al., 1994, 1995; Olsen et al., 1996; Griffon et al., 2000), and long term. As stated previously, Pavletic and colleagues (1994) studied new graduates from the Tufts

University veterinary class of 1990, which included 12 students who had participated in an alternative small animal medical and surgical procedures course. This involved the use of ethically-sourced cadavers and additional clinical rotations in small animal surgery (4 weeks), small animal medicine (1 week) and intensive care (1 week). These students and 36 of their conventionally trained peers were assessed by questionnaires sent to their employers, who were asked to rate their competency at the time of hiring and 12 months later. There was no significant difference on either occasion in the abilities of the conventional and alternative graduates when performing common surgical, medical and diagnostic procedures, in their attitudes towards performing orthopaedic or soft tissue surgery, confidence in performing the specified procedures, or ability to perform them unassisted.

The success of humane surgical training has also been reported for UK veterinary graduates. The UK is the only major region of the developed world where harmful animal use has been removed from the veterinary surgical curriculum for decades; instead students gain practical experience by assisting with beneficial surgeries during extramural rotations at private veterinary clinics. In 1998 Fitzpatrick & Mellor (2003) surveyed graduates from all veterinary schools in Great Britain and Ireland who had graduated within the previous five years. Ninety-five per cent of respondents were working full time in veterinary practice. Graduates rated extramural studies as "very useful" for three subjects, two of which were small animal surgery and cattle surgery.

Veterinary disciplines other than surgery

Both historically and contemporarily, surgery and physiology respectively are the disciplines that have resulted in the greatest harmful animal use during veterinary education. Disciplines other than surgery were poorly represented in comparative studies of veterinary student performance, totalling only two studies.

Abutarbush and colleagues (2006) found that a CD-ROM was more effective than a live animal demonstration by an instructor of the correct method for

inserting a nasogastric tube into a horse. Students using the CD-ROM performed significantly better on a test of knowledge, were more confident, and were significantly quicker at successfully inserting a nasogastric tube into a live horse, than their traditionally instructed peers.

Fawver and colleagues (1990) found that first year veterinary students learnt cardiovascular physiology principles more efficiently from interactive videodisc simulations than from live animal laboratories, resulting in both student and staff time savings.

Related non-veterinary disciplines

Fourteen studies examined learning outcomes of undergraduate biology, medical, nursing, pharmacology, physiology and psychology students. A very slightly higher proportion of non-veterinary students achieved superior or equivalent learning outcomes using humane alternatives (92.9%; 13/14), when compared to veterinary students (90.9%; 10/11).

Cardiovascular physiology students achieved equivalent learning outcomes using computer simulations (Clarke, 1987; Dewhurst et al., 1988), and superior learning outcomes using an interactive video program (nursing students, Phelps et al., 1992), compared to animal based laboratories, and rated computer simulations as superior for learning (medical students, Samsel et al., 1994). Intestinal physiology students working independently with a computer program gained equal knowledge, at one-fifth the cost, compared to students using freshly killed rats (Dewhurst et al., 1994; Leathard and Dewhurst, 1995). Physiology and pharmacology students using computer simulations performed as well as students using traditional animal laboratories (Dewhurst and Meehan, 1993). Pharmacology students achieved superior learning outcomes using biovideograph videotapes (Henman and Leach, 1983), and equivalent learning outcomes overall (superior initially in each of five experiments, but possibly with inferior long-term recall of experimental details), using computer simulations (Hughes, 2001), in comparison to outcomes achieved via animal based laboratories. Biology students achieved superior (computer simulations, More and Ralph, 1992) or equivalent

(videodisc, Leonard, 1992; models, Downie and Meadows, 1995) learning outcomes using alternatives to dissections. Additionally, the videodisc group used only half the time required by the traditional laboratory group.

Only one study of non-veterinary students demonstrated inferior learning outcomes when the humane teaching option was used. Eight undergraduate biology students who dissected foetal pigs scored significantly higher on an oral test with prosected foetal pigs than twelve students who studied using a computer simulation (“MacPig”, Matthews, 1998). However, MacPig is considered to be insufficiently detailed for college level biology instruction (Balcombe, 1998).

