A variety of chemicals are used in medical imaging as developer and fixer ingredients, germicides, and cleaning agents. Glutaraldehyde, a potent sensitizer, may cause occupational skin and respiratory diseases in exposed individuals. Poor ventilation, unsafe practices, and lack of hazard recognition may contribute to occupational asthma and other respiratory disease in susceptible medical imaging personnel. Failure to respond effectively to initial health complaints and reduce exposure levels can have serious consequences for affected employees. It is therefore important for occupational safety and health professionals to alert health facility managers to potential dangers and to recommend effective intervention strategies. When problems are identified, a multidisciplinary team approach is the best method for evaluating and controlling hazards. This team should include industrial hygienists, safety staff, occupational medicine physicians, mechanical and ventilation engineers, personnel specialists, and medical imaging staff. A thorough hazard assessment, medical diagnosis, and administrative personnel actions are critical to effective problem identification and correction. In the case of chemical sensitization, removal of the affected employee may be necessary. By working with designers and equipment installers to monitor compliance with appropriate codes and manufacturers’ specifications, hazards can be prevented. We present additional operations, ventilation, and design improvements to reduce chemical exposures to radiology employees.

Keywords Radiology, Medical Imaging, Glutaraldehyde, Chemical Sensitivity, Darkroom Disease

Radiography provides a critical diagnostic function in inpatient health care facilities and large ambulatory care centers. Although there have been advances in digital radiography, most radiographs are recorded on film. As a result, each health care facility with a medical imaging department will have a darkroom or daylight processing system. (In daylight processing, the automatic processor is out in the open and light-sensitive film is protected through the use of a glove box arrangement or an auto-film loader arrangement.) The use of film requires a complex chemical development process to turn silver ions into black metallic silver. Developer and fixer solutions are provided to the medical imaging department in either a premixed or a concentrated form. These solutions contain known chemical irritants and sensitizers, and considerable exposure to these may occur during mixing, especially during manual batch mixing. However, even with ready-mixed solutions, dermal or respiratory contact is possible.

Adverse health effects, including immunological sensitization and mucous membrane irritation have been reported in Great Britain and Commonwealth countries among medical imaging personnel. By comparison, chemical hazards in medical imaging departments have received little attention in the United States.

Exposure to radiographic processing chemicals presents a potentially serious health risk that warrants attention by industrial hygienists and other occupational health professionals. Two cases from the Indian Health Service (IHS) illustrate some of the issues involved in evaluating and managing health problems that may be associated with medical imaging departments. These cases are exemplary of a relatively recent phenomenon known as “darkroom disease.” Marjorie Gordon, a radiographer from New Zealand who is recently deceased, was the first to report a variety of health complaints from exposure to medical imaging chemicals. Gordon reported symptoms including heart arrhythmias and tachycardia, sore throat, nausea, headaches, fatigue, and other complaints. It was believed that these and other symptoms such as asthma, upper airway irritation, and laryngeal dysfunction are the result of gradually increasing sensitivity to one or more film processing chemicals. Even common complaints
such as rhinitis and sinusitis may be caused or exacerbated by exposure to medical imaging chemicals. The purpose of this article is to highlight this emerging syndrome and to recommend a systematic method of investigating and controlling the problem.

CASE STUDIES

In the first case, a radiological technologist (RT) in a small rural hospital complained of strong chemical smells within a week after the installation of a new radiographic film processor. She continued to work in the area. Seven years later, she was diagnosed with asthma and chronic bronchitis from chemical exposure and was removed from the workplace. Her symptoms subsequently improved.

In the second case, an RT in a remote clinic had three years of exposure to a new processor. Her initial symptoms developed within about six weeks of exposure and included headaches, skin irritation, and gastrointestinal symptoms. She continued the same work for two and one-half years, and was removed from exposure only after developing shortness of breath that was never definitively diagnosed.

Initially, she was transferred to a hospital radiology reception desk at a different facility. However, her symptoms continued, and an investigation of that facility’s medical imaging department revealed that the darkroom and processor had the same substandard ventilation as the facility from which she had transferred. Ultimately, she left her position in the IHS.

RESULTS

In each case, the investigation included an environmental survey, a clinical evaluation, and personnel actions, such as employee removal. The environmental surveys consisted of a review of products and procedures, personal sampling, and ventilation measurements. In the first case, the survey found that the automatic processor was vented directly into the darkroom. Dilution ventilation was measured to be only one-half of that recommended by the American Institute of Architects (AIA),\(^4\) that is, only five air changes per hour (ACH), whereas the standard is 10 ACH, and no make-up air was provided for the darkroom. Maintenance of the processor appeared to be poor, for example, when the operator complained that the unit was leaking processor chemicals onto the floor, she was given a drip pan. Air samples collected by an Occupational Safety and Health Administration (OSHA) inspector and an IHS employee were reported as “within normal limits” (no specific information was available on the samples that were obtained).

In the second case, the environmental survey showed that the processor was passively vented to the outside. The manufacturer’s specifications called for the processor vent to have a mechanical exhaust with a minimum of 0.25 to 0.75 mm of water static pressure, depending on the diameter of the duct. Reliance on non-mechanical ventilation means that the static pressure within the vent is variable and under certain atmospheric conditions could be under positive pressure. This could increