Reference Point

Systematic review of comparative studies examining alternatives to the harmful use of animals in biomedical education

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Objective—To systematically review the published literature for controlled studies comparing learning outcomes of traditional methods that require the terminal use of animals (eg, dissection, live-animal surgery, and live-animal laboratory demonstrations) with outcomes obtained with alternative teaching methods.

Design—Systematic review.

Study Population—Controlled studies published between 1996 and 2004.

Procedures—PubMed was searched with the following keywords, used alone and in combination: educational alternatives, nonlethal teaching methods, veterinary alternatives, medical education, and nonterminal animal use. Cited references of retrieved reports were reviewed to identify additional reports. Reports were selected for review only if a comparison group was included.

Results—17 studies that were randomized controlled trials or nonrandomized trials that included a comparison group were identified. Five involved veterinary students, 3 involved medical students, 6 involved university undergraduate students, and 3 involved high school biology students. Sample size ranged from 14 to 283 students. Eleven studies appeared to be randomized, parallel-group trials, 4 involved comparative groups to which participants were not randomly assigned or for which the randomization process was not clear, 1 was a 2-period crossover study, and 1 involved a retrospective review of grades. In all 17 studies reviewed, results associated with the alternative method of instruction were not significantly different from or superior to results associated with the conventional method.

Conclusions and Clinical Relevance—Although the number of controlled studies identified was small, the results seem to support more widespread adoption of alternative teaching methods in biomedical education. (*J Am Vet Med Assoc* 2007;230:37–43)

Prior to the late 1970s, the terminal use of animals in biomedical education was routine. By the mid 1980s, however, objections to the use of animals for this purpose began to arise, reflecting the overall change in social attitudes towards animals. Veterinary medicine has been at the center of this debate from its early days,[1-4] with an increasing number of schools and colleges of veterinary medicine eliminating, reducing, modifying, or replacing educational experiences that involve euthanasia of animals or pain.[5-8] As an example, at least 8 schools and colleges of veterinary medicine in the United States have established programs whereby clients can donate the bodies of their animals for use in anatomic and surgical training programs,[8] reducing or eliminating the need to obtain purpose-bred animals for these programs. In contrast, it is difficult to gauge the degree to which alternatives to the terminal use of animals have been incorporated into undergraduate, high school, and middle school educational programs.

The primary objections to the terminal use of animals in biomedical education include a belief that it is ethically wrong to kill healthy animals for educational purposes[5,9] and a conviction that medical and surgical skills can be obtained without such use of animals.[6,10] It has also been suggested that the terminal use of animals could lead to decreased sensitivity among professional students[11] and to a sense of irreverence for life.[10,12] In addition, some have considered the use of animals from particular sources (eg, shelter animals, animals obtained from the racing industry, and purpose-bred animals) to be ethically unacceptable. Finally, there are concerns about the effect on biodiversity and species survival when large numbers of animals, such as frogs, are indiscriminately collected from the wild. The latter is not an unimportant concern, given that in 2000, 9 million vertebrate animals were used for biomedical education in the United States, with the number of invertebrate animals used thought to be equal to the number of vertebrate animals.[13]

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Apart from ethical concerns, it has been noted that some medical and graduate students have a strong emotional response to seeing, for the first time, an animal immobilized under anesthesia in preparation for an invasive procedure. Some students have described this experience as "shocking," and this emotional response detracts from learning, even in the presence of excellent teaching.[14] There are also economic and logistic considerations associated with the use of live animals in training programs, particularly because such programs require extensive close supervision by professional faculty, whereas alternatives, such as computer simulations, require less faculty input, putting less pressure on faculty time and budgets. Several reports[14,15] have documented time and cost savings when nonanimal alternatives were implemented.

