Hierarchy of Controls

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Introduction

OSHA [Occupational Safety and Health Administration] (1998) defined industrial hygiene as "the science of anticipating, recognizing, evaluating, and controlling workplace conditions that may cause workers' injury or illness" (p. 5). The principles of industrial hygiene apply to the safe handling of hazardous drugs. The primary method of decreasing employee exposure to hazardous drugs is by implementing engineering, work practice, and administrative controls.

Engineering controls reduce worker exposure at the source by eliminating the hazard or by isolating the worker from the hazard. Engineering controls include machines and equipment that are designed to either contain the hazard or provide appropriate ventilation. When engineering controls do not eliminate the risk, PPE [personal protective equipment] can provide protection. Specific work practices that change the way work is performed may effectively reduce worker exposure. Administrative controls reduce workers' exposure by scheduling risky tasks so that the fewest employees are exposed. This section will discuss how this hierarchy of controls applies to hazardous drug handling in the healthcare environment.

Engineering Controls

Biologic Safety Cabinets

A class II type B or class III vertical airflow BSC [biologic safety cabinet] is necessary to minimize exposure of personnel to cytotoxic agents during preparation and mixing of the agents. This type of laminar (vertical) airflow BSC provides protection for the product by filtering incoming air and protection for the healthcare worker by filtering the exhaust through a HEPA [high-efficiency particulate air] filter. These filters are not effective for volatile materials because they do not capture vapors and gases (National Institutes of Health [NIH], 1994).

There are four main types of BSCs. All type II models have an open front, a downward airflow mechanism, and a HEPA filter (OSHA, 1995).

- Type A cabinets recirculate approximately 70% of air through HEPA filters and direct it back into the cabinet. The remaining 30% is discharged through the HEPA filter and back into the preparation room. For this reason, it is not recommended to use this type of cabinet to prepare hazardous drugs.
- Type B1 cabinets have higher velocity air inflow, recirculate 30% of the cabinet air, and exhaust the rest to the outside through HEPA filters.
- Type B2 cabinets are the same as type B1 cabinets except no air is recirculated.
- Type B3 cabinets are similar to type A cabinets except instead of the remaining 30% of the air being recirculated back into the preparation area, it is vented to the outside.

Class III cabinets are totally enclosed with gas-tight construction. The entire cabinet is under negative pressure, and preparation of drugs is performed using attached gloves. All of the air is HEPA filtered.

The class II cabinets should remain in the "on" position so that the blower operates continuously to eliminate particles. If turned off, the BSC should first be cleaned and the front opening sealed with plastic and tape to prevent any contaminants from escaping. BSCs should be serviced and certified by a qualified technician at least every six months. In addition, a technician should check the BSC any time the cabinet is repaired or moved (ASHP [American Society of Health-System Pharmacists], 1990).

The BSC should be located in a room that is restricted to authorized personnel. No eating, drinking, smoking, chewing gum, application of cosmetics, or storage of food should occur in this area (OSHA, 1995). The door to the area should be kept closed and labeled with a sign stating these guidelines.

Closed-system devices: Several studies have shown that surface contamination with a hazardous drug occurs in areas where the agents are prepared, even when the drugs are mixed in a BSC (Connor et al., 1999; McDevitt et al., 1993; Sessink, Wittenhorst, Anzion, & Bos, 1997). Surface contamination with hazardous drugs is also prevalent in administration areas. Connor et al. (1999) sampled work surfaces in six cancer treatment centers in Canada and the United States to determine the presence of three commonly used agents: cyclophosphamide, ifosfamide, and fluorouracil. Measurable amounts of all three agents were found in 75% of the samples from the pharmacy mixing areas and in 65% of the samples from the administration areas.

Several studies have reported very little surface contamination with the use of a closed-system device (Connor et al., 1999; Sessink, Rolf, & Ryden, 1999; Vandenbrouke, 2001). The PhaSeal® system (Baxa

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Corporation, Englewood, CO) is the only documented closed system on the market. This system is designed to prevent leakage of drugs into the environment during preparation and administration. The system has several components, all of which use a double membrane with a diaphragm that prevents the release of drugs into the environment when proper technique is used. One piece fits onto a drug vial and prevents the release of aerosols when using a syringe to add a diluent or remove a drug. Another piece is a cartridge that attaches to a syringe with a protected needle. The tip of the needle is never exposed, thus preventing needle-stick injuries as well as leakage when adding a drug to infusion containers or directly injecting drugs. Another component allows spiking of IV tubing into a dry connector, thereby eliminating exposure that can occur when spiking a drug-containing IV solution container.

A recent study by Connor, Anderson, Sessink, and Spivey (2001) examined surface contamination levels of cyclophosphamide and ifosfamide when the PhaSeal system was used in addition to a BSC. Wipe samples were collected from 18 different sites within the pharmacy after a renovation, prior to beginning to mix drugs in the area. From that time on, all ifosfamide and cyclophosphamide was mixed using the closed system. As a control, fluorouracil was mixed not using the closed system. All drugs were prepared within a BSC. Samples were taken prior to using this system and at weeks 4, 8, 12, 16, 20, and 24. Levels of contamination were negligible for all three drugs tested. There was, however, one large spike of ifosfamide that the researchers could not account for, which may have been caused by poor technique on the part of one individual. The authors concluded that contamination inside a BSC is contained through the use of a closed-system device.