4.2 Impact of chronology on comparative studies

Of the 11 studies comparing veterinary student learning outcomes, eight were more than a decade old (published prior to 1996). Of the 21 papers describing non-veterinary student learning outcomes, 18 were more than a decade old. Hence, a considerable number of these studies examined humane teaching methods such as films, interactive video discs, and early computer simulations, which have been largely superseded by more advanced alternatives, particularly in the field of computer simulations. The laboratories these alternatives were designed to replace, such as animal dissections and live animal experimental or surgical laboratories, have, on the other hand, remained largely unaltered. It is a damning indictment of harmful animal use that even such relatively antiquated alternatives resulted in superior or equivalent learning outcomes in almost all cases. It is likely that comparative studies of modern alternative teaching methods would yield an even higher proportion of studies demonstrating superior learning outcomes when compared to harmful animal use.

4.3 Additional educational advantages of humane teaching methods

Veterinary disciplines

Twenty nine papers describing humane teaching methods in veterinary education that did not involve comparisons with

harmful animal use (although comparison with non-harmful teaching methods did sometimes occur) illustrated other advantages of these methods (Tab. 3). These included:

- customisation (e.g. ability to work at own pace and explore areas of deficient understanding) and repeatability of the learning exercise (Galle and Bubna-Littitz, 1983; Simpson and Meuten, 1992; Holmberg et al., 1993; Whithear et al., 1994; Baillie et al., 2003, 2005a-b; Dhein and Memon, 2003; Howe et al., 2005; Josephon and Moore, 2006), and increased flexibility of use (Dhein and Memon, 2003; Ellaway et al., 2005; Hines et al., 2005);
- increased clinical (Baillie et al., 2003, 2005a-b; Hawkins et al., 2003), surgical (Smeak et al., 1991; Richardson et al., 1994; Allen and Chambers, 1997; Howe and Slater, 1997; Silva et al., 2003; Mori et al., 2006) and anaesthetic (Richardson et al., 1994; Howe and Slater, 1997; Dyson, 2003) skill acquisition and development;
- superior understanding of complex biological processes (specifically, interactions between intracellular molecules and their spatial relationships within cells, Buchanan et al., 2005), and of systemic pathology (Hines et al., 2005); rapid access to relevant anatomical views such as radiographs, and increased learning efficiency (Linton et al., 2005);
- enhanced preparedness for laboratories (Howe et al., 2005), and even, on occasion, increased realism of the laboratory experience (Modell et al., 2002);
- increased examination results (parasitology, Pinkney et al., 2001; anaesthesiology, Modell et al., 2002 and anatomy, Josephon and Moore, 2006);
- decreased student stress (Holmberg et al., 1993), increased student satisfaction (Erickson and Clegg, 1993; Hines et al., 2005; Howe et al., 2005) and confidence (Linton et al., 2005), including when coping with complex clinical problems (Modell et al., 2002);
- enhanced student information retrieval and communication abilities, improved student attitudes towards computers, and increased employer perception of computer literacy (Waldhalm and Bushby, 1996);

- facilitation of ongoing undergraduate and postgraduate learning (Whithear et al., 1994; Dhein and Memon, 2003);
- increased teaching efficiency and decreased costs (Rudas et al., 1993; Dhein and Memon, 2003);
- increased compliance with animal use regulations, elimination of student and faculty objections to the use of purpose-killed animals, and integration of clinical perspectives and ethics early in the curriculum (Greenfield et al., 1994; Kumar et al., 2001); and,
- increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it, and increased awareness of the activities of humane organisations, when veterinary students participate in animal shelter sterilisation programs (Richardson et al., 1994; Howe and Slater, 1997).

Unusually, one alternative teaching model, the “Bovine Rectal Palpation Simulator,” was described in three of these papers (Baillie et al., 2003, 2005a-b). Bovine rectal palpation is most commonly conducted for the purposes of pregnancy diagnosis. Designed to teach the necessary skills via a haptic system, this model applies anatomically appropriate tension to a student’s fingers depending on their spatial location inside a simulated cow. Haptic technology simulates the tactile feedback that would be experienced when manipulating real tissue, and is an important component of many virtual reality simulators.

