



Health Devices

Inspection and Preventive Maintenance System™

IPM Guidance Section 7 IPM Safety

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IPM Safety

Safety in the workplace is the responsibility of both the employer and the employee: each employer is obligated to provide a safe working environment, and each employee should strive to work in as safe a manner as possible. Inspecting medical devices involves some risks; to protect test personnel, staff, and patients, observe the special precautions noted in many of the procedures. When performing hazardous inspections, post signs to warn visitors and staff. Do not leave hazardous test setups unattended. Follow manufacturer or other appropriate guidelines concerning lasers, ionizing radiation, and chemical hazards. And use common sense.

Electrical and mechanical devices

Inspecting medical devices for electrical safety involves proximity to voltages and currents that can cause injury to test personnel, staff, and patients. Deliberately simulating faults increases the need for caution.

Test a device's electrical safety before testing its performance. First, confirm the continuity between the chassis and the ground pin of the line cord plug before applying power. This continuity normally provides primary protection against shock to equipment users, patients, and test personnel. Also, leakage current measurements made through the power cord ground (as some electrical safety analyzers measure) will be erroneous unless there is continuity.

Do not test equipment that is in use on a patient. Electrical safety tests intentionally simulate faults that may be hazardous. Not only will the patient be exposed to unnecessary risks, but test results may also be misleading. Arrange with appropriate clinical personnel to disconnect the device from the patient, or have them advise clinical engineering when the device is no longer in use.

Do not test electrical power distribution systems on which patient equipment is operating. Some receptacle ground integrity tests may inject several amperes into the ground line and can cause hazardously high current to flow through a patient who is connected to a device on the branch under test, especially if the grounding is defective. You can safely test receptacle wiring (e.g., with a three-lamp polarity tester) and measure line voltage and low-current ground resistance on branch circuits or receptacles in use. (See Electrical Receptacles Procedure 437 for further details.)

Tests of isolated power systems temporarily lower the protective barrier normally associated with isolated power. If the receptacle has a ground-fault circuit interrupter (GFCI), power to all devices on the line could be shut off. This emphasizes the need to ensure that critical or life-support equipment is never powered from a GFCI-protected circuit.

Confirm that the outlet used to power the safety analyzer is correctly wired. Grounding the analyzer case through the receptacle ground prevents a shock hazard while testing a defective piece of equipment. A GFCI trip point measurement often uses the analyzer ground for a return path of the test current; if the analyzer is connected to an ungrounded receptacle, there may be line voltage (115/230 VAC) on the analyzer case. Do not touch the case of the equipment being tested, especially when measuring ungrounded leakage current.

To avoid damaging the device being tested or interrupting a fuse or circuit in the device or branch circuit panel, turn off devices with motors and compressors and wait until they completely stop before reversing hot-neutral polarity; turn off and wait 10 seconds for microprocessor-controlled devices, including computer and clinical laboratory analyzers. Also, turn off power to the device being tested if it is necessary to insert or remove modules.

Lead isolation testing involves line voltage use. We recommend performing the test only with equipment properly designed to allow safe application of the voltage to the patient leads. If an electrical safety analyzer is not available, devise or buy an adapter that limits the current flow to 1 mA or less to ground from any exposed terminals of the test setup. Do not touch patient leads during lead isolation testing, and avoid using exposed clips or improvised test setups that make it easy to accidentally contact the input circuit. Touching the leads may cause a shock even with a current-limiting resistor in the test circuit.

Testing pneumatic and mechanical devices can result in injuries such as crushed fingers, lacerations, and punctures and in hazards such as flying projectiles. When inspecting devices with cams, gears, levers, sliding components, or other moving parts (e.g., blood pumps, electric beds, x-ray film processors), keep fingers and clothing away from moving parts. Perform parts inspection, cleaning, and lubrication with power disconnected. Do not get underneath electric beds, patient lifts, radiology systems, or similar devices while they are connected to a power source or loaded.

Lockout/tagout requirements

Lockout and tagout procedures are protective measures that usually include the use of security devices such as padlocks applied to manual circuit breakers and cutout switches or tags prominently placed on such devices to warn of work in progress. Locks are placed so that electrical service to a device will not be activated inadvertently by someone who is unaware of the work in progress.

Occupational Safety and Health Administration (OSHA) regulations codify requirements for lockout and tagout procedures to reduce the risk of injury from energized sources during maintenance and servicing (29 CFR 1910.147). The regulations protect against electrical mishaps as well as injury from other energy sources, such as mechanical (both stored, as in compressed springs, and kinetic), pneumatic, hydraulic, thermal, and chemical sources. Thus, a lockout can—and should—be applied to a pressurized steam valve and an electrical switch box, as well.

Lockout is accomplished when all of the technicians (maintenance personnel) servicing a piece of equipment ensure that all power sources to the device are turned off and apply a lock (usually a keyed or combination padlock) to the switch(es) before beginning work. This ensures that the unit can be energized only when the last technician has completed work and has removed the lock. When a switch provides for only one lock, a key box is provided into which the single key for the lock can be placed; the box, in turn, has multiple lock holes so that each technician can place a lock on the key box.

Tagout is a comparable, though less secure, procedure. Under OSHA regulations, it may be used where providing lockout is not feasible and where adequate procedures that provide the necessary protection are in place and properly understood. A durable and prominent tag, with appropriate information clearly displayed on it, is placed on the disconnecting means at the time the unit is deenergized. The tag warns others not to turn the power on and is removed only by the technician after work is completed. The tag is usually accompanied by some means (e.g., a sturdy nylon wire tie) that impedes operation of the disconnecting device.

Clinical engineering personnel commonly work with line cord and plug-connected devices. Servicing these devices, whether they are portable or mobile or operate in fixed locations, is exempted from lockout/tagout requirements *provided that the line cord and plug are under the exclusive control of the person doing the servicing*. In these cases, lockout is accomplished simply by unplugging the device.

Clinical engineers (CEs) and biomedical equipment technicians (BMETs) should practice lockout or tagout of hard-wired devices such as radiology equipment, CT and MRI scanners, and film processors. Lockout/tagout also applies to major installed appliances and systems (e.g., steam and ethylene oxide sterilizers, cart washers, blanket and solution warmers, hyperbaric chambers). Likewise, plant engineering personnel should use these procedures on air handlers, trash compactors, incinerators, boilers, pumps, and elevator equipment. CEs and BMETs should respect and pay attention to these procedures as they are encountered. Where isolation devices for such equipment lack lockout provisions, tagout procedures must be used. New installation or major replacement, repair, renovation, or modification of equipment must include energy-isolating devices with lockout provision.

Employers must develop documented energy-source control procedures appropriate for the equipment in their facility and ensure that employees are trained in those procedures. Employers must also conduct inspections at least annually to ensure that these procedures are carried out and that requirements of the standard are being met.

Below is a checklist of typical procedures that should be performed diligently within an institution to reduce the risk of injury and ensure conformity with OSHA's requirements:

- Identify all energy-isolating devices that must be locked or tagged out.
- Carry out lockout/tagout procedure:
 - Notify affected personnel.
 - Shut off equipment by normal means.
 - Operate isolators (e.g., switches, valves, disconnects); relieve or protect against stored energy (see below).
 - Lock out or tag out device.
 - Operate normal controls to be certain that equipment will not operate.
 - Be sure that controls are returned to off/neutral position.
- Perform service or maintenance.
- After completion of service or maintenance:
 - Replace guards, remove tools.
 - Check area to be sure that no personnel are exposed.
 - Be sure that controls are returned to off/neutral position.
 - Remove lockout/tagout and related protective devices.
 - Operate isolating devices to restore energy to equipment.

The OSHA requirements also stress the need to protect against exposure to stored energy, which can be released suddenly and unexpectedly. Some of the activities that must be considered include blocking spring-loaded components that might accidentally be tripped, chocking mobile devices, immobilizing counterweights so they cannot fall, and discharging pressurized chambers or charged capacitors. While steps taken to provide such protection would not strictly be viewed as locking or tagging out, they are, nevertheless, important to implement.

The OSHA standard generally requires employers to document specific procedures for the equipment on the property. However, one exception relieves the need to document lockout/tagout procedures for specific machines or equipment when a series of eight specific conditions are met. The essence of these conditions can be summarized as follows: The device is supplied from a single power source that can be totally isolated by a single lockout device and has no potential for releasing any form of stored energy after shutdown; the employee authorized to service the device has exclusive control over the lockout device, and the maintenance poses no risk to other employees; and the employer has had no accidents with this device that resulted from unexpected activation or reenergization during maintenance or servicing.

The standard does not describe responsibility for or obligations to outside service personnel. It seems reasonable, however, to assume that hospitals are responsible for installing lockout capabilities on their equipment and for providing lockout/tagout devices to outside repairpersons, whereas training is the responsibility of the companies employing these service personnel.

Even with lockout and tagout procedures implemented, CEs, BMETs, or other engineering/maintenance personnel may find an open disconnect or other energy-control device that is not locked or tagged out. Under no circumstances should anyone close an open switch or other energy isolator (with or without lockout or tagout devices) without being absolutely certain that it is safe and appropriate to do so.

Compressed gases

Compressed gas cylinders must be handled carefully to avoid being contaminated or knocked about. High pressures can turn loose connectors into projectiles. Gas-driven particles can cause ignition of downstream components. The Compressed Gas Association's (CGA)* *Characteristics and Safe Handling of Medical Gases* provides recommended practices for handling medical gases, including many of the following:

- Never permit oil (e.g., from oily hands or gloves), grease, or other combustible substances to come in contact with cylinders, valves, regulators, gauges, hoses, or fittings. Oil and certain gases (e.g., oxygen, nitrous oxide) may combine with explosive violence.
- Use commercial leak-detector solutions or a mild soapy water solution to detect gas leaks. Use only oxygen-compatible leak-detector solutions on oxygen and nitrous oxide systems.
- Do not deface or remove any markings (e.g., labels, decals, tags, stenciled marks) used to identify the contents of a cylinder.
- Never attempt to repair or alter cylinders, stem valves, or indexing pins. Replace any damaged cylinder with a new one, and return the damaged cylinder to the supplier.
- Never drop cylinders or permit them to strike each other violently. Ensure that all cylinders are securely mounted or chained so that they cannot roll or fall during use or while in storage.
- Never drag, roll, or slide cylinders. Never use a cylinder valve as a handle to move a cylinder. Move larger cylinders, even for short distances, with a suitable truck, making sure that the cylinder-retaining chain or strap is fastened in place.
- Do not use regulators, pressure gauges, or manifolds intended for use with a particular gas or group of gases with cylinders containing other gases.

* Compressed Gas Association, Suite 1004, 1725 Jefferson Davis Hwy, Arlington, VA 22202; (703) 412-0900.

- Never interconnect medical gases without appropriate check valves. They may become contaminated by the feedback of other gases or foreign material.
- Always use pressure-reducing regulators when withdrawing the contents of gas cylinders, because regulators deliver a constant, safe working pressure. Do not use needle valves or similar devices without pressure-regulating mechanisms in place; excessive pressures may develop downstream of such devices and may result in injury or damage to equipment.
- Ensure that the threads on regulator-to-cylinder valve connections or the pin indexing devices on yoke-to-cylinder valve connections are properly mated. Never force connections that do not fit.
- After removing the protective valve cap, and with the opening pointed away from all personnel, slightly and briefly open the valve to clear the outlet of any dust and dirt. Do not do this with cylinders containing flammable or toxic gas.
- When opening a valve, point the outlet away from all personnel. Never use wrenches or tools except those provided or approved by the gas supplier; incompatible tools may damage the valve. Use only nonferrous (e.g., brass, aluminum) tools in the presence of flammable or combustion-supporting gases to prevent sparks. Never hammer the valve wheel when attempting to open or close the valve.
- Open the cylinder valve slowly, and keep it fully open when the cylinder is in use.
- Use secure fittings to prevent a tube or connector from suddenly disconnecting and whipping about or becoming a projectile. Do not use friction fittings (e.g., hose barbs, Luer slip) for 50 psi and higher circuits—use threaded or positive-locking devices.
- Before disconnecting regulating devices from cylinders, close the cylinder valve and release all pressure from the regulator. Cylinder valves should be closed at all times except when the gas is actually being used.

Lasers

Inspecting and maintaining lasers is a dangerous but necessary process that demands far greater care than is required with most devices. U.S. Food and Drug Administration (FDA) medical-laser incident reports reveal that many of the accidents that occur during laser maintenance can be attributed to a failure to follow basic laser safety precautions. Personnel who inspect or service lasers should receive special training from the manufacturer or from a qualified alternative training source.

Laser energy can cause serious injury. This hazard is especially great when an interlock is overridden or in any other situation where the energy does not diverge significantly over long distances. Under some circumstances, the beam may not diverge significantly even a full room length or more from the laser (an unfocused laser beam from a mirrored articulating arm or from an exit port can harm tissue or burn material across a room). Therefore, exercise great care whenever an unfocused laser beam is accessible.

Area security and use of personnel protective devices and practices should be consistent with hospitalwide laser safety procedures and/or approved by the laser safety committee. Windows should be covered with absorbing or laser-opaque material to prevent transmission of laser energy into other areas. (Window covers are not necessary with carbon dioxide lasers.) Wear appropriate laser safety eyewear at all times whenever the laser is in the operating mode. **WARNING:** Verify that laser safety eyewear is appropriate for the specific wavelength of laser being used (e.g., YAG lasers are becoming available in different wavelengths; glasses appropriate for a Ho:YAG 2,100 nm wavelength are not appropriate for Er:YAG lasers at 2,940 nm). The American National Standards Institute (ANSI) standard Z136.1-1993, *Safe Use of Lasers*, calls for protective eyewear to be labeled with the wavelength for which protection is afforded. Laser safety eyewear may not

protect the wearer from the aiming system light. Do not stare directly into the aiming system beam or the therapeutic laser, even when wearing laser safety eyewear. Eyewear should be inspected periodically for physical condition and light leaks (see Section 4.6.2.7 of the ANSI standard). Avoid placing the laser beam path at eye level (sitting or standing).

Do not perform inspection and preventive maintenance (IPM) procedures when a patient is present or clinical staff is working. Do not aim the laser across a path that a person might normally use as a thoroughfare. Post doors to the room with an appropriate laser safety sign that identifies that the laser is in use and that it is unsafe to enter the room without authorization by the service person performing the procedure. A second person should be present, especially during procedures of recognized risk, to summon help in case of an accident.

The laser should remain in the off position when not in use. When in use, the laser should be in the standby/disabled mode. Do not switch it to the operating mode until the procedure is about to begin and the laser and its delivery system are properly positioned. If the procedure must be interrupted, disconnect the laser from line voltage; remove the laser operating key, and store it in a controlled location.

Do not use the laser in the presence of flammable anesthetics or other volatile substances or materials (e.g., alcohol, acetone) because of the serious risk of explosion and fire. Remove from the working area or cover with flame-resistant opaque material all reflective surfaces likely to be irradiated by the laser beam. Whenever possible, use a firebrick or other nonflammable material (e.g., black Delrin) behind the target material when the laser is to be activated. A carbon dioxide fire extinguisher should be readily available in the room in which the laser is used.

Some surgical lasers use high voltages (e.g., 20 kV), which can be lethal. Capacitors may store charges long after the device has been disconnected from line voltage. Consult the manufacturer's recommended procedures for servicing high-voltage laser circuits, and avoid contact with any portion of the high-voltage circuit until the charge has been drained. When possible, disconnect the laser from line voltage before entering the laser cabinet, and use insulated gloves for those procedures in which contact with a high-voltage source is possible (and the gloves are not otherwise contraindicated). Ensure that equipment intended to be used to measure, drain, or insulate high voltages carries the appropriate insulation rating (e.g., above 20 kV).

Report any laser accident immediately to the laser safety officer (or equivalent) and to the hospital risk manager.

For a comprehensive discussion of laser safety, see ANSI Z136.1-1993, *Safe Use of Lasers*, and Z136.3-1996, *Safe Use of Lasers in Health Care Facilities*. See also:

Canadian Standards Organization (CSA). Laser safety in health care facilities [standard]. CAN/CSA-Z386-92. 1992.

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Radiology equipment

Personnel working on equipment that emits ionizing radiation (e.g., x-rays) must be knowledgeable in radiation safety procedures. For personnel not already familiar with the safety and maintenance of this equipment, radiation safety should be included as a formal part of their training. Even if maintenance personnel spend far less time with radiology equipment than users (technologists and physicians), they should be aware of occupational radiation exposure issues and take practical steps to minimize exposure. In addition to radiation exposure issues faced by typical users, maintenance personnel should also take precautions against special risks such as the following:

- Excessive or unnecessary radiation exposure from unintentional activation or activation with normal protective components of the device removed or disabled.
- Risk of exposure to high voltages made accessible during maintenance procedures; contact with these voltages can lead to serious injury or death.
- Thermal risks from contact with a hot tube or tube housing or with the hot oil that insulates the x-ray tube. (Contact with oil might occur if the tube is damaged from overheating.) For personnel safety, and to avoid damaging the tube, do not exceed the tube rating for housing or anode heat capacities.
- Mechanical risks (e.g., crushing) caused by component movement associated with inadvertent activation (or brake mechanism release) and by disconnection of compensating weights, brakes, or other restraining components. Also, precautions must be taken against movement of the compensating weights when removing the corresponding components, such as the x-ray tube or image intensifier.
- Chemical risks from fixer and developer solutions in film processors and, on old x-ray generators, the polychlorinated biphenyl (PCB) insulating fluid used in transformers.

Personnel exposure limits

To ensure safety, personnel exposure to radiation should be kept as low as reasonably possible. Personnel exposure to radiation is commonly specified in dose-equivalent units. Current federal regulations limit whole-body occupational exposure to 5 rem (50 mSv) per year (29 CFR 1996). The cumulative lifetime occupational limit specified by current federal regulations is $5 \times (N-18)$ rem, or $50 \times (N-18)$ mSv, where N is the age of the worker.

Continuing improvement of our understanding of the effects of low levels of radiation is likely to lead to lower limits. In 1990, the National Academy of Sciences (NAS) published its BEIR V report, in which it suggested that harmful effects of low-level radiation may be higher—by a factor of two to three—than previously thought. The limits recommended by the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP), which typically are the basis for federal limits, have already been lowered. NCRP now recommends a lifetime limit of $(1 \times \text{age})$ rem, or $(10 \times \text{age})$ mSv, which represents a significant reduction from the previously recommended limit; for example, at age 55, this represents a reduction in the allowed lifetime limit from 185 rem (1,850 mSv) to 55 rem (550 mSv). The annual limit recommended by NCRP remains the same. ICRP has effectively lowered its annual limit to 2 rem (20 mSv) per year; however, a provision in its recommendation states that 2 rem per year is the average during five years, with the annual maximum limit of 5 rem (50 mSv) for any given year (service technicians should not come anywhere near this level of radiation).

Radiation measurement units

RADIATION EXPOSURE—A measurement of the ionization created in air by radiation, measured with an ionization chamber. The traditional measurement unit is the roentgen (R); the standard international (SI) unit is coulombs per kilogram (C/kg) ($1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg}$). (Also see ABSORBED DOSE.)

ABSORBED DOSE—A measurement of the amount of energy deposited in a medium. The traditional measurement unit is the rad; the SI unit is the gray (Gy) ($1 \text{ rad} = 10 \text{ mGy}$). (RADIATION EXPOSURE can also be specified in Gy; when using this unit, it is implicit that the medium in which the energy is deposited is air.) For x-ray photons, a radiation exposure of 1 R is about equivalent to an absorbed dose of 1 rad.

DOSE EQUIVALENT—A measurement of the ABSORBED DOSE that produces the same biological effect regardless of the type of ionizing radiation (e.g., alpha particles, beta particles, x-ray or gamma-ray photons); commonly used in protection literature. The traditional measurement unit is the rem or mrem (thousandths of a rem); the SI unit is the sievert (Sv) ($1 \text{ rem} = 10 \text{ mSv}$). The dose equivalent is obtained by multiplying the absorbed dose by the quality factor (Q), which varies according to the type of radiation:

$$\text{Dose equivalent} = \text{Absorbed dose} \times Q$$

For x-rays, $Q = 1$; therefore, $1 \text{ rem} = 1 \text{ rad}$ (approximately equal to 1 R).

Precautions during IPM

- When possible, avoid x-ray exposure by standing behind a permanent shield. Otherwise, wear a lead apron and thyroid shield at all times during x-ray exposure, or use overhead or mobile lead shields.
- Maintain the greatest possible reasonable distance from the x-ray source and all scattering material.
- Do not place hands or fingers in the x-ray beam. If unavoidable, wear lead gloves.
- Keep x-ray exposure time to a minimum.
- For tests that require the use of cine or serial film changer acquisitions, staff should leave the room, if possible, when these images are being acquired because much higher exposure rates are used for these images than in conventional fluoroscopy.
- Radiation badges should be worn by all personnel and should be processed monthly. A radiation safety officer should review all badge readings and take immediate remedial actions if exposures exceed expected limits.
- Take precautions against radiation exposure, high voltage, thermal, mechanical, infection, and chemical risks associated with inadvertent activation, device disassembly and removal, or disabling of protective features.
- It is critical that personnel performing IPM or servicing of radiology devices receive initial and periodic training to raise their awareness of radiation safety and to help them use optimum protection practices.

References

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National Academy of Sciences (NAS). *Health effects of exposure to low levels of ionizing radiation (BEIR V)*. Washington (DC): National Academy of Sciences Press; 1990.

National Council on Radiation Protection and Measurements (NCRP). *Ionizing radiation exposure of the population of the United States*. Bethesda (MD): NCRP; 1987. NCRP Report 93.

Infection control

Clinical engineering personnel face a risk of infection during medical equipment maintenance and should take appropriate infection control measures. Disease can be transmitted by several modes; for clinical engineering personnel, contact transmission and, to a lesser extent, airborne transmission are the most likely modes. Contact transmission can occur through direct contact with an infected patient, droplet contact (e.g., from a cough or sneeze), or indirect contact (i.e., from handling equipment that is contaminated by infectious material from a patient). Airborne transmission can occur through inhaling disease-causing microorganisms on dust particles or infectious residue on evaporated droplets (droplet nuclei); the airborne transmission of tuberculosis (TB) by this process is a particular risk in healthcare facilities. To protect against unnecessary exposure to infectious diseases, clinical engineers should be familiar with basic infection control practices, as well as disinfection, sterilization, and decontamination procedures that may be necessary before servicing medical devices.

Basic infection control practices

Good personal hygiene and common sense are instrumental to developing an effective infection control program. Infection control practitioners should provide clinical engineering personnel with training that includes review of general principles of TB and bloodborne pathogen transmission and prevention, as well as voluntary hepatitis B virus (HBV) immunization and postexposure follow-up procedures. Below are some basic infection control practices that are appropriate for clinical engineering personnel:

Wash hands routinely—when hands are obviously soiled, after handling soiled equipment, after removing protective gloves, before eating, and before leaving the hospital.

Do not eat, drink, chew gum, smoke, or apply cosmetics in work areas.

Wear a lab coat or other appropriate outer garment to prevent contaminating street clothing. Do not take lab coats home. Have them washed frequently in the hospital laundry.

Wear gloves when in contact with equipment that may have come in contact with blood, body fluids, or other infectious materials (e.g., surgical instruments, transducers, sensors, breathing circuits). **CAUTION:** Wearing gloves does not protect against cuts and puncture wounds; exercise care when handling contaminated medical equipment. (Also see “Latex Examination and Surgical Gloves” and “Synthetic Surgical Gloves” in *Health Devices* 1989 Oct;18:358-60 and 2000 Feb-Mar;29:37-66, respectively.)

Do not touch clean items (e.g., doorknobs, telephones, test equipment, computer terminals, keyboards) with soiled gloved hands.

Wear face shields or masks and protective eyewear during cleaning and decontamination procedures that are likely to aerosolize or splash droplets of blood or body fluid onto mucous membranes.

Wear gowns or protective aprons during cleaning and decontamination procedures that are likely to aerosolize or splash droplets of patient material onto clothing.

Where there is a special concern about exposure to aerosolized infectious agents, especially TB, take appropriate respiratory precautions, including wearing a respirator approved by the National Institute for Occupational Safety and Health (NIOSH). However, first obtain training on the use and fit-testing of the respirator. Follow your hospital's TB control plan. (See Handling and disposing of TB-contaminated HEPA filters, below.)

Do not rub eyes or other mucous membranes.

Inspect or repair devices that normally require cleaning, disinfecting, or sterilizing only after such procedures are completed. Clean, disinfect, or sterilize these devices again before returning them to patient care areas.

Use standard hospital procedures when entering, leaving, and working in areas that pose special infection control problems (e.g., surgical suites, dialysis units, nurseries, neonatal ICUs, burn units, isolation rooms, critical care areas). Patients in these areas may be unusually susceptible to infection, and the inspector may be at considerable risk.

Follow the hospital's TB control plan when entering, working in, and leaving areas where confirmed or suspected infectious TB patients are present (e.g., a negative-pressure TB isolation room).

Even if the patient is not in the area, continue to follow appropriate procedures when entering an isolation room or area where a TB patient was present until the area has received final cleaning and adequate time has passed. Check your hospital's policy for the appropriate time to wait; the Centers for Disease Control and Prevention (CDC; in: CDC final guidelines for preventing the transmission of *Mycobacterium Tuberculosis* in health-care facilities, 1994. *Fed Regist* 1994 Oct 28;59[208]:54242-303.) implies that cleaning personnel require personal protective equipment for at least 69 minutes after the patient has left if the room has an air exchange rate of six air changes per hour (ACH) and 99.9% removal efficiency is to be achieved. (This time can be increased as much as 10-fold to take into account nonideal mixing. Also, the time will depend on the air exchange rate [6 ACH is the minimum recommended rate for an isolation room] and the desired percent removal efficiency.)

Any device that is visibly soiled with patient material—even if dried—or that has been in contact with patient fluids or tissues should be treated in accordance with the facility's bloodborne pathogens exposure plan. However, even if a device appears to be clean, do not handle it in an unhygienic manner. Consideration and awareness of infection control issues may be particularly appropriate for the following devices (even when they appear to be clean):

- Dialysis equipment. In addition to a routinely high risk of equipment contamination by bloodborne pathogens, some dialysis units may be dedicated to patients with HBV or HIV; consider maintaining separate, dedicated tool sets for servicing dialysis equipment and for units dedicated to patients with HBV or HIV.
- All devices or items in the OR and ER, especially footswitches of devices used during surgery (e.g., electrosurgical units).
- Any handheld items or other items that can be found in beds (e.g., nurse call buttons, remote controls for television sets, pillow speakers, blood-pressure cuffs, telemetry transmitters).
- Clinical laboratory equipment, including centrifuges, in which blood splashes and fragments of glass from broken blood collection tubes may be present; vacuuming the interior may be necessary.
- Breathing circuits.
- Blood warmers.
- In general, devices from any area where body fluids are spilled, splashed, or routinely handled, as well as devices that are in contact with or contain patient material. While device contact is usually limited to or contained within a disposable set, fluid squirts, leaks, and spills or handling by personnel whose hands are contaminated often results in device contamination (e.g., in dialysis equipment, blood warmers, autotransfusion units).