The advantages and disadvantages of alternatives to the terminal use of animals in biomedical education have been widely discussed. Deeply held opinions about the essential elements of biomedical education and about what constitutes appropriate use of animals, along with the personal experiences of faculty members and the perception that accepting alternatives in education may suggest that other uses of animals are equally inappropriate, all influence how individual students, faculty members, administrators, and institutions have approached the issue.

The range of alternatives to the terminal use of animals in biomedical research is currently quite large.[16-19] However, despite the passionate arguments and strongly held opinions by advocates on both sides of the issue, there has been surprisingly little focus on the actual learning outcomes achieved when alternatives replace conventional teaching methods. The purpose of the study reported here, therefore, was to systematically review the published literature for controlled studies comparing learning outcomes of traditional methods that require the terminal use of animals (eg, dissection, live-animal surgery, and live-animal laboratory demonstrations) with outcomes obtained with alternative teaching methods (eg, interactive videodisk or computer-based simulation, surgical models, and ethically sourced cadavers). Studies involving any area of biomedical education from secondary school through postprofessional training were considered.

Methods

Published reports for inclusion in the present study were identified by searching archival materials maintained by the Center for Animals and Public Policy at the Cummings School of Veterinary Medicine and an unpublished bibliography[a] of studies of student performance. In addition, PubMed was searched for articles published between 1966 and 2004 with the following keywords, used alone and in combination: educational alternatives, nonlethal teaching methods, veterinary alternatives, medical education, and nonterminal animal use. Cited references of retrieved reports were reviewed to identify additional reports. Published reports were included in the present study only if a comparison group was included.

Results

Studies retrieved—The systematic review process yielded 17 studies that were either randomized controlled trials or nonrandomized trials that included a comparison group. Five of the 17 studies involved veterinary students,[20-24] 3 involved medical students,[14,25,26] 6 involved university undergraduate students,[27-30,b,c] and 3 involved high school biology students.[31-33] Two studies were reported only in abstract form[b,c]; the remainder were full manuscripts. Sample size ranged from 14 to 283 students.

Eleven of the studies appeared to be randomized, parallel-group trials,[20-25,27,30-32,c] 4 involved comparative groups to which participants were not randomly assigned or for which the randomization process was not clear,[26,28,29,33] 1 was a 2-period crossover study,[14] and 1 involved a retrospective review of grades.[b]

Types of alternatives studied—A wide range of alternatives were compared with traditional animal-based instructional methods (**Appendix**). The studies involving veterinary students included a study of intestinal anastomosis performed on cadavers versus anesthetized dogs,[20] a comparison of an interactive videodisk simulation versus a live animal demonstration or participation laboratory,[21] studies of surgical training with animal models versus anesthetized dogs[22] or cadavers,[23] and a study[24] comparing a hemostasis model with splenectomy in anesthetized dogs.

All but 1 of the 17 studies consisted of comparison of an alternative method that involved a nonharmful use of animals with live-animal demonstration, live-animal surgery, or animal dissection. In the remaining study,[20] surgical training with cadavers was compared with surgical training on anesthetized animals. This study was included because at the time, use of cadavers for surgical training in veterinary medicine represented the state-of-the-art alternative to live-animal surgery. In addition, it is possible to obtain cadavers from animals euthanized for medical reasons and several schools and colleges of veterinary medicine have implemented client donation programs.

Evaluation methods—With the exception of the 2-period crossover study,[14] which compared faculty and student impressions of a software program demonstrating cardiovascular principles versus live animal demonstration, all of the studies[20,22-24] incorporated some type of standardized, quantifiable outcome, such as an assessment of surgical performance. In 1 study,[20] burst pressure of anastomoses was examined. Other quantifiable outcomes included performance on laboratory reports[b] and grades on examinations.[21,25-33,c]

Outcomes—In all 17 studies, results associated with the alternative method of instruction were either not significantly different from or superior to results associated with the conventional method of instruction.

Discussion

In the present study, although we were able to identify a relatively limited number (17) of controlled studies that evaluated leaning outcomes of traditional

versus alternative methods, in all studies that were identified, the alternative method yielded results that were not significantly different from or were superior to results obtained with the conventional method of instruction. These findings appeared to be robust, as they involved a wide range of participants, alternatives, and outcomes. All studies used a comparison group, and most were randomized. All but 1 included quantifiable outcomes, such as examination grades, and in the veterinary studies that involved subjective assessments of surgical skills, the evaluators were blinded to teaching method. Thus, our findings seem to support more widespread adoption of alternatives to the terminal use of animals in biomedical education.

Our review of the literature revealed that alternative methods have been developed for a wide range of teaching outcomes. In the field of veterinary education in particular, models of parenchymal abdominal organs that have been developed have been found to be as realistic in regard to tissue handling properties as actual organs.[34] This seems to suggest that barriers to more widespread adoption of alternatives are not technological.

Many of the studies that we reviewed are > 10 years old. Thus, some of the alternative methods that were used are themselves now outdated. This is particularly true for films, videotapes, and early computer-based alternatives, which have become outmoded because of subsequent advances in computer technology. In contrast, animal-based dissection, demonstration, and surgical teaching exercises have likely changed little in terms of the technical aspects of the learning. Thus, many of the comparisons in the present study in which no differences were found between alternative and conventional teaching methods likely represent worst-case scenarios. It could be argued that with the use of currently available virtual-reality technology, alternatives might score considerably higher in formal comparisons.

Some of the advantages cited for alternative teaching methods include reductions in faculty teaching time, costs associated with purchasing animals and maintaining animal colonies, and the number of animals killed; an increased ability for students to repeat procedures until skills are mastered; greater flexibility in terms of when students can complete exercises; greater ability for students to work at their own pace; and, for many students, equal or superior academic mastery of the subject matter and the required manual dexterity skills. In addition, alternative methods provide students and faculty members who have ethical objections to the terminal or harmful use of animals a viable method for achieving their educational objectives.

Virtual reality technology has the potential to revolutionize alternative teaching methods,[35] and virtual reality methods are being applied in veterinary medicine.[16,19] However, even relatively unsophisticated methods can be used to provide students with training in basic surgical skills.[36-40]

Importantly, studies included in the present review had some limitations. Some studies[20,28] included small sample sizes, and some measured outcomes of individual students when groups or teams were used for randomization purposes,[20,21,31,33] included only vague descriptions of methodology and testing methods,[25] provided insufficient information about the extent of use of conventional methods in the alternative teaching group,[27] or provided limited head-to-head comparisons of alternative with conventional groups.[14] The 2 studies[b,c] published only in abstract form were difficult to assess because of the limited amount of information provided.

Despite these limitations, none of the studies included in the present review reported that the alternative method that was studied was inferior to the conventional method. This finding, coupled with the successful implementation of alternative teaching methods in a wide variety of veterinary school programs, argues that alternatives are a viable method of instruction in the field of biomedical education. Thus, we would encourage biomedical educators to consider how adopting alternative teaching methods could be of benefit to their teaching programs, students, and faculty members.

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Appendix

Summary of 17 comparative studies involving alternatives to harmful use of animals in biomedical education.

Carpenter LG, et al[20]

Purpose—To determine whether substitution of cadavers for anesthetized dogs when teaching surgical skills would result in an equivalent learning experience.
Design—Randomized parallel-group study.
Subjects—24 second-year veterinary students.
Subject selection—Subjects were randomly selected from those who applied to complete an elective surgery laboratory.
Alternative method—Student surgery teams performed procedures on 3 days on cadavers; on the fourth day, student teams performed an intestinal anastomosis on a live dog.
Control method—Student surgery teams performed procedures on 3 days on anesthetized dogs.
Measured outcomes—Surgical performance was scored by blinded evaluators. Anastomoses were tested for burst strength.
Results—There were no significant differences between the scores for the 2 groups.
Author conclusion—The cadaver experience seemed to strengthen student preference for use of live animals; cadavers might be best suited for preliminary skill-building.