Baillie and colleagues found that students using the simulator were able to customise their learning experiences according to individual need, and that they performed better when examining real cows for the first time, than their traditionally trained peers. However, bovine rectal palpation is not normally harmful or unduly stressful unless performed repeatedly. Hence, this animal use was not considered harmful for the purposes of this review, although some repeated use does occur in veterinary practical classes.

Related non-veterinary disciplines

Numerous papers describing related non-veterinary disciplines not involving comparisons with harmful animal use (although comparison with non-harmful



teaching methods did sometimes occur) have illustrated additional advantages, and occasionally, disadvantages, of humane teaching methods. Over 500 such papers published from 1974 to 2006 were identified by this review. Many of these described the development, validation, and effects on surgical planning, skill levels and other surgical or educational outcomes of endoscopic or other surgical simulators. Validation refers to the ability of a simulator to accurately predict real surgical skill levels, and is typically achieved when experienced and inexperienced surgeons demonstrate differing skill levels while using the simulator.

A rigorous analysis of these papers is beyond the scope of this review. However, examples of papers of particular interest to veterinary educators include:

- twenty three papers demonstrating increased development of endoscopic diagnostic and surgical (Tsai and Heinrichs, 1994; Edmond, 2002; Garuda et al., 2002; Seymour et al., 2002; Waterson et al., 2002; Wilhelm et al., 2002; Ahmad et al., 2003; Sedlack et al., 2003, 2004; Strom et al., 2003; Di Giulio et al., 2004; Grantcharov et al., 2004; Uribe et al., 2004; Clark et al., 2005; Hochberger et al., 2005; Maiss et al., 2005; Matthes et al., 2005; Long and Kalloo, 2006) or other surgical skills, particularly suturing skills, (O'Toole et al., 1999; Stefanich and Cruz-Neira, 1999; Summers et al., 1999; Moody et al., 2002; Chaer et al., 2006), achieved by medical students or practitioners through the use of computer based virtual reality, or haptic, endoscopic or other surgical simulators;
- three papers indicating equivalent learning outcomes when alternatives to the dissection of human cadavers (projected specimens, a stereoscopic slide based auto-instructional program, interactive videodiscs and computer simulations) were used (medical students, Prentice et al., 1977; Jones et al., 1978; human gross anatomy, pre-nursing and allied medical profession students, Guy and Frisby, 1992);
- a paper by Szinicz et al. (1997) describing the use of the pulsatile organ perfusion ("POP trainer"), in which arteries in waste organs (commonly,

from slaughterhouses, although ethically-sourced cadavers could also be used) are perfused with an artificial blood solution connected to a pulsatile pump, for training in both minimally invasive and conventional surgical techniques. Unlike many surgical simulators, this model allows practice of haemostatic techniques. Even complex operations, such as colorectal and antireflux procedures, may be performed;

- two papers discussing the potential for globalised surgical teaching via telesurgery: the introduction of miniaturised cameras into patients during surgery (Marescaux et al., 1999a-b);
- a paper by Kunzel and Dier (2001) describing the development of a realistic intubation simulator for practicing endotracheal intubation in dogs. A study by Hall et al. (2005) demonstrated that the human intubation skills of paramedical students who were trained using a simulator were equivalent to those trained on human subjects;
- a study by Huang and Aloji (1991), which demonstrated the improved learning outcomes of undergraduate biology students who used computer simulations of dissections. Similarly, Holt et al. (2001) demonstrated that computer assisted learning can be effective at teaching endocrinology to medical students;
- one study demonstrating increased satisfaction and examination results for cardiovascular physiology students when computer simulations were used (Lilienfield and Broering, 1994). Another demonstrated cardiovascular physiology knowledge acquisition equivalent to that gained from a textbook, although these medical students rated the computer simulation superior for reinforcement and review (Specht, 1988); and,
- a study by Dewhurst and Jenkinson (1995) demonstrating that computer simulations generally saved teaching staff time, were less expensive, and were an effective and enjoyable mode of undergraduate biomedical student learning.

A small minority of studies demonstrated inferior learning outcomes when humane teaching methods were used. For example, Rogers and colleagues (1998)

demonstrated lesser basic surgical skill acquisition (the ability to correctly tie a square knot) acquired by medical students when a computer-aided learning (CAL) program was used instead of a lecture and feedback seminar. Student comments suggested that the lack of feedback in this CAL model resulted in the significant difference between these two learning outcomes. Caversaccio and colleagues (2003) found that a virtual simulator enhanced understanding of endonasal surgery, but failed to make an impact on operating room performance. The simulator's effectiveness was limited by the absence of force feedback, subtle handling of the joysticks, and considerable time consumption. Gerson and Van Dam (2004) found that medical residents trained to perform a sigmoidoscopy via traditional bedside teaching techniques achieved greater skill than those trained using an endoscopy simulator. Furthermore, a review of 30 randomised controlled trials assessing any training technique using at least some elements of surgical simulation found that none of the methods of simulated training (computer simulation, models, cadavers) were conclusively superior to one another or to standard surgical training, primarily of medical students and practitioners (Sutherland et al., 2006). These studies emphasise the importance of ensuring that humane teaching methods are well designed, and focused on achieving the specific learning outcomes desired.

4.4 Animal welfare benefits and improved legislative compliance

Advantages of humane alternatives other than educational efficacy include the saving of substantial numbers of animal lives. Few countries record the numbers of animals used for educational purposes, and of those that do, most consider only live vertebrate use, and fail to include invertebrates or vertebrates killed for dissections. Additionally, the small proportion of non-harmful use is rarely, if ever, differentiated from overall animal use. Consequently, estimates of the numbers of animals harmed for educational purposes are problematic. Nevertheless, it is clear that those numbers are substantial. Approximately nine million vertebrate animals and a similar number of in-



vertebrates were used in biomedical education in the United States in 2000 (Balcombe, 2000b). From 1985 to 1996, the Canadian Council on Animal Care estimated that around 85,000 living vertebrates and some 'higher' invertebrates such as cephalopods were used annually in Canadian university teaching (Balcombe, 2000a). The total number of animals used in Australian teaching is unclear, but in just four states that kept partial statistics (New South Wales, South Australia, Tasmania and Victoria), the recorded use was in excess of 100,000 annually, around 1996 (Office of Animal Welfare, 1996; Animal Research Review Panel New South Wales, 1997; Bureau of Animal Welfare, Agriculture and Resources, 1997; Public Health and Animal Welfare Section, 1997).

Apart from directly saving large numbers of animal lives, humane teaching methods also facilitate increased compliance with legislative and Code of Practice requirements restricting educational or other scientific animal use, which exist in an increasing number of countries (Balcombe, 2000a). In Australia, for example, the *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes*, which is legally enforceable in every state and territory, requires alternatives to the use of animals for educational and other scientific purposes, wherever possible (NHMRC, 2004).

The considerable importance of these factors is expected to further increase as society becomes ever more conscious of the importance of animal welfare (Siegford et al., 2005), and consequently, less willing to permit harmful animal use for educational purposes (Scalese and Isenberg, 2005).

Additionally, as stated previously, where veterinary students participate in animal shelter sterilisation programs, uncontrolled companion animal breeding is decreased and adoption rates are increased, directly and positively impacting on animal welfare (Clevenger and Kass, 2003).

Finally, there is evidence to suggest that veterinary education may result in the decreased likeliness of students to view animals as sentient, a decreased empathy towards animals, a decreased propensity to administer peri-operative

analgesics, and the impedance of normal development of moral reasoning ability (Self et al., 1991, 1996; Hellyer et al., 1999; Paul and Podberscek, 2000; Levine et al., 2005). Along with inadequate curricular attention to animal welfare science, the human-animal bond and the development of critical reasoning ability and ethics (Self et al., 1994; Williams et al., 1999), the harmful use of animals during veterinary education is a likely cause of such phenomena (Serpell, 2005; De Boo and Knight, 2005, 2006). The apparent reduction in concern for animal welfare may, in some cases, represent psychological adaptations enabling veterinary students to withstand what could otherwise be intolerable psychological stresses resulting from curricular requirements to harm sentient creatures in the absence of overwhelming necessity (Capaldo, 2004). Consequently, the replacement of harmful animal use with humane teaching methods is likely to result in veterinarians with more positive attitudes towards animal welfare, which is likely to directly benefit their animal patients.

