The basics of animal biosafety and biocontainment training

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The threat of biocontamination in an animal facility is best subdued by training. 'Training' is an ambiguous designation that may not be adequately appreciated in all animal facilities. The authors set down concrete training topics and provide practical advice on incorporating the basic principles of facility biosafety training—as well as the precautions and procedures that employees must know in case of accident or emergency—into various training models. They also discuss the current biosafety publications and guidelines and their relationship to biosafety training.

The laboratory animal science community has experienced a surge in research activities involving biohazardous agents during the past several years (see **Box 1**). Increased funding from the federal government, consolidation of resources through the Regional Centers for Excellence for Biodefense and Emerging Infectious Diseases, and a focus on biological agents that present opportunities for bioterrorism have resulted in the creation of numerous biocontainment research facilities throughout the United States that require highly trained staff to carry out hazardous research in a safe manner. As the global health community grapples with emerging disease threats and resistance to drugs and vaccines, the need for this type of research is critical[1].

Personnel managing laboratory animal facilities and programs must now deal with the long-term ramifications of this expanding area of biomedical research. This includes the need to find personnel (in an already tight labor market) willing to work in biocontainment facilities, the development of training materials to meet the specific needs of the facilities and research protocols, and the establishment of training standards for animal husbandry and research staff.

While work with certain biological organisms will require specific and directed training (for example, select agent training), several topics related to biosafety should be integrated into any biocontainment training program. These topics include applicable regulations (including select agent requirements), guidelines found in the fifth edition of *Biosafety in Microbiological and Biomedical Laboratories* (*BMBL*)[2], information on the institution's occupational health and safety (OHS) program, exposure prevention tools, security measures, and standard laboratory precautions.

CULTURE OF SAFETY

Any institution looking to start, improve, or revise its biocontainment training program must first work to incorporate a 'culture of safety' into its overall operations. Health and safety professionals often use the term 'culture of safety,' which implies that the organization strives to ensure that safety is an integral part of every activity, as are service, quality, and profitability. In such an environment, potentially adverse events, issues, and opportunities are systematically identified and measures are taken to ensure employee safety and well-being. In addition, such organizations exhibit a willingness to devote resources to address safety concerns, form safety goals aligned with business and research goals, and follow through on corrective actions needed to prevent unsafe conditions[3].

A critical component of a successful safety program is designing and delivering effective training for employees at all levels. Training presents many challenges, not the least of which is the need to remove people from their 'job' for training sessions. In an environment where a 'safety culture' exists, training is considered a critical part of the job. The challenge is to design and

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BOX 1. RELEVANT DEFINITIONS[a]

Biosafety: Safety from exposure to infectious agents. This includes safety for the workers, animals, and environment.

Biohazard: A biological agent, such as an infectious microorganism, that constitutes a threat to the health of humans or the environment, especially one produced in biological research or experimentation.

Biocontainment: The containment of biological agents that are harmful, or potentially harmful, to humans or the environment.

[a]Adapted from http://www.dictionary.com.

deliver training programs that not only meet regulatory and company requirements, but allow flexibility and provide information employees need to perform their activities safely and responsibly.

BASIC SAFETY

The Occupational Safety and Health Administration (OSHA) delineates basic standards and regulations for work with hazardous materials. The bulk of the standards and regulations focus on work with chemical hazards, but a variety of requirements also apply to work with biohazardous agents. The document *Training Requirements in OSHA Standards and Training Guidelines,* which is available online (http://www.osha.gov/Publications/2254.html), provides an overview of training requirements as mandated by OSHA. OSHA training requirements for the following areas should be covered in a biocontainment training program:

- Means of egress in emergencies
- Hazard communication
- Chemical hygiene (adopted as a 'Reference Resource' by the Association for Assessment and Accreditation of Laboratory Animal Science International (AAALAC International); http://www.aaalac.org/accreditation/resouces.cfm)
- Blood-borne pathogens (adopted as a 'Reference Resource' by AAALAC International)
- Respiratory protection
- Personal protective equipment (PPE)
- Hazardous waste removal
- Availability of medical services; first aid
- Lock out/tag out (safeguarding employees during equipment maintenance and/or repair)

Within larger organizations, institutional health and safety offices may provide all or part of the above training. Commercially available training modules (such as videos, CD ROMs/DVDs, online courses, onsite workshops, workshop development tools) can also be used. These modules allow trainers to avoid having to create material from scratch. Also, these modules often have training assessment tools that can be used to appraise a trainee's knowledge of the information presented. Additionally, some of these materials may allow trainers to customize training by infusing institution- or department-specific items into the information presented to the trainees.

Occupational Health and Safety in the Care and Use of Laborartory Animals[4], a publication from the National Research Council's Institute for Laboratory Animal Research (ILAR) adopted as a Reference Resource for AAALAC International, contains recommendations for training on work with biohazardous agents. In particular, the publication emphasizes one-on-one training and mentoring, and calls for the training of all personnel potentially exposed to biohazards, including those that might be indirectly exposed, such as janitorial and maintenance workers. Signs, posters, safety bulletins, and newsletters are recommended as tools to inform employees of any changes or updates to safety requirements and information.

BIOSAFETY-RELATED GUIDELINES

The *BMBL*

The *Biosafety in Microbiological and Biomedical Laboratories* (*BMBL*), which is published by the Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH), serves as the crux of biosafety guidelines in the United States. The fifth edition of the *BMBL* was released online in February 2007.

Specific training about the *BMBL* should be part of a training program for laboratory animal personnel in biocontainment facilities. In particular, such a program should define the four animal biosafety levels (ABSL) and the standard practices for operating ABSL facilities. ABSL guidelines cover practices, safety equipment, and facilities for experimentation with animals infected with agents that cause, or may cause, human infection[2]. The standard practices outline the acceptable procedures within each ABSL, including special practices such as decontamination of equipment and safety training requirements.

ABSL facilities have primary and secondary barriers. Primary barriers are the safety equipment required in each ABSL unit. Training in this area would include descriptional and operational information on this safety equipment, such as biological safety cabinets, respirators, disposable gowns or suits, face shields, or positive-pressure ventilated suits. Secondary barriers are those integrating the facility with the ABSL unit. The airflow design within the facility is an important secondary barrier and training should cover the facility's ventilation requirements, alarm mechanisms, and emergency procedures.

The *BMBL* provides excellent recommendations for working with animals in biocontainment facilities. Personnel should be trained on the basic aspects of primary and secondary barriers for each type of ABSL. Usually, the biosafety procedures for ABSL-3 and -4 facilities (often codified in a biosafety manual) are based

on the recommendations of the *BMBL*. If veterinary support personnel understand how each type of facility operates and the safety precautions in place, they can provide quality and safe support for the research.

In the fifth edition of the *BMBL*, the 'Biological Risk Assessment' section is relocated to the front of the publication (to emphasize its importance). Risk assessments are the most important process in operating a biocontainment animal facility. The risks associated with working with animals in ABSL-3 and ABSL-4 should be determined by the institutional safety committee or biosafety committee. Species-specific risks, as well as those associated with animal equipment, should be included in the risk assessment[5]. Also, each procedure or treatment should have a risk assigned to determine the total risk to personnel during the protocol. Animal-equipment risk includes sharp edges on equipment, heavy equipment, and the potential for crushing injuries (of fingers, for instance). The likelihood of bites, scratches, physical trauma, or, in the case of macaques, potential exposure to *Cercopithecine herpesvirus 1* (B virus), are all species-specific risks. Procedures associated with risk include inoculation, lavage/gavage, venipuncture, necropsy, handling, and other diagnostic procedures[2]. The risks of these procedures must be included in the overall risk factors for working with infectious agents in a biocontainment facility and included in the training program.

The fifth edition of the *BMBL* also rearranges the order of several historical chapters and appendices to accommodate new material. This new material includes the following sections:

- 'Principles of Laboratory Biosecurity': This section provides detailed advice on securing biological agents in the laboratory. Biosecurity has increased in importance due to select agent regulations and personnel security requirements.
- 'Occupational Health and Immunoprophylaxis': This section provides facility managers with more clarity on vaccination frequency and other requirements for personnel working in biocontainment facilities.
- 'Decontamination and Disinfection': This appendix explains how to properly minimize or eliminate the potential exposure of personnel to biological agents through physical or chemical means.
- 'Agriculture Pathogen Biosafety': This appendix sets forth criteria for working with ABSL-3 agriculture agents and details facility parameters and work practices to help reduce the risk of agents escaping into the environment.
- Agriculture Agent Summary Statements (for animal-Ag agents)
- Biological toxins (Select Agent focus)
- Reference to NIH rDNA program (an appendix)

Other guidelines

Biosafety guidelines may also be found in several other texts and guidance documents as well as with other organizations. Not every document will apply to animal-based research, but information on specific training topics such as biosafety-cabinet use, transportation of hazardous materials, and work with recombinant DNA may be found in these publications. **Box 2** lists various resources for biosafety training information.

BOX 2. ANIMAL BIOSAFETY TRAINING & INFORMATIONAL RESOURCES

AALAS Technician Certification and National Meeting (http://www.aalas.org)

AALAS Learning Library (http://www.aalaslearninglibrary.com)

American Biological Safety Association (http://www.absa.org)

CDC/NIH Biosafety in Microbiological and Biomedical Laboratories (http://www.cdc.gov/od/ohs/biosfty/bmbl5/bmbl5toc.htm)

CDC/NIH Primary Containment for Biohazards: Selection, Installation, and Use of Biological Safety Cabinets (http://www.cdc.gov/od/ohs/biosfty/bsc/bsc.htm)

Centers for Disease Control and Prevention (http://www.bt.cdc.gov/training/agentmodules/)

Eagleson Institute (http://www.eagleson.org)

Emory University Rollins School of Public Health Center for Public Health Preparedness and Research (http://www.sph.emory.edu/CPHPR/biosafetytraining/index.html)

Guidelines for the Safe Transport of Infectious Substances and Diagnostic Specimens (http://www.absa.org/pdf/who97.pdf)

Laboratory Animal Welfare Training Exchange (http://www.lawte.org)

NIH Guidelines on Recombinant DNA Molecules (http://www4.od.nih.gov/oba/rac/guidelines/guidelines.html)

Occupational Safety and Health Administration Training Guidelines (http://www.osha.gov/publications/osha2254.pdf)

Scientists Center for Animal Welfare (http://www.scaw.com)

World Health Organization Laboratory Biosafety Manual (http://www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR_LYO_2004_11/en/)

OCCUPATIONAL HEALTH AND SAFETY PROGRAM

OHS program training

Overall, the mission of any OHS program is to maximize employee health and productivity through the targeted delivery of preventive and wellness services, including active oversight and management of employee injury, disease, and disability[6]. Each institution maintaining an Assurance through the NIH's Office of Laboratory Animal Welfare (OLAW), as outlined in the Public Health Service *Policy on Humane Care and Use of Laboratory Animals*[7], is responsible for conducting their individual OHS program, which must be part of the

overall animal care and use program[8,9]. Management sets the tone for safety and compliance in every institution; they must understand the importance of an OHS program that fully integrates the facility design, the animal species involved, and the nature of the ongoing research[4,10,11]. The Institutional Animal Care and Use Committee (IACUC) should consider the maintenance of a safe working environment during review of animal protocols and during semiannual inspections[9].

OHS programs are integral to a sustainable and productive workforce in the animal research facility. Because of the unique employment responsibilities in the field of biomedical research, personnel must be made aware of OHS issues related to their jobs. OHS programs must also be consistent with applicable local, state, and federal regulations to maintain a safe and healthy work environment[8].

OHS program concerns are among the most common deficiencies identified by AAALAC International[11,12]. Deficiencies in any of the components of the OHS program may be documented by AAALAC, but often these deficits merely represent difficulty in coordinating all of the elements for successful personnel health and safety oversight at individual institutions[11]. Therefore, initial and ongoing investments in worker protection strategies and safety assessments are invaluable.

There are many policies and publications in place to ensure the safety of animal care personnel as well as the animals under their care[13]. ILAR's *Guide for the Care and Use of Laboratory Animals*[8] (*Guide*) is the standard reference used by AAALAC for assessment of laboratory animal facilities. The *Guide* offers recommendations for health and safety oversight to "animal technicians, clinicians, investigators, pre-doctoral and postdoctoral trainees, research technicians, consultants, maintenance workers, and security personnel," among others, that have contact with or duties involving laboratory animals. Interpretation of the *Guide* requires the use of 'professional judgment' in application of 'performance-based' standards, including those standards applicable to OHS programs. In addition to the *Guide,* and the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Testing*[14] (*Ag Guide*), produced by the Federation of Animal Science Societies (FASS), several other reference texts are available to management professionals and laboratory animal professionals interested in initiating or reviewing an OHS program. The most recognized references include the *BMBL* and the *Occupational Health and Safety in the Care and Use of Animals*[4]. Also, the text *Occupational Health and Safety in the Care and Use of Nonhuman Primates*[15] specifically addresses the risks associated with exposure to nonhuman primates (NHPs) in biomedical research, including infectious and non-infectious hazards and information on risk management[16].

Standard precautions

Standard precautions serve as the backbone of safety procedures in the laboratory environment. Personnel working in laboratories should be trained on standard precautions and any standard operating procedures (SOPs) that the organization or laboratory maintains that elaborate on these concepts. Basic topics include required signage and how to interpret signage (such as the universal biohazard symbol), proper hand hygiene, PPE, maintaining appropriate workspaces, sharps usage, equipment usage (especially equipment that is likely to become contaminated, such as centrifuges), disinfection/sterilization procedures, and biohazard waste management. PPE training should encompass how to correctly don and doff PPE, where to find PPE items, and how to replenish PPE stock. Maintaining appropriate workspaces involves sustaining uncluttered areas, ensuring that work surfaces are impervious, and allowing only authorized personnel to have access. Through the training program, personnel should be made aware that research with different biological agents will require additional precautions, beyond the standard precautions, depending on the hazard level of the agents and research. Training on the shipping procedures and regulations surrounding biohazardous materials should also be included.

Medical surveillance

Medical surveillance refers to programs that enable continuous monitoring for the potential or occurrence of disease in a given population[10]. Medical evaluations, as part of the medical surveillance program for animal care personnel, can fall into distinct categories that may or may not be necessary at every facility. Determining which types of evaluation to perform depends upon the risks assessed at each institution[6]. Examinations for employees can occur prior to the start of the job (pre-placement), as job duties are changed or shifted (periodic), when symptoms that may be related to workplace illnesses arise (episodic), or at the cessation of employment (exit).

All of these points of contact with the employee serve as training opportunities. Depending upon the inherent risks of a particular infectious disease agent, biosafety officers and occupational medicine staff may encourage heightened medical surveillance and associated training of animal care employees. Additional expectations could include baseline serum banking, special immunizations, routine antibody titer evaluations, and counseling for difficult medical decisions[17,18]. Employees should be trained as to why these additional precautions are taken and, in particular, how these actions mitigate the hazards presented in the work they are performing or will perform. Work with NHPs requires heightened surveillance measures and training, including routine tuberculosis testing and specific zoonotic disease training. Animal allergies pose an added level of risk that

should be assessed with defined frequency, including regular training sessions and updates, as allergies can worsen with increased exposure length.

Occupational medicine physicians are typically incorporated into the medical surveillance program and can play an integral role in the team, which may also include safety officers, industrial hygienists, ergonomists, and other environmental engineers[19]. Ideally, these professionals would be involved in the training program.

AAALAC-identified deficiencies are commonly related to issues of medical surveillance[6]. Some of the main concerns, based on the level of risk involved with the work, include the lack of periodic health checks or follow-up on personnel, limited access by staff to health services, and the absence of complete medical histories for facility employees[20]. More specifically, animal care employees may not be receiving the appropriate vaccinations warranted by their work duties, they may be ill-trained in practices related to the prevention of Q fever (caused by *Coxiella burnetii)* exposure, and there may be inadequate testing for tuberculosis in those individuals interacting with NHPs[6,20].