Dewhurst DG, et al[b]

Purpose—To compare student performance in classes that used a computer simulation program versus a traditional approach.
Design—Retrospective review of grades.
Subjects—65 undergraduates in various courses.
Subject selection—All students taking courses that used computer simulation programs.
Alternative method—Not clearly specified.
Control method—Not clearly specified.
Measured outcomes—Grades awarded for laboratory reports.
Results—No significant differences between groups.
Author conclusion—Computer simulations may offer a realistic alternative to traditional teaching methods for undergraduate students.

Dewhurst DG, et al[28]

Purpose—To evaluate the effectiveness of an interactive computer-assisted learning program versus a traditional laboratory.
Design—Parallel-group study.
Subjects—14 second-year undergraduate honors physiology students.
Subject selection—Students were allotted to 2 groups (8 control and 6 experimental).
Alternative method—Computer-assisted learning program and independent study.
Control method—Students performed a series of laboratory experiments evaluating nutrient transport in rat small intestine under close supervision.
Measured outcomes—Scores on tests of knowledge and attitude taken before and after the intervention.
Results—Groups had comparable baseline knowledge scores and similar improvements in scores after the intervention.
Author conclusion—The live-animal laboratory session was almost 5 times as expensive as the computer-assisted learning program.

Downie R, Meadows J[29]

Purpose—To evaluate effectiveness of an opt-out scheme for rat dissection.
Design—Nonrandomized comparative trial.
Subjects—256 students in an introductory university-level biology course.
Subject selection—Students who chose to opt out were compared with those who did not.
Alternative method—Equivalent laboratory exercises were performed with a model.
Control method—Standard rat dissection.
Measured outcomes—Examination scores.
Results—Students in the 2 groups had similar scores for the 10 examinations recorded during the 6-year study.
Author conclusion—Examination results for students choosing to opt out were not significantly different from results for those who did not.

Fawver AL, et al[21]

Purpose—To compare simulated and traditional cardiovascular physiology laboratories.
Design—Randomized, parallel-group study.
Subjects—85 first-year veterinary students.
Subject selection—Self-selected lab groups of 3 to 4 students each were randomly assigned to interventions.
Alternative method—Interactive videodisk simulation of a cardiovascular physiology laboratory.
Control method—Traditional live-animal participation laboratory and traditional live-animal demonstration laboratory.
Measured outcomes—Scores on a 22-item multiple-choice test.
Results—There were no significant differences in test scores among groups; time savings for faculty involved in the alternative laboratory were substantial.
Author conclusion—The videodisk laboratory for teaching cardiovascular physiology was just as effective and more time efficient than traditional laboratories.

Fowler HS, Bosius EJ[31]

Purpose—To compare film versus dissection in a tenth-grade biology class.
Design—Randomized, parallel-group study.
Subjects—156 tenth-grade biology students.
Subject selection—3 sections of biology classes were randomly assigned to each intervention.
Alternative method—Films of crayfish, frog, earthworm, and perch dissection were shown.
Control method—Dissection of animals was performed.
Measured outcomes—Scores on various investigator-constructed and standardized tests.
Results—Although individual test results were not reported, the alternative method was reported to be as effective or better for the outcomes studied.
Author conclusion—The alternative method was as good as or better than traditional dissection.

Appendix continued on page 42.

Appendix (continued)

Summary of 17 comparative studies involving alternatives to harmful use of animals in biomedical education.

Greenfield CL, et al[22]

Purpose—To determine whether use of soft tissue models would prepare veterinary students as well as traditional nonsurvival surgery to perform subsequent survival surgery.
Design—Randomized, parallel-group study.
Subjects—36 third-year veterinary students.
Subject selection—Participants were randomly assigned to groups by level of previous surgical experience.
Alternative method—Students trained with soft tissue models.
Control method—Students trained on anesthetized dogs that were euthanatized at the end of the laboratory period.
Measured outcomes—Student performance during ovariohysterectomy as assessed by blinded evaluators and performance during fourth-year surgery rotations.
Results—There were no significant differences in scores between groups.
Author conclusion—The models were an acceptable alternative for teaching a part of the small animal surgery curriculum.