4.5 Student concerns

Two key benefits of humane alternatives relate to students. The highly toxic chemicals used to preserve anatomy specimens between dissections present health hazards, incurring the potential for legal and financial liability should students suffer exposure-related adverse health effects. In the experience of this author and veterinary student colleagues from 1998-2006, recommended safety guidelines such as the use of gloves, gowns and masks are not commonly met with full compliance in veterinary schools. Examples include the Murdoch University Division of Veterinary and Biomedical Sciences, 1998 (personal experience); the University of Sydney Faculty of Veterinary Science, 2003 (Anon., 2006); and the Ontario Veterinary College, University of Guelph (Canada), 2004-2006 (Papp, 2006). These veterinary schools all had high standards, and once again this very limited survey suggests that there may be a wider problem internationally, rather than indicating a unique problem with these specific schools.

Additionally, faculty opposition to

strong student desires for humane teaching methods frequently result in conflict. A substantial number of countries have banned the harmful use of animals in primary and secondary school (mostly) or university education, outright. In a smaller group, including England, Germany, India, Italy, The Netherlands and the US, the rights of students to educational methods that do not violate their conscientiously held ethical or religious beliefs against harming animals are protected by various constitutional safeguards, legislation, policies or conventions, which have contributed to several successful lawsuits by students (Francione and Charlton, 1992; Balcombe, 2000a, 2000b). Examples include the University of Frankfurt Faculty of Medicine, 1988-1991 (Völlm, 1998); the Ohio State University College of Veterinary Medicine, 1992 (Anon., 1997); the University of Santa Catarina, Biological Sciences (Brazil), 1998-1999 (Tréz, 2002); and the University of Colorado School of Medicine, 1993-1995 (McCaffrey, 1995). In the latter case, besides being required to introduce humane teaching methods, USD 95,000 in damages and costs was awarded against the University of Colorado in 1995. The use of humane teaching methods eliminates the potential for such conflicts.

5 Conclusions

Sufficient studies have been conducted to draw some conclusions about the efficacy of humane teaching methods in imparting surgical skills or knowledge. Well designed humane alternatives generally perform at least as well as methods that rely upon harmful animal use, in some cases achieving superior learning outcomes. These have included superior surgical, anaesthetic and other clinical skill acquisition and development, superior understanding of complex biological processes, increased learning efficiency, and increased examination results. Additionally, increased teaching efficiency and decreased costs, along with enhanced potential for customisation and repeatability of the learning exercise, frequently result. Increased student confidence and satisfaction, enhanced pre-



paredness for laboratories, and decreased student stress may also occur, as may enhanced student information retrieval and communication abilities, improved student attitudes towards computers, and increased employer perception of computer literacy. Increased compliance with animal use legislation or regulations, elimination of student and faculty objections to the use of purpose-killed animals, and integration of clinical perspectives and ethics early in the curriculum may also result. Substantial numbers of animal lives are saved, and some evidence suggests that veterinarians trained without harmful animal use may develop higher animal welfare standards, potentially benefiting their future patients. They may also gain increased understanding of the pet overpopulation problem and the role of the veterinarian in combating it.

Rather than continuing to rely upon harmful animal use, the evidence clearly indicates that veterinary educators can best serve their students and animals, and can minimise financial and time burdens upon their faculties, by introducing well designed, humane teaching methodologies.

Detailed information about the alternatives available for various academic disciplines is provided by Jukes and Chiuiua (2003) and by web sites such as www.vetmed.ucdavis.edu/Animal_Alternatives and www.clive.ed.ac.uk. Synopses of surgical simulators designed for medical students and practitioners are provided at www.virtualsurgery.vision.ee.ethz.ch.

Links to libraries from which a variety of alternatives may be borrowed, along with free on-line computer simulations, comprehensive alternatives databases, academic reviews of leading alternatives, and hundreds of educational studies of alternatives organised by discipline, are also available through web sites www.HumaneLearning.info and www.EURCA.org.

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