Employees need to be fully aware of internal procedures for accident reporting. Personnel in management or human resources-related positions are responsible for the legal documentation of work-related injuries as mandated by OSHA in the Labor Code of Federal Regulations[21].

Risk identification and assessment

Successful development of the OHS program depends on the identification of hazards that are inherent or intrinsic to employees' interactions with animals. The importance of identified hazards to the risks of occupational injury and illness must be understood[4]. It is imperative to identify the unique hazards present in each facility; without this, conducting an adequate risk assessment of the employees in contact with animals is not possible[11,22].

A hierarchy of risk reduction begins with the elimination of the hazard, if possible. Next, established engineering measures should be followed to contain the hazard exposure. Administrative controls for how to design animal room entry, modify room pressures, and properly use safety equipment must be in place. Appropriate work practices can be continually reinforced by education and training with safety professionals. Finally, the provision of PPE for employees must be made within all facilities. An effective OHS program ensures that risks are reduced to acceptable levels and that employees are trained on those risks as well as risk-reduction behaviors and procedures[8].

Essential to the understanding of risk identification (or risk assessment) and risk reduction is knowledge of the institutional procedures put in place to protect employees. Thus, a comprehensive biosafety training program will include a discussion of the facility's biosafety manual (as suggested by the *BMBL*), biosafety committee procedures, local ordinances, frequency of required and refresher training, and training tools (such as online modules, didactic sessions, newsletter updates).

Engineering measures

The various procedures performed by employees in animal research and the facilities in which those procedures are performed must adhere to a standard of safety. Engineering controls are uniformly recognized as the most effective means to limit hazard exposures and can include modified or novel equipment, renovations or physical changes to the facility, and structural design. Problems with uneven or wet floors, broken or aged equipment, narrow hallways, or faulty heating ventilation and air conditioning (HVAC) systems all present injury risks for personnel. Providing ergonomically sound operations that reduce physical injury risks will support the health and safety of personnel[8]. Engineering controls are also crucial to protect areas outside the confines of the animal facility, including public spaces in other parts of the institution and the extramural environment[23].

Directional air flow and pressure gradients are expected for all ABSL work, but pressure gradients are required for ABSL-3, -3 Ag, and -4 facilities[5]. In general, negative pressure relative to the adjacent hallways is expected in research rooms to contain biohazards and pull air in a 'clean-to-contaminated' direction. A comprehensive table has been published that delineates the ventilation requirements for facilities based upon level of animal biohazard work being performed[5]. Personnel working in areas with specialized ventilation should be accustomed to the proper functioning of the involved systems and how to identify and handle alarm situations.

Exposures

Reporting exposures should always follow an institutional standard operating procedure. Typically the supervisor of the exposed worker should be immediately contacted. Injured or exposed employees should be promptly released from work duties and, if necessary, escorted to visit the institutional occupational health clinic. As well, there should be a mechanism for follow-up to ensure that the exposed worker has been seen by a medical professional and received an assessment and treatment plan. Post-exposure management of personnel should focus on heightened safety[10] and summaries of important learning points that can be relayed to the workforce as a whole. Two recent articles review approaches to medical management for exposures to agents of bioterrorism[18,24].

The fifth edition of the *BMBL* also provides specific recommendations for individuals seeking medical care

after exposure to biohazardous agents. These recommendations, which should be included in the institution's biosafety training program, include giving the health care provider the following information:

- Description of the injury
- Name of the potential infectious agent involved
- Mechanism and route of exposure
- Time and place of incident
- PPE worn
- First and other aid provided
- Nature and duration of cleaning
- Any relevant aspects of medical history

Animal workers are most likely to be exposed to potential infectious pathogens during laboratory procedures involving the pathogen or vector, such as necropsy, injections, animal-handling, and restraint. When working with live animals, it is important to assess whether the pathogen or vector is shed from the infected animal and by what route, if this is known. In the case of handling euthanized animals, tissues, or fluids, personnel must be appropriately trained in methods to prevent exposure and infection.

A recent survey of laboratory animal workers assessed contemporary exposure rates in animal facilities[25]. Of over 1,000 individuals surveyed, only 28 cases of infection with zoonotic agents were self-identified from years 2000 to 2005. Veterinarians had the greatest number of exposures, followed in decreasing order by husbandry technicians, supervisors, and then veterinary technicians. Underreporting of exposures and clinical signs is believed to be problematic. Employees cited the lack of concern about the potential significance to their health and the perception of punitive consequences as the main reasons for not disclosing exposures in the work environment. It is critical to guard against complacency toward exposures in everyday work practices and training sessions, even in the face of rare exposure events in animal facilities[26].

Select agents

Select agent security preparation should start immediately for animal husbandry and veterinary support personnel. With the backlog of new security clearance requests and updates, the completion of a security clearance can take as long as six months. While personnel are awaiting clearance, they should be prepared to work in the biocontainment facilities through a training program. The following discussion will briefly describe some of the procedures for processing animal caretakers and veterinary support personnel for select agent clearance in animal holding areas that are registered for select agents.

For anyone to have unescorted access to registered select agent areas, they must undergo a Department of Justice Security Risk Assessment (SRA). SRAs are updated every five years. Once a person has been granted an SRA approval, they are permitted unescorted access to select agent areas as long as they complete additional requirements.

To gain access to secured select agent animal-holding rooms, personnel must complete initial and annual select agent training. Animal caretakers and veterinary support personnel are required to undergo the same training that is provided to laboratory personnel (as opposed to other support-personnel training) because once an animal is infected with the select agent, then all the tissue and waste that the animal generates is regulated by the select agent rules.

In addition to general select agent training, personnel must receive documented agent-specific training. A checklist maintained by the area supervisor would be considered adequate documentation as long as the supervisor and employee signed the checklist verifying that the employee understood the training (by passing a quiz, for instance). Animal protocols may be useful in providing specific knowledge or details required of persons providing animal support services. For more information on the requirements for your facility, refer to the Select Agent Program website (http://www.cdc.gov/od/sap/).

TRAINING

Training documentation

A comprehensive look at training documentation in laboratory animal science was presented in Pritt *et al.*[27].

Each training program will vary in its documentation methods depending on the techniques used to deliver the training and gauge the attendance and knowledge of the trainees. For example, sign-in sheets and paper quizzes might be used when training is presented in a classroom setting, while electronic signatures from trainees who successfully answered a minimal number of questions after an online module might be maintained in a computer database, spreadsheet, or learning management system (LMS). Regardless of documentation method, training records need to be complete, up-to-date, readily accessible (to accommodate regulatory, client, and other inspections), and consistent throughout the organization[27]. Training coordinators or managers usually maintain training records when such individuals exist within an organization[28]. Select agent-training documentation must include the name of the individual trained, date of training, description of the training provided, and the means used to verify that the trainee understood the material.

Tools, resources, and methodologies

Several resources exist for biocontainment training materials, both from inside and outside the laboratory animal science community. As discussed previously, several vendors provide generic online modules, in-person instruction, or other materials that can be purchased and possibly customized for institutional use. Blood-borne

pathogens, chemical hygiene, and respiratory protection are examples of training topics for which materials are readily available from outside vendors.

Animal-based research training materials may be found through the American Association of Laboratory Animal Science (AALAS) and the CDC. AALAS has several biosafety-related modules available on its AALAS Learning Library (ALL) that focus on both regulatory guidelines and methodologies. AALAS is also exploring the creation of a biosafety specialization program for animal care technicians. The CDC, in conjunction with Emory University, offers specific training courses in general biosafety, animal biosafety, and emergency response. Online modules and didactic training sessions can also be developed in-house by knowledgeable individuals. For training the trainer, conferences and seminars sponsored by the American Biological Safety Association (ABSA), AALAS, the CDC, the Scientists Center for Animal Welfare (SCAW), the Laboratory Animal Welfare Training Exchange (LAWTE), and institutions with robust biosafety programs can be invaluable sources of guidance and training materials, as well as real-life examples of successful training curricula.