Personal protective equipment: The use of PPE is one of the best ways for healthcare workers to prevent occupational exposure to hazardous drugs. Since the widespread use of PPE, employee exposure to hazardous drugs has decreased. Studies have demonstrated that gloves provide protection against skin contact with tested hazardous drugs, and preventing skin exposure decreases symptoms in people with occupational contact with hazardous drugs (Nygren & Lundgren, 1997; Valanis, Vollmer, Labuhn, & Glass, 1993a, 1993b). ONS defined PPE as gloves, gowns, respirators, facemasks, face shields, or goggles (Brown et al., 2001).

Gloves: Gloves should be worn during all hazardous drug-handling activities. Glove thickness, type, and time worn are major determinants of their permeability by hazardous drugs. Powder-free gloves are preferred because powder may absorb contaminants, leading to aerosolization and increased risk of touch contamination. Longer gloves that cover the gown cuff are preferred because they protect the wrist area from exposure. Thicker gloves tend to be less permeable to hazardous drugs than thinner ones, although differences in permeability have been found even within the same lot of gloves (Connor, 1999). Thus, double-gloving is recommended for drug preparation activities (ASHP, 1990; Connor, 1999; OSHA, 1995). Both ASHP (1990) and OSHA (1995) recommended changing gloves every hour and whenever contamination occurs. Visual inspection of gloves to assess for pinhole leaks is a prudent practice, as variability of glove integrity within lots has been identified.

When double-gloving, the inner glove should be placed under the gown sleeve, and the outer glove should be placed over the gown cuff. This technique ensures that skin on the wrist area is not exposed and facilitates correct sequencing (i.e., outer glove, gown, inner glove) during removal of PPE (ASHP, 1990).

Traditionally, latex or surgical latex gloves were recommended for handling hazardous drugs because of their thickness and decreased permeability when compared with PVC and other glove materials (Welch & Silveira, 1997). Recent concerns about latex sensitivity have prompted testing of newer glove materials. In one study, thin-gauge 0.0045-inch nitrile gloves demonstrated efficacy in preventing penetration by 11 antineoplastic drugs (Gross & Groce, 1998).

Connor (1995) demonstrated that a single layer of surgical and chemotherapy gloves were impermeable to five antineoplastic agents. In the same study, one glove was permeable to fluorouracil, which the author attributed to a break in the integrity of the glove rather than permeation. Despite the evidence that a single glove and thinner gloves may prevent penetration of antineoplastic agents, it remains prudent to double glove when preparing hazardous drugs.

In 1999, Connor tested nitrile rubber, latex, polyurethane, and neoprene gloves for drug permeation after 30, 60, 90, and 120 minutes of exposure to 18 antineoplastic drugs. The results showed that one nitrile rubber glove was permeable to thiotepa at 30 minutes, but the other 11 gloves were not permeable to thiotepa. The authors speculate that there was a pinhole leak in the one glove. Permeability of less than or equal to 1% was found for carmustine at 90 minutes in one latex glove, for paclitaxel at 60 minutes in one polyurethane glove, and for paclitaxel at 120 minutes in one neoprene glove. The nitrile rubber gloves were the thinnest (0.12 mm), and the latex gloves were the thickest (0.18 mm). Thus, the four types of gloves were impermeable to the 18 antineoplastic agents in most cases (Connor, 1999).

Singleton and Connor (1999) tested 14 gloves (10 latex chemotherapy, 1 latex exam, and 3 nitrile) for permeability to three antineoplastic agents. Only two of the gloves, both latex chemotherapy gloves, were impermeable to all three drugs. All 14 gloves were impermeable to BCNU (carmustine), whereas only two of the gloves were impermeable to etoposide. Clinicians need to review all current literature when evaluating which glove types to utilize in their clinical settings.

Connor and Xiang (2000) studied the effect of isopropyl alcohol on the permeation of gloves exposed to antineoplastic agents. They found that the use of isopropyl alcohol for cleaning and decontaminating does not have a significant impact on the integrity of either latex or nitrile gloves during the limited study period of 30 minutes. This is an important finding, as alcohol is used routinely in the BSC during hazardous drug preparation.

Summary of gloves recommended for use in hazardous drug handling:

- Use good-quality gloves made of latex, nitrile, polyurethane, neoprene, or other materials that have been tested with hazardous drugs.
- Select powder-free gloves.
- Inspect gloves for visible defects.
- Wear double gloves for drug preparation.
- Change gloves every hour or immediately if damaged or contaminated.

Gowns: Gowns that provide adequate protection from hazardous drugs are disposable, made of a lint-free, low-permeability fabric. They should have a solid front (back closure) and knit or elastic cuffs (ASHP, 1990; OSHA, 1995). Laboratory coats and other cloth fabrics absorb fluids, so they provide an inadequate barrier to hazardous drugs and are not recommended. The existing guidelines do not contain a recommendation for the maximum length of time that a gown should be worn. Because no recommendations are stated in the literature, at a minimum, change the gown every time it is contaminated or gloves are changed.

In a study of gowns, Harrison and Kloos (1999) evaluated the permeability of six commercially available protective gowns by splash testing them with 15 antineoplastic agents. Gowns with polyethylene or vinyl

coatings provided adequate splash protection and prevented penetration of the antineoplastic agents. Unfortunately, they made the researchers feel warmer and were less breathable than the more permeable gowns. Two gowns made of polypropylene were permeable in less than one minute, leading the researchers to recommend that they not be used in hazardous drug handling.

Gowns always should be worn during chemotherapy preparation and when administering IV chemotherapy (ASHP, 1990; OSHA, 1995). Gowns also should be used during the administration of hazardous drugs by any other route, especially if splashing is possible (OSHA, 1995). This represents a change in practice for many nurses but is necessary to provide adequate protection against exposure to hazardous drugs.

Gowns worn while preparing hazardous drugs should be removed before leaving the immediate BSC area, before the inner gloves are removed (ASHP, 1990). Gowns worn while administering hazardous drugs should be changed when leaving the patient care area or immediately if contaminated. The practice of hanging up a gown between uses may lead to surface contamination and should be discontinued. Gowns are intended to be single use and should not be worn more than once.

Eye and facial protection: A plastic face shield should be worn in situations where eye, mouth, or nasal splashing or aerosolization is possible (such as during a bladder instillation of hazardous drugs). Goggles protect the eyes, but not the face, against spraying. Surgical masks do not provide respiratory protection and should not be relied upon for protection against aerosolized powders or liquids, such as during drug preparation. For drug preparation, the BSC provides eye and face protection (ASHP, 1990; OSHA, 1995). For drug administration, working below eye level greatly reduces the likelihood of eye and facial splashing.

Areas where hazardous drugs are handled should have a sink with an eye wash station. Two functionally equivalent and cost-effective alternatives to an eye wash station are an IV bag of 0.9% sodium chloride solution (normal saline) connected to IV tubing or an irrigation bag of water or normal saline with attached tubing (ASHP, 1990).

Work Practice Controls

Another way to reduce occupational exposure to hazardous drugs is to utilize appropriate work practices. A critical examination of the existing work practices is necessary to identify potentials for exposure. Certain work practices can result in surface contamination with hazardous drugs, such as

- Exiting and reentering the BSC to obtain additional equipment without changing gloves
- Failing to wipe hazardous drug containers with a damp cloth to remove drug residue
- Inadequate cleaning of spills on equipment, such as infusion pumps
- Priming IV tubing with a hazardous drug instead of saline or priming tubing outside the BSC
- Inadequate hand washing after hazardous drug-handling activities
- Contaminating hands and other areas while removing PPE.

There are many possible causes of touch contamination. Direct observation of nurses', pharmacists', and others' techniques of preparation, handling, and administration may yield information about potential sources of contamination. Unless actual sources of surface contamination are identified, they cannot be eliminated.

The following work practices are likely to result in decreased touch contamination.

- Prepare all hazardous drugs in one pharmacy or centralized drug preparation area.
- Designate one staff member who will work in the BSC preparing hazardous drugs for the day to reduce the number of individuals entering and exiting the BSC. Pharmacy technicians often implement this practice, but nurses who prepare hazardous drugs may not.
- Gather all necessary supplies before placing hands in the BSC.
- Change gloves every hour and whenever contamination occurs.
- Wash hands after removing gloves for any reason and prior to donning new gloves.
- Place waste generated in the BSC (e.g., outer gloves, vials, gauze) in a sealed plastic bag before removing it from the BSC.
- Discard the sealed bag containing used equipment in a puncture-proof hazardous drug waste receptacle placed immediately outside the BSC.
- Avoid reaching into sealed bags used to transport drugs without PPE. Visually examine the contents of the sealed bag. If visible leakage is present, do not open the outer bag. To reduce the risk of touch contamination, dose verification can occur at the administration site. For example, one RN wearing PPE can remove the drug container from the bag while another nurse who need not wear PPE holds the order. This allows a double-check but minimizes the risk of touch contamination. An alternative is to use clear sealable bags for transport so that the doses can be verified without removing the drug containers from the bag. This practice might not be possible if ultraviolet light-blocking bags are used.
- Use locking connections on all IV delivery devices.
- Use and dispose of sharps carefully.
- Avoid spiking IV bags or bottles that contain hazardous drugs. Attach and prime all tubing in the pharmacy with nondrug solution before adding hazardous drugs.
- Avoid "unspiking" IV bags or bottles. Discontinue and discard infusion bags and bottles with tubing intact.
- Place hazardous drug disposal containers near the workspace.
- Keep the lid closed on hazardous drug disposal containers except for when placing contaminated materials into the containers.
- Clean BSC and countertops in mixing area with a two-step cleaning method, such as Surface Safe® (SuperGen, Dublin, CA) daily, once all other contaminated materials are removed from the area.

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