Griffon DJ, et al[23]

Purpose—To evaluate the efficacy of a reusable plastic model for teaching basic surgical skills.
Design—Randomized, parallel-group study.
Subjects—40 veterinary students.
Subject selection—Not specified.
Alternative method—Students performed ovariohysterectomy on a model.
Control method—Students performed ovariohysterectomy on a cadaver.
Measured outcomes—Psychomotor and basic surgical skills were assessed; ability to perform ovariohysterectomy on a live dog was assessed with a scoring system.
Results—Psychomotor and basic surgical skills scores were higher for the model group; the model group also scored higher when performing ovariohysterectomy on a live dog.
Author conclusion—The model was more effective than cadavers in teaching basic surgical skills and ovariohysterectomy of the dog.

Guy JF, Frisby AJ[27]

Purpose—To determine whether interactive videodisk can replace some laboratories in human gross anatomy for undergraduates seeking careers in allied health professions.
Design—Randomized, parallel-group study.
Subjects—Undergraduate students in prenursing or allied health professions; 190 students in a pilot study and 283 in a full study.
Subject selection—Students were randomly assigned to computer or cadaver demonstration.
Alternative method—Computerized interactive videodisk.
Control method—Cadaver laboratory demonstrations by teaching assistants.
Measured outcomes—Pilot study: unannounced practical examination involving a cadaver 1 week after completing the laboratory; full study: weekly quizzes and comprehensive examination.
Results—In the pilot study, the computer-trained students scored as well as the cadaver-trained students in 2 of the 3 sections. In the full study, there were no significant differences in scores between groups.
Author conclusion—The visual science of anatomy can be taught by means of interactive videodisk as a supplement to or replacement for cadaver laboratories.

Henman MC, Leach GDH[c]

Purpose—To compare videotape versus laboratory instruction for a pharmacology laboratory.
Design—Randomized, parallel-group study.
Subjects—24 and 26 second-year pharmacology undergraduate students.
Subject selection—Random, but otherwise not described.
Alternative method—Biovideograph instruction technique.
Control method—Standard animal laboratories.
Measured outcomes—Scores on tests taken before and after intervention.
Results—Mean scores were significantly higher for students undergoing biovideograph instruction.
Author conclusion—The biovideograph was an effective alternative.

Jones NA, et al[26]

Purpose—To compare a multimedia program and prosection tutorials with traditional lecture and dissection.
Design—Comparative group trial.
Subjects—First-year medical students.
Subject selection—Every fifth student was selected for the intervention.
Alternative method—Multimedia presentations and prosections.
Control method—Traditional lecture and cadaver dissection.
Measured outcomes—Written and practical gross anatomy examination scores and scores for National Board Examination questions on anatomy.
Results—Overall, student performance appeared similar with both methods of instruction.
Author conclusion—Students in the alternative teaching group learned human anatomy as well as those in the traditional lecture-dissection program.

Kinzie MB, et al[32]

Purpose—To evaluate the effects of an interactive videodisk on student learning of anatomy.
Design—Randomized, parallel-group study.
Subjects—61 high school students enrolled in a general biology class.
Subject selection—Students were randomly assigned to 1 of 4 groups (interactive videodisk only, dissection only, interactive videodisk preparation followed by dissection, and videotape preparation followed by dissection).
Alternative method—Interactive videodisk simulation of frog dissection
Control method—Standard dissection of frog, with or without preparation with an interactive videodisk or videotape.
Measured outcomes—Scores on a 30-item test before and after intervention and observer ratings of dissection performance.
Results—There was no significant difference in scores for students receiving the interactive videodisk only versus dissection only.
Author conclusion—An interactive videodisk simulation was as effective as dissection in promoting learning about frog anatomy and dissection.
Students who used a dissection preparation performed better on the dissection than those who did not.