Beyond didactic sessions and online modules, components of training programs can include the uploading of information (such as SOPs, regulatory documents) onto the internet or institution intranet, posters and signs (although care must be taken to ensure that these are posted in a meaningful manner and kept up-to-date), easy-to-follow flow diagrams for more complicated processes (emergency response, for example), coaching, mentoring, and hands-on training.

The mentoring/coaching training method provides excellent hands-on training. In this scenario, the trainer provides one-on-one training for each person working in the biocontainment area and teaches them about the facility and the type of PPE to use. This type of training is advantageous because it involves experienced trainers providing biocontainment information specific for their facility and the type of agents they work with; because the trainer can correct deficiencies as they arise during training; and because scrutiny and repetition increase the trainee's knowledge base of biocontainment principles. The disadvantages to this type of training program are the limited number of mentors or coaches at each facility, the potentially limited knowledge of would-be trainers, the time-intensive nature of this training, and the difficulty of implementing such training in the midst of active protocols.

Didactic or computer-based courses can provide a great amount of information on biocontainment principles. In one session, personnel can be exposed to all of the information about animal biosafety, personnel security, risk assessments, facility design, air flow, waste disposal, and decontamination. These types of training tools allow experienced personnel to develop computer skills. Moreover, the training is easily documented, convenient to schedule, involves less time compared to other methods (exclusive of the development of training materials), can be easily modified, and can be held for multiple employees simultaneously. Classroom sessions in particular allow for a beneficial trainee-trainer exchange. The disadvantages of computer-based programs include decreased or minimal hands on experience in the facility, an implied minimization of the significance of animal biocontainment, and limited observation or examination of trainees.

A combination of mentored, didactic, and computer-based training should be incorporated into biocontainment training for veterinary support personnel. Biocontainment personnel receiving the training will learn the principles of biocontainment and all of the regulations/recommendations to consider when working in that environment. Then, after personnel receive the background knowledge of biocontainment principles and practices, they can apply them in their everyday work environment through the mentoring program. Some programs will provide hands-on training in mock laboratories or simulate ABSL-3 conditions in ABSL-2 facilities. Mock laboratories or ABSL-2 training scenarios decrease the amount of stress on trainees while they are still trying to apply the new procedures and practices they have just learned. Oftentimes, trainees feel enormous stress when first entering ABSL-3/4 facilities, which could interfere with learning.

Beyond the widely recognized training tools and methodologies described above, behavioral-based training is designed to enhance the quality of laboratory safety practices by providing a rigorous training experience that emphasizes the cognitive and practical aspects of ABSL-3 and -4 science and safety procedures[28]. Behavioral-based training instructs the trainees to perform tasks by learned instinct. Such programs also increase participant retention, allow for individual critique, provide documentation, promote self-awareness, and allow for mistakes. These types of programs are typically conducted off-site at a dedicated facility. Significant time must be invested in this type of training. However, this type of training does offer several advantages because it:

- Provides training documentation
- Reduces participant fear and anxiety
- Magnifies participant weaknesses
- Identifies participant issues (that typically would not be seen)
- Maintains training curriculum
- Exercises participants

To appeal to employees with a bent for video games, an interactive game developed by personnel training biocontainment practices and procedures could be a great benefit to facility managers. The Sims game concept could be valuable in simulating facility design and

multiple aspects of facility operation, such as air flow, movement of animals, flow of supplies/personnel, and biosecurity. Overall, increasing the knowledge base of all employees in a biocontainment facility is the main priority, which requires creativity and measures beyond conventional training methods[29].

CONCLUSIONS

Typically, institutions venture into the realm of animal-based research involving biological hazards after considerable forethought and financial expenditure. Since 9/11, the United States and other countries have invested heavily in research involving such biological hazards to increase understanding of public health and to prepare for potential acts of bioterrorism. Biosafety and biocontainment training for individuals working in these research environments is integral to this initiative.

While there are several mandatory requirements for such training, the protection of human, animal, and environmental health is the supreme objective of these training programs. Trainers and others can incorporate the basic concepts of biosafety into a blended training format that combines OSHA-mandated training, facility operations, and guidelines from the new edition (fifth) of the *BMBL* into a successful and complete education program.

COMPETING INTERESTS STATEMENT

The authors declare no competing financial interests.

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