Despite these limitations, this study provides important suggestions for methods that can be used to minimize the risks of dual-use research. Further research is necessary to confirm these findings and to provide a detailed plan of action, which incorporates the suggestions described in this study.

References


Biosafety “Behavioral-Based” Training for High Biocontainment Laboratories: Bringing Theory into Practice for Biosafety Training

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Abstract

As the number of individuals working in high biocontainment laboratories (BSL-3 and -4) increases over time, human error remains one of the most important factors in the origin of hazardous incidents in laboratories. With support from the National Institutes of Allergy and Infectious Diseases (NIAID), the Southeast Regional Center of Excellence for Emerging Infections and Biodefense (SERCEB) supported construction of a mock BSL-4 laboratory for training on the Emory Campus, and development of a curriculum for BSL-3 and -4 training. In close collaboration with the Centers for Disease Control and Prevention (CDC) and other scientists and safety professionals, the Rollins School of Public Health has developed one-week, intensive behaviorally-based (“hands-on”) training courses for those working in BSL-3 and BSL-4 laboratories. Since January 2005, over 200 scientists, graduate students and staff have successfully participated in these courses, and the evaluations have been excellent. Long-term evaluation of participants’ knowledge retention
and practice is still needed. Separately, we are collaborating with scientists and safety professionals at individual institutions to develop tailored onsite training programs for individuals at their own facilities. In addition, we are planning video and distance-based electronic modules for biosafety training.

Background

In the past five years, the United States government has dramatically increased its investment in research with dangerous pathogens, with $1.5 billion appropriated to NIAID and National Institutes of Health (NIH) for biodefense research in 2006. New laboratories will be used to conduct additional research on dangerous pathogens, from the highly pathogenic avian influenza to anthrax and botulism. Concomitant with the growth in research is a heightened concern that the work be conducted safely. The goal of biosafety is to minimize the risk of infection to individual workers and reduce the potential for introduction of a pathogen into the community at large. In addition to potential health consequences, laboratory-acquired infections, or fear of them, may create public fear and outrage that could impair the ability to conduct critical scientific research.

Work with dangerous pathogens has been conducted safely in high biocontainment laboratories, such as the BSL-4 laboratories at the CDC for more than two decades. These high-containment settings typically have engineering controls such as air-handling systems and biosafety cabinets, which minimize both the risk of exposure to individuals working in these environments as well as the potential for release of a pathogen into the community.

Human error, however, remains one of the most important factors at the origin of hazardous incidents (WHO, 2006). Those individuals working in high biocontainment laboratories must be trained in safe laboratory practices. Historically, workers in high biocontainment laboratories have completed an introductory occupational health program, and extensive mentoring by senior staff has been required. These individuals must demonstrate successful and safe laboratory behaviors before being granted the freedom of working independently in a high biocontainment laboratory.

Today, biosafety is strongly influenced by the inherent liability of the employer to protect employees and the ability to satisfy public interest that adequate steps have been taken to prepare and train individuals working in these high-containment laboratories. In addition, the United States Department of Health and Human Services (HHS) Select Agent Regulation (42CFR73) mandates additional requirements for biosafety training of individuals before entering the laboratory environment.

As the number of individuals requiring training in safe practices in high biocontainment laboratories increases, standardized introductory biosafety training may be helpful. Such biosafety training may prove useful not only for those entering biocontainment laboratories for the first time, but also for others, including seasoned staff, whose responsibilities include assuring safe laboratory practices among all staff, and exploring safer methods for handling these highly dangerous pathogens. It is important to emphasize that standardized training alone should not replace the intensive one-on-one mentoring needed over extended periods of time (months to years) by a thoroughly seasoned laboratorian.

NIAID at the NIH recently funded 10 Regional Centers for Excellence (RCEs) in biodefense and emerging infections. SERCEB, as part of its scientific portfolio, determined that the demand for biosafety training in high biocontainment laboratories would be increasing. David Stephens, MD, of Emory University, proposed to build a mock BSL-4 laboratory on the Emory campus to support biosafety training in collaboration with scientists and biosafety personnel at the CDC. We believe this was the first mock BSL-4 laboratory in the United States built solely for the purpose of training; it has been used to train individuals in BSL-3 and BSL-4 biosafety practices.

Unlike most previous programs related to high biocontainment biosafety, the program we developed is behavioral-based and focuses on hands-on training in the mock laboratory (Figure 1). The knowledge, attitudes, and perception of laboratory staff about biosafety, including their confidence in their own skills, are an important part of this program as well.

Methods for Course Development and Implementation

Theories are used as the basis for program development. As defined, a theory is a set of integrated ideas, definitions, and suggestions, which allows for a systematic study of an event or situation through the identification of relationships among variables in order to explain and predict the circumstance (Glanz, Lewis, & Rimer, 1997). Using the PRECEDE-PROCEED planning model (Green & Kreuter, 1999), key informant interviews were conducted with experts at the CDC, the United States Army Medical Research Institute for Infectious Diseases (USAMRIID), Emory University, biosafety officers, facility managers, and animal care specialists at the BSL-3 and BSL-4 levels to identify current needs and review existing biosafety training resources. Existing gaps and biosafety issues were listed, the causes for these gaps and safety issues were identified, and a set of 25 behavioral learning objectives were developed. The Science and Safety Course was then developed and implemented as a one-week course of intensive practice, lecture, and examination that focuses on key learning objectives. Evaluation of the 25 key learning objectives occurs through both written and observational examinations. Each day, participants master approximately six learning objectives that are measured and evaluated using a written and observational examination at three stages: pre-training, during training, and...
post-training. The written examination is 25 essay questions (each question is worth four points and makes up the pre-assessment) four quizzes, and the final assessment, while the observational examination allows faculty members to observe and evaluate participants based on behavior that takes place throughout the training program. The questions serve as indicators for participant achievement of learning objectives during the four training days.

To successfully master these learning objectives, the Science and Safety Training Program places participants in practical situations. Seasoned scientists and biosafety professionals facilitate discussions during lecture sessions, challenge participants with case studies in a learning team environment, and utilize experts who share personal experiences that focus on the daily learning objectives.

**Laboratory Activities**

Participants spend 30% of the training program in a laboratory setting. Each participant is asked to master proper donning and doffing procedures according to mock laboratory standard operating procedures (SOPs), including laboratory inspection of engineering controls, spill clean-up, sharps handling, animal escapes, risk assessment, needle-sticks, cuts, animal bites, and life-threatening emergency response situations (Figures 2 and 3). For example, participants are reminded of directional airflow each time a door is opened as alarms sound until doors are closed. Participants must demonstrate checking manomeric gauges and reading signage before entering the laboratory. Faculty is frequently hanging signs on doors asking participants to perform a particular behavior; if the participant does not demonstrate this behavior, they are approached and asked to read the signs. Faculty also tear holes in personal protective equipment (PPE) to ensure that proper inspection of PPE takes place by all participants. Exercises such as these serve as key reminders of appropriate and safe behavior for all participants returning to work in high biocontainment laboratory environments.

In another role playing scenario, faculty makes a hole in a glove and fills the glove with fake blood. The participant is asked to play the role of an individual who receives a cut, passes out and falls to the ground while walking to the sink. These activities are designed to reinforce effective biosafety practices and allow participants to practice these behaviors under close supervision of experienced faculty.

**Learning Team Exercises**

Participants spend 30% of the training working together to develop constructive approaches to several case studies. In one exercise, participants are asked to construct a laboratory and place equipment in the appropriate areas. In another example, participants develop communication messages while discussing an incident that occurred in a high-containment laboratory. Participants are also asked to conduct risk assessments, package samples, properly receive mailed samples, review published laboratory incidents to determine what went wrong and finally, to develop a solution to prevent future incidents. These learning team exercises allow participants to work together as a team to solve problems. This reinforces the 25 key learning objectives identified by expert staff. In a small and non-threatening environment, participants are
also introduced to the concept of biosecurity and led in discussions of the dual-use research dilemma.