Handling and disposing of TB-contaminated HEPA filters

Manufacturers' instructions for inspecting, cleaning, and maintaining high-efficiency particulate-air (HEPA) filters and respirators should be followed to ensure proper function. HEPA filter maintenance should be performed only by adequately trained personnel. Appropriate respiratory protection and gloves must be worn while performing maintenance or testing procedures or while removing or disposing of the filter. In addition, filter housing and ducts leading to the housing must be labeled clearly (e.g., "contaminated air" or a similar warning).

To date, CDC has not issued any recommendations or guidance regarding the infectious nature of HEPA filters. Because HEPA filters may contain infectious organisms (the survival characteristics and re-aerosolization properties of TB from HEPA filter media are unknown), ECRI recommends that healthcare facilities dispose of these filters in accordance with their state laws for the disposal of infectious or regulated medical wastes. Manufacturers of HEPA air filtration units sometimes provide recommended handling and disposal techniques in the service or operating manuals that include disinfecting with glutaraldehyde, with formaldehyde gas, or by spraying a phenolic disinfectant such as Amphyl, Lysol, or undiluted bleach into the filter. Disinfected filters can be disposed of as ordinary waste. Follow these recommendations (but first resolve any conflicts with ECRI's recommendations or other procedures that have been set up at the facility by infection control or biosafety engineering).

Because the viability of TB on HEPA filters is presently unknown, transportation of a contaminated HEPA filter appears to be regulated by the U.S. Department of Transportation (DOT) as a Class 6 hazard (e.g., poisonous or infectious materials) (49 CFR 173.2). This is because the DOT regulations apply to CDC's list of "certain etiologic agents," which specifically includes all species of *Mycobacterium* (42 CFR 72.3). This means that it is subject to certain packaging and label requirements. Consult with your legal counsel, risk manager, or biohazardous material shipping expert.

Decontamination

Decontamination, the process of reducing microorganisms to a level considered safe to handle, can be accomplished by thorough cleaning followed by an appropriate disinfection or sterilization procedure.

Disinfection is the process of killing virtually all recognized pathogenic organisms, but not necessarily all forms of microbial life, on inanimate objects (Rutala 1995). Disinfectants are classified in three levels (high, intermediate, or low) depending on their lethality. The effectiveness of a disinfectant depends on several factors, including the nature and number of contaminating microorganisms (especially the presence of spores), concentration of the disinfectant, the length of the application period, the amount of organic soil present, the type and condition of the material to be disinfected, and the temperature. Thus, the effectiveness of disinfectants can range from sterility to minimal reduction of microorganisms.

Sterilization is the process of eliminating all microorganisms, including vegetative bacteria, viruses, fungi, and bacterial spores (dormant forms of microorganisms that are more resistant to heat and chemicals than their nondormant forms). In healthcare settings, sterilization is generally accomplished by using physical

agents (e.g., steam autoclaving) or chemical agents (e.g., ethylene oxide gas, gas plasma). These procedures require specialized equipment and should be performed only by personnel trained in sterile processing.

To assess the need for decontamination, medical devices can be classified in three categories:

Devices visibly contaminated (e.g., with blood, feces, or urine).

Devices used for perfusion, hemodialysis units, autotransfusion devices, aspiration probes of clinical laboratory instruments, and any other device that routinely comes into contact with blood. Treat these devices as though they are contaminated even if no visible contamination is evident.

Devices not visibly contaminated and not very likely to be contaminated (e.g., infusion pumps, bedside monitors). Although these devices may not require decontamination, handle them and all clinical equipment with care and an awareness of infection control issues.

Manufacturers are responsible for outlining decontamination procedures in the instruction manuals for their devices. If decontamination procedures are not included in the manual, contact the manufacturer for explicit instructions. Before purchasing equipment, insist that manufacturers supply appropriate decontamination procedures, and have the infection control practitioner review them. If a manufacturer does not include decontamination procedures in its manual, or if its instructions for proper decontamination for a particular device are not clear, file a problem report with ECRI, and consult with the hospital's infection control practitioner to develop a decontamination protocol. Consider these guidelines for decontamination procedures.

Central supply personnel should routinely perform decontamination procedures; clinical engineering staff should perform them only if necessary. When it is necessary, use an appropriate physical or chemical disinfection or sterilization procedure as outlined in Decontamination Procedures, below, and do the following:

- Remove all visible contamination before proceeding with the decontamination process—large quantities of protein (as found in blood, body fluids, and other patient material) may hinder disinfection.
- Use plastic-backed gauze or puncture-resistant gloves to reduce the risk of cuts or puncture wounds when cleaning instruments or components with sharp edges, metal probes, or other structures that present a risk of skin injury. Punctures may occur even with protective materials or gloves, so always use caution.
- Be sure that the medical device is exposed to the decontamination agent according to the manufacturer's recommendations, including the proper length of time, concentration, and temperature.

Tag and bag, if possible, all visibly contaminated medical equipment (or equipment known or strongly suspected to be contaminated) that must be transported to the clinical engineering department for service to indicate the nature of the contamination and to contain the contamination before transport. Some hospitals may have policies regarding transport of contaminated equipment. Be consistent with existing policies where applicable.

Use OSHA's universal precautions when handling medical equipment that is or may have been contaminated with blood or body fluids. Treat all blood and body fluids as though they are able to transmit infection.

Designate specific areas where decontamination and servicing of contaminated movable equipment can be performed without risk of infecting patients or other employees. The decontamination area should not be near any patient care areas, food preparation or storage areas, medication areas, or other clean areas. Preferably, the designated area should be away from direct employee traffic and free from excessive draft. (Proper ventilation is essential because many chemicals used for disinfection can cause eye, nose, throat, or respiratory irritation.) The surface of the decontamination area should itself be able to withstand decontamination (i.e., be made of metal or a nonporous surface other than wood).

CAUTION: Do not perform electrical device repairs on metal surfaces—this increases the risk of electric shock.

Use barrier protection (gloves, face shields or masks and protective eyewear, gowns, and respiratory protection) as needed during cleaning and decontamination procedures to prevent exposure to potentially infectious materials. (See Basic infection control practices, above.)

Use appropriate procedures to decontaminate any tools or equipment that come into contact with blood or body fluids or other potentially infectious materials during servicing.

Exercise care when opening a device for cleaning or repair.

- The likelihood of being infected as a result of contamination from the interior of a device is low unless visible contamination with blood, body fluids, or other infectious materials is present. If contamination is present (or suspected), contact the device manufacturer for specific recommendations for decontaminating the interior of the device. If the manufacturer cannot offer specific recommendations, use detergent and water to remove visible contamination, rinse, soak in alcohol, and thoroughly dry the device; this will significantly reduce the number of contaminating microorganisms. If soaking is not practical, spraying the device with alcohol may be an appropriate solution. (Also, see Decontamination Procedures, below.)
- *WARNING: Even this procedure may damage some components. Obtain and use the manufacturer's recommendations if possible.*
- Whenever decontaminating the interior of a device, verify device safety and performance before returning it to use.
- Remove dust by brushing and vacuuming (rather than blowing) to minimize resuspending dust particles and to avoid blowing dust into other parts of the device or other devices. If filters are present, clean them in a manner that will minimize resuspending the dust. Vacuuming followed by cleaning with soap and water may be adequate. (Although the risk of personnel infection from dust is not well established, it is likely to be minimal.)
- When special concerns exist, use the respiratory precautions described above.

Decontaminate any contaminated equipment or components that must be returned to suppliers or sent out for service.

Dispose of all used cleaning and disinfecting materials, gloves, masks, and gowns in accordance with the hospital's policy. Dispose of glass and any other sharp objects in a proper sharps container. (See: Sharps disposal containers. *Health Devices* 1993;22[8-9].)

In the event of a percutaneous or mucous membrane exposure to blood or body fluids, report the incident to the hospital's infection control specialist or employee health administrator.

Decontamination Procedures

In the absence of manufacturer recommendations for decontaminating equipment, clinical engineering personnel can help decide what decontamination procedure to use depending on the nature of the contamination, the level of disinfection or sterilization needed, and the type of material to be decontaminated. Central supply personnel trained in sterilization and disinfection procedures should process contaminated equipment and devices. If this is not possible in a specific instance, disinfect the device using a chemical disinfectant. Discuss the advantages and disadvantages of various disinfectants with an infection control practitioner.

Where relevant, procedures set forth in the facility's written bloodborne pathogens exposure control plan and TB control plan must be followed.

Clinical engineering decontamination applications and some of the disinfectants that may be particularly suitable for them are listed below. Most of these agents contain chemicals that have OSHA-recommended exposure limits. Exercise care to reduce exposure—avoid inhaling vapors, minimize skin contact, and protect eyes if splashes are anticipated.

CAUTION: Because of the diversity of medical devices and the various materials used to manufacture them, one procedure cannot adequately decontaminate all equipment. Unless manufacturer approved, any decontamination procedure poses the risk of damage. *We cannot guarantee that the following procedures will not harm some devices*, and we stress that they should be used only in the absence of a manufacturer-approved decontamination protocol. Report any problems regarding manufacturer-supplied decontamination procedures to ECRI for further investigation and resolution.

1. Sterilization or high-level disinfection (depends on concentration and exposure time):

- *Glutaraldehyde.*

The required exposure time when using glutaraldehyde remains unclear. The Association for Professionals in Infection Control and Epidemiology Inc. (APIC) recommends guidelines for high-level disinfection calling for 20 minutes or longer at 20°C. However, the time and temperature specified by Johnson & Johnson for CIDEX-activated dialdehyde (a 2.4% solution of glutaraldehyde-base disinfectant) is 45 minutes at 25°C to support a high-level disinfection claim.

CIDEX has had this label claim since 1984. However, with its 510(k) clearance, FDA required the package insert to state precisely that immersion for 45 minutes at 25°C is *required* for high-level disinfection. Competitive 2% alkaline glutaraldehyde product manufacturers face the same labeling requirements. Of course, all disinfectant and sterilant labeling directions assume precleaning of equipment with an enzymatic detergent or a detergent that removes debris and significantly reduces microbial contaminant.

ECRI believes that users should follow all instructions of a disinfectant/sterilant supplier, including its directions for precleaning. For additional information and guidelines regarding clinical applications of glutaraldehyde, see “Choosing a low-temperature sterilization technology”, a guidance article in the November 1999 issue of *Health Devices*. Clinical engineering personnel can also check with a healthcare facility's housekeeping department to determine what it is using for surface decontamination

Comment: OSHA currently does not have a permissible exposure limit for glutaraldehyde. The American Conference of Governmental Industrial Hygienists (ACGIH) has set a threshold limit value ceiling (TLV-C) of 0.05 ppm for glutaraldehyde. Because glutaraldehyde is an eye, nose, and respiratory irritant, contact the appropriate staff member (e.g., infection control practitioner, hospital safety officer, employee health specialist) to be sure that its use is permitted in the work area, and ask about any precautions that should be taken when using any glutaraldehyde-containing product.

- *Formaldehyde.*

Comment: Formaldehyde use may be limited to certain areas within the hospital and is not recommended for typical clinical engineering applications. It can cause eye, nose, throat, and respiratory irritation and allergic reactions and is a suspected carcinogen. OSHA has established a specific standard for formaldehyde exposure (the permissible exposure limit is 0.75 ppm and the short-term exposure limit is 2 ppm), which requires exposure monitoring, medical examination, and medical surveillance for employees exposed to formaldehyde in the workplace.

2. Intermediate-level disinfection:

- *Chlorine compounds* (>500 mg/L free available chlorine).

Comment: A 1:10 dilution of household bleach provides 5,000 mg/L of available chlorine. This concentration exceeds the intermediate level of 500 mg/L, which inactivates HBV in 10 minutes and HIV in 2 minutes (NCCLS 1991). At this concentration, chlorine-containing disinfectants are a good general-purpose, broad-spectrum disinfectant for tabletops and other surfaces, but they may corrode metals. Note: A bleach solution should be mixed daily to be effective.

- *Iodophors* (30 to 50 mg/L free iodine or 70 to 150 mg/L available iodine).

Comment: Iodophors are serious eye, nose, and throat irritants and, if sold as antiseptics, should not be used as equipment disinfectants. Only iodophors registered with the EPA as hard-surface disinfectants should be used, and manufacturers' instructions for concentration and exposure time should be followed (NCCLS 1991).

- *Iodine + alcohol* (0.5% + 70%).
- *Isopropyl alcohol* (70%).

Comment: Overexposure to isopropyl alcohol can cause eye, nose, and throat irritation, as well as neurobehavioral effects. Consult OSHA's exposure limits before using. Rapid evaporation of isopropyl alcohol may shorten contact time unacceptably. Although an alcohol wipedown may reduce contamination levels, swabbing does not allow sufficient contact time for decontamination. Generally, soaking in alcohol for a period of time is necessary. Alcohol may damage some plastics.

- *Phenolic compounds, aqueous* (0.5% to 3%) (rated as intermediate to low-level disinfectants).

3. Low-level disinfection:

- *Quaternary ammonium compounds* (0.1% to 0.2%).

Comment: Quaternary ammonium compounds are eye, nose, and throat irritants. They are good, general-purpose cleaners for surfaces, such as tabletops, walls, and floors.

Mercury

Although mercury use has decreased because of concerns over toxicity, mercury (and mercury compounds) can still be found in sphygmomanometers, thermometers and thermostats, esophageal dilators, gastric decompression tubes, and histology fixatives and stains.

Mercury and mercury compounds are among the most toxic substances found in healthcare facilities, and few healthcare employees fully understand the importance of proper handling and spill cleanup. Exposure to high levels of mercury and mercury compounds can lead to acute poisoning, even death. It is essential to identify any mercury-related problems in the hospital. Policies and procedures must be established to handle these problems; employees need to know the procedures and must adhere to them.

Health risks

Mercury is poisonous in all forms. Elemental or metallic mercury is a liquid at room temperature that readily vaporizes. Accidental spills, improper handling, and poor ventilation can result in toxic levels of mercury vapor in room air. When mercury vapor is inhaled, approximately 80% is absorbed into the bloodstream; to a lesser degree, mercury can also be absorbed through the skin and digestive tract.

Mercury vapor is easily absorbed through the alveoli of the lungs. Short-term, high-level exposures can cause acute poisoning, leading to interstitial pneumonitis, bronchitis, bronchiolitis, or, in severe cases, death. Chronic (long-term) exposure to lower levels of mercury can cause symptoms such as muscle tremor, irritability, and gingivitis (inflammation of the gums). Other symptoms include personality changes, such as outbursts of temper, increased excitability, shyness, or indecision. In addition, researchers are finding that long-term exposures can slow worker reaction times and interfere with performance of intricate tasks.

Mercury salts (inorganic mercury compounds) are readily absorbed through the skin and digestive tract and can cause localized skin reactions or generalized symptoms; mercuric chloride is commonly used in the histology laboratory as a fixative. Organomercurials (organic mercury compounds) can produce a variety of toxic effects; these compounds include fungicides, germicides, and bacteriostats such as merbromin (Mercurchrome), mercocresols (e.g., tincture of Mercresin), and thimerosal (Merthiolate). Occupational mercury exposure can cause contact dermatitis, but reports in the literature of mercury allergy are rare.

While the mercury from a broken thermometer in a patient's room is not likely to pose a significant health risk, high-use areas such as sphygmomanometer calibration locations can easily have mercury vapor levels exceeding the OSHA permissible exposure limit (0.05 mg/m^3 , as a time-weighted average) (29 CFR 1910.1000, Ide 1986).

Toxicity depends on the amount and frequency of exposure. The effect of workplace exposure can be exacerbated by exposures to mercury and its compounds from dietary sources (e.g., contaminated fish, seed grain treated with mercury fungicides) or environmental sources (water or air contamination). Gloves can protect personnel against contact with mercury and mercury-containing compounds. Use nonmercury thermometers when possible.

Exposure monitoring

Mercury-vapor monitoring in high-use areas is important for a safe working environment. However, cleanup personnel and employees who work in high-use areas should undergo periodic screening urinalysis for

mercury. Employees who handle mercury on a daily basis should wear a mercury exposure dosimeter. Screening should also be conducted following any spills or if employees exhibit signs or symptoms of mercury poisoning.

Federal regulation

OSHA lists mercury and mercuric chloride as *hazardous chemicals*. Hospitals must maintain up-to-date material safety data sheets (MSDSs) on these chemicals and are required to comply with the OSHA hazard communication standard (ECRI 2000). OSHA has also established permissible air exposure limits (PELs) for mercury and mercury compounds (29 CFR 1910.1000, Table Z2).

Used mercury is a Resource Conservation and Recovery Act D-listed hazardous waste, according to the Environmental Protection Agency (EPA) (40 CFR 261.24, 40 CFR 261.33). Disposal of mercury and of the waste resulting from spill cleanup must meet EPA requirements. As with other hazardous substances, state and local legislation may be even more stringent than federal legislation.

Mercury-spill cleanup and disposal

Accidental spills are the greatest source of mercury vapor contamination. Whether small (thermometer) or large (sphygmomanometer, esophageal dilator), all spills should be cleaned up immediately and completely. (Note that if the spill is too large to be handled by the immediate staff, it may be considered an emergency and trigger OSHA's Hazardous Waste Emergency Response Operation [29 CFR 1910.120]. Because this will necessitate use of a fully trained HAZMAT team, declaring a mercury spill an emergency should be avoided whenever possible by making sure that staff in the immediate work area know how to contain and control the spill.)

When mercury is spilled, it breaks up into tiny droplets that lodge in cracks and sink traps, mix with dust, and penetrate cracked or porous materials. It can also cling to gold jewelry, clothing (especially knitted fabrics), and shoe soles, so that a staff member can easily carry the mercury to places outside the immediate work site. In high-use areas, enough mercury can accumulate on work surfaces to cause a serious health hazard.

Floor surfaces can affect the extent of mercury spill cleanup. A carpet may lessen scatter but provides crevices in which mercury droplets can hide. In many cases, contaminated carpet must be removed. Tile and vinyl flooring allow wider dispersal and formation of smaller droplets, and mercury can pool beneath tiles under certain conditions.

The surface area of each droplet allows mercury to vaporize (at a rate proportional to the temperature—droplets near a heat source will vaporize more readily). Left untouched, the surfaces of these drops oxidize, slowing the vaporization rate. Disturbing the droplets with a broom or foot traffic can break them into smaller droplets, providing fresh surfaces for vaporization. Mops, brooms, and vacuum cleaners can also carry mercury contamination to other areas of the healthcare facility.

To clean mercury spills, designated spill team personnel should do the following:

Clean up all visible droplets of mercury. This is accomplished by aspirating the droplets with a plastic disposable syringe or vacuuming the droplets using a mercury vacuum with a trap for the mercury droplets and filters to absorb mercury vapor. In some cases, small amounts of mercury can be picked up with adhesive tape or a sponge device designed to pick up mercury and deposit it in a collection container. Choosing a cleanup device should be based on the amount of mercury to be collected, as well as device cost and effectiveness.

Use appropriate cleanup equipment. Mercury vacuums are specially designed to handle mercury liquid and vapor and can be purchased commercially. The exhaust of the vacuum is equipped with special

mercury-absorbing filters; these filters must be changed when their absorbing capacity is consumed to the point that effective filtering is lost. Because these units can vacuum contaminated dust and mercury decontamination powders, workers can clean up spills more quickly with less likelihood of exposure. Mercury spill control kits are designed for cleanup of small spills and should be placed in designated areas where mercury spillage is possible. These kits include a method for retrieving mercury droplets and chemicals for decontaminating surfaces. Also, in any mercury spill cleanup, protective equipment such as impervious gloves, shoe covers, and respirators should be used.

Dispose of mercury. All mercury droplets should be disposed of in a manner that will prevent further vaporization and that is in compliance with federal, state, and local hazardous waste regulations. All waste elemental (metallic) mercury should be recycled. (All healthcare staff using devices containing mercury should be aware of policies and procedures established for cleanup of large and small spills. Mercury should never be disposed of into a drain.)

Decontaminate surfaces. Because spilled mercury tends to disperse into microdroplets and fall into cracks and crevices (invisible to the unaided eye), surface decontamination should be accomplished by applying one of the chemicals available to coat mercury droplets (sulfur compounds) or to react with the mercury (Hg Absorb), forming an amalgam; these chemicals virtually eliminate mercury vaporization. Some surfaces (such as shag carpet) cannot be decontaminated and may need to be removed.

Perform area monitoring. Area monitoring is necessary to ensure that decontamination is complete and that the area is safe for occupancy. In spills involving small quantities of mercury (e.g., from a thermometer), this step is not necessary.

Dirty metallic mercury should not be disposed of as waste but should be recycled. Hospitals should not clean and reprocess their own mercury because this increases the risk to personnel from accidental spills or poor technique. Used mercury can be accumulated in small, airtight, unbreakable containers and sold as scrap to mercury refineries.

Managing mercury sources

Sphygmomanometers

Mercury-containing sphygmomanometers are used in patient areas to measure blood pressure; they may be mounted on a wall, on a mobile stand, or in a carrying case.

Planned elimination of mercury sphygmomanometers is advisable to reduce the risk of staff and patient mercury exposure. Mercury sphygmomanometers are traditionally considered more accurate and reliable in high-use hospital settings, but newer, high-quality, wall-mounted aneroid gauges are available that are more reliable than earlier designs. Although costs will be associated with replacing and maintaining new aneroid units, the personnel and materials costs associated with maintaining the mercury units and controlling mercury exposure will be eliminated.

All workers who use, clean, or maintain mercury sphygmomanometers should understand the properties of mercury and its associated hazards and should be instructed in safe handling procedures. Specific policies and procedures must be established for mercury spill cleanup, and specific areas should be designated for maintenance activities.

Hospitals with well-trained maintenance personnel who have established practices for cleaning and calibrating mercury sphygmomanometers and effective spill-control procedures may decide not to replace the mercury sphygmomanometers or to replace them only as they lose their usefulness.

When sphygmomanometers are dropped or broken, prompt, thorough cleanup is important, especially in high-use areas, such as a sphygmomanometer calibration laboratory, where mercury vapor levels can build.

Any room where sphygmomanometer calibration and repair is performed should be well ventilated. It should be reserved for the exclusive task of handling mercury, especially if calibration or repairs are performed often. Traffic through the area should be limited. There should be no smoking, drinking, or eating in the room. Floors should not be carpeted, and benches should be equipped with troughs to collect mercury spills. Personnel should remove all jewelry, especially if it is gold or gold plated (mercury readily combines with gold), and they should wear disposable gloves. In high-use areas, workers should wear disposable gowns and shoe coverings to minimize skin and clothing contamination, which can increase worker exposure and carry mercury to other areas of the healthcare facility. Consider use of a mercury vapor respirator and periodic surveys of mercury vapor levels in areas where sphygmomanometer maintenance and calibration is performed.

Bougies

Maloney or Hurst bougies (esophageal dilators) are, typically, red (natural) rubber tubes approximately 30 in long that are filled with mercury. A variety of diameters (approximately 0.2 in to 0.8 in) are available to treat esophageal constriction. They are commonly found in operating rooms, gastrointestinal labs, and endoscopy departments; each tube may contain as much as three pounds of mercury. Over time, the red rubber becomes brittle and can rupture, spilling its contents. Before each use, these tubes should be inspected for any signs of deterioration so that mercury can be collected in an airtight container for recycling, thus avoiding employee exposure and spill-site cleanup and decontamination.

Gastric decompression tubes (e.g., Cantor, Miller-Abbott), which are used to remove gas from the alimentary tract, have a balloon to hold the tube in place. The balloon is filled with mercury by the surgeon during the procedure. The tube is usually removed in the patient's room. Personnel involved with insertion or removal of these tubes and with handling the mercury must be educated in safe handling of the mercury and what procedures to follow in the event of a spill.

Infant incubators

Some older incubators still in use today have hood thermometers and/or high-temperature thermostats that contain mercury. ECRI recommends replacing all mercury-containing components in infant incubators. Should an incubator thermometer or thermostat containing mercury break, personnel should immediately transfer the infant to another incubator and remove the contaminated incubator from service. Personnel who are unfamiliar with decontamination procedures and equipment should not attempt to clean up the spill.

Laboratory chemicals

Mercuric chloride, a major constituent of B5 and Zenker's solution, is an extremely toxic chemical used in pathology laboratories for fixing tissue specimens. Sources of contamination include accidental spills on benchtops, floors, and clothing and in sink traps and plumbing (Stewart et al. 1977). To control mercury contamination in the laboratory, do the following:

Use chemicals without mercury when possible (e.g., Bovin's fixative solution [picric acid]).

Cover workbenches and floors with impermeable surfaces.

Clean spills immediately.

Wear gloves whenever using mercury solutions.

Adequately ventilate the laboratory.

Other sources

Thermometers used in patient areas and the laboratory frequently contain mercury. *All* spills from broken thermometers should be cleaned up with proper mercury disposal techniques.

In the past, it was believed that weighting an enteral feeding tube with mercury made it easier to insert the tube and anchor it in the stomach. Mercury-weighted enteral feeding tubes are reportedly no longer manufactured. (Tungsten-weighted tubes are still available, but unweighted tubes are generally considered as effective as weighted tubes.) However, it is possible that some hospitals still have mercury-weighted tubes in stock; their disposal can pose a problem because the mercury in the tube makes the tube a hazardous waste and its contact with the patient can make it an infectious waste.

Various instruments in the clinical laboratory use mercury in their operating mechanisms. Some hematology analyzers, for example, use mercury in their hydraulic system to draw samples through the counting chamber. Disposal of old instruments or leaks from the instrument will require appropriate cleanup and decontamination.

Recommendations for avoiding mercury contamination

Urge the safety committee to adopt procedures for safely storing and using toxic substances such as mercury.

The safety committee should consult with appropriate health professionals in the hospital concerning the proper handling of toxic substances.

Confine large-scale use of mercury to properly designed areas. Floor coverings should be seamless, and carpets should not be installed in areas where mercury might be spilled.

Require all personnel involved in decontamination of mercury spills or maintenance in which significant mercury exposure is possible to undergo preemployment testing. Also, include annual mercury-level testing as a part of their regular physical examinations.

Survey maintenance shops and other locations where mercury has been spilled and improperly cleaned to determine the location and severity of contamination.

Draft formal procedures, and instruct all affected staff in the safe handling of mercury as part of the OSHA hazard communication standard program. These procedures should include development of a mercury spill reporting system, which involves placing warning placards in designated mercury use areas (e.g., sphygmomanometer calibration area) and designation of a spill cleanup team. Very minor spills can be handled locally by using strategically located emergency spill kits.

Should there be a mercury spill (e.g., a sphygmomanometer break) in a patient room, relocate the patient (if possible) until the spill is contained and a mercury vapor monitor has demonstrated that vapor levels are acceptable.

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