Appendix (continued)

Summary of 17 comparative studies involving alternatives to harmful use of animals in biomedical education.

Leathard HL, Dewhurst DG[25]

Purpose—To compare 2 approaches to teaching the pharmacology of colonic motility.
Design—Randomized, parallel-group study.
Subjects—156 second-year medical students.
Subject selection—Students were randomly assigned to groups.
Alternative method—A computer-assisted learning program.
Control method—Standard instructor-led demonstration.
Measured outcomes—Scores on a 20-item test.
Results—There was no significant difference in mean scores between groups. Staff resources were considerably less for the computer-assisted group.
Author conclusion—Student learning, as measured by answers to key questions, was not significantly different, but the computer-assisted group did not perform as well as the instructor-led group.

Leonard WH[30]

Purpose—To compare student performance in a videodisk biology laboratory versus a conventional laboratory.
Design—Randomized, parallel-group study.
Subjects—142 students in a university-level introductory biology class.
Subject selection—Students were randomly assigned to groups.
Alternative method—An interactive videodisk showing frog and mouse respiration at various temperatures.
Control method—Respiration of live animals was observed as temperature was increased.
Measured outcomes—Scores on laboratory reports, quizzes, and examinations.
Results—Learning outcomes were equivalent for the 2 approaches.
Author conclusion—Students learned as much about cellular respiration with the videodisk as they did with hands-on laboratory experience.

Olsen D, et al[24]

Purpose—To compare student performance on basic skills in blood vessel separation and ligation following training with a hemostasis model versus splenectomy.
Design—Randomized parallel-group study.
Subjects—40 second-year veterinary students.
Subject selection—Students were randomly assigned to groups.
Alternative method—Hemostasis model.
Control method—Splenectomy on a live dog with ligation of jejunal vessels.
Measured outcomes—Videotaped performance of hemostasis skills, direct traction of ligatures, evaluation of knots under a dissecting microscope, and testing on an electronic suture board.
Results—The model group had a lower number of errors and lower time to complete exercises; more students in the model group tied square knots and tight ligatures, and instrument grip was rated better for the model group.
Author conclusion—The hemostasis model was at least as effective as use of live animals in teaching basic skills involved in vessel ligation.

Samsel RW, et al[14]

Purpose—To compare computer-based versus animal demonstrations in teaching cardiovascular physiology.
Design—2-period crossover trial.
Subjects—Approximately 110 first-year medical students.
Subject selection—Students were divided into 2 groups; both groups received each intervention.
Alternative method—A computerized software program was used by a faculty member to demonstrate principles of cardiovascular physiology.
Control method—Principles of cardiovascular physiology were demonstrated by a faculty member using an anesthetized dog.
Measured outcomes—Faculty impressions and student responses were recorded; students were asked to rate the utility of each laboratory and their preference for laboratory.
Results—All students gave the computer laboratory a score of 4 or better, whereas only 85% of students gave the live-animal laboratory a score of 3 or better.
Author conclusion—Students who objected to the dog laboratory on principle accounted for much of the apparent preference for the computer laboratory.

Strauss RT, Kinzie MB[33]

Purpose—To examine the effectiveness of interactive videodisk simulation of frog dissection as an alternative to frog dissection.
Design—Parallel-group study.
Subjects—2 classes of 17 high school biology students.
Subject selection—Classes were randomly assigned to interventions.
Alternative method—Interactive videodisk simulation.
Control method—Traditional dissection.
Measured outcomes—Scores on a 25-item test before and after the intervention.
Results—Scores were not significantly different between groups.
Author conclusion—The results supported the notion that educationally effective alternatives to dissection can be developed.