**Examination and Lecture Session**

Participants spend 30% of their training completing written and observational examinations and listening to a lecture summarizing their daily activities. Examinations are always administered before the lecture, because the lecture reviews the learning objectives of that day. Typically, it takes about two days before participants get used to this method and learn that answers will not be provided to them, and they need to work together and seek out the correct answers in participant materials and through the laboratory and learning team sessions. Faculty observe strict adherence to the testing policy and do not discuss answers to the written and oral examination. This places the responsibility on the participant and holds them accountable for their personal learning experience. Additionally, it brings the participants together and by the third day (regardless of their professional background) everyone is working collaboratively to complete the course successfully.

**Figure 2**

Examples of Science and Safety BSL-3 laboratory activities. Participants are asked to clean a spill (left) and doff PPE following standard operating procedures (right).

**Figure 3**

Participants respond to don BSL-4 PPE (left) and participate in several emergency response exercises, including medical emergencies (right).
Expert Seminars

Participants spend 10% of their training listening and participating in a discussion of biosafety based on expert experiences. Experts discuss how the environment can be modified based on the characteristics of individual pathogens to make it a safer work environment. Other discussions focus on select agent program development, shipment and receipt of laboratory packages, mistakes and lessons learned specific to working in high-containment laboratories, and risk communication and community perception of high-biocontainment laboratories.

Results and Evaluation

Identifying 25 key learning objectives provides a tool for the development of an evaluation process. The success of each participant is determined through observational and written examinations, providing expert faculty the opportunity to witness the growth of each participant on a daily basis. This produces statistical curves for each learning objective (Figure 4). Since the development of the program, over 200 students have been trained using the Science and Safety Training Program, with individuals trained either at their own facility, or onsite at the Emory mock laboratory. Both programs have been successful in terms of test scores of individuals in practical and written exercises. Historically, participants average an approximate score of 25% on the initial written examination, 75% on the second written examination, and 95% on the final written examination. Only one participant was unable to complete the course, demonstrating the curriculum’s ability to challenge individuals with a wide range of educational backgrounds.

This training model allows faculty to monitor participants very closely. In past training programs, scoring of the written examination (in addition to personal observation of practices) has allowed faculty to identify participants who are having difficulties with the material and experiencing high levels of anxiety around the issue of working in the laboratory environment. The written examination serves as an effective discovery tool for identifying participants experiencing, but not physically demonstrating problems they may be having relative to working in a high biocontainment laboratory.

Participants are also asked to evaluate each module and the overall training program. Evaluations are reviewed, summarized and shared with all participating faculty in a “hot-wash” session. If participants report having problems with a particular module, staff and faculty work to develop solutions for the next biosafety course. Overall, participants have rated the course as excellent and would recommend it to others.

Discussion

The behavioral-based biosafety training curriculum has demonstrated successful learning experiences for participants from a wide range of educational backgrounds.

Figure 4

June 2006 BSL-3 Science and Safety statistical curve that measures competency of 25 learning objectives among participants. Each of the 25 learning objectives is worth four points and participants are measured pre-training (lowest curve), during training (middle curve), and post-training (highest curve).
Good laboratory practices are behaviors that must be sustained over extended periods of time. For sustained behavior to occur, individuals must understand the risk of poor laboratory practices, have access to resources that aid in good laboratory practices, practice the skills needed to be successful, and believe in their abilities to carry out good laboratory practices (Bandura, 1994; Hochbaum, 1958; and Rosenstock, 1997). Participants become aware of this concept and begin to identify enabling factors at their institutions, which can be used to promote safer laboratory practices.

During this course, participants report being equally challenged, demonstrating effective learning curves, and comparing this course to a biosafety “boot-camp,” which (as stated by most participants) laboratory scientists and staff should complete. Regardless of effective learning curves and positive participant feedback, the ultimate evaluation is the lack of infections, or other adverse events resulting from occupational exposure. Success of the program will be best judged by the safety record of participants, which, in turn, is dependent on institutional mentoring and practices as well as on the program.

Evaluations of participants in the programs by their supervisors following the course would be useful in assessing the course’s success, and as an additional guide for future course modifications. It would also be of interest to know if the practices that participants learned in the course have resulted in the adoption of safer practices by their colleagues practicing in the same laboratory.

Conceptually, the Science and Safety Training Program has four phases: a) general communication to all participants and supervisors about the organization’s commitment to biosafety and science; b) general biosafety training course for all individuals working in the laboratory setting; c) agent specific training for all individuals working in the laboratory setting; and d) job specific training for all staff working in the laboratory (Figure 5).

The Science and Safety Training at Emory University is phase two of four phases needed for a complete and successful biosafety training program.

The Science and Safety Training Program has been packaged and taken to a BSL-3 laboratory, and tailored and implemented to fit the specific needs of that environment. Over 100 individuals were trained, demonstrating similar learning curves and participant evaluations. Additionally, leadership staff at the laboratory facilitated phases one through four, and staff reported feeling more empowered and safer when considering the work they would be asked to do with infectious disease agents.

Even after participants complete all four phases of the Science and Safety Training Program, the program can never replace the value, or importance of professional mentoring that should take place for all staff working in high-containment laboratories. Every scientist and staff member who is new to working in a biocontainment laboratory should be closely observed; they should not be allowed to work alone until a seasoned practitioner is assured that the individual is exhibiting consistently safe practices. This practice is a priority, and must take place to assure individuals working in these environments are adequately prepared and consistently demonstrate the behaviors needed to be safe and effective in high biocontainment laboratories.

In January 2007, Emory University and SERCEB hosted a national conference to bring professionals from the Regional Centers of Excellence (RCEs) and from the Regional and the National Biocontainment Laboratories (RBLs, NBLs) to share their biosafety training programs.
and to exchange ideas for improving their long- and short-term training programs. All participants expressed a need for enhanced training opportunities in biosafety and the need for continued mentorship after standardized training.

The Emory University Science and Safety Training Program (www.sph.emory.edu/CPHPR/biosafetytraining) is currently developing other training for high biocontainment laboratories, including training programs for emergency response activities, training for communicating laboratory issues to media and community organizations, and the development of a leadership program for biosafety professionals. Future trainings will be developed based on needs identified by participants of Science and Safety Training Programs and feedback provided at professional biosafety and scientific conferences. Initiatives for evaluating the effectiveness of the Science and Safety Training program are presently underway.

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References


Reliability of ULPA Filters in Air Handling Systems

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Abstract

Eighteen ultra low penetration air filters were installed in exhaust air systems in a microbiological high containment facility. Their performance was measured annually for integrity and efficiency. After seven years, their reliability was comparable with that of high efficiency particulate air filters in similar systems and are considered a suitable alternative to the latter.

Introduction

High efficiency particulate air (HEPA) filters having a minimum efficiency of 99.97% for particles 0.3 microns in diameter have been widely used to remove infectious aerosols from microbiological containment laboratories and animal rooms (Abraham, Le Blanc Smith, & Nguyen, 1996). The standards to which filters are manufactured and tested have been reviewed (First, 1996).

Ultra low penetration air (ULPA) filters (Liu, Rubow, & Pui, 1985; Avery, 1986) having a minimum collection efficiency of 99.997% for particles in the size range of 0.1 to 2 microns have been developed to provide higher efficiencies for removing particles from air for clean room technologies (Kapoor & Gupta, 2003; Schroth, 1996). ULPA filters have been used where dust-free environments are required for microelectronic, computer and pharmaceutical manufacturing industries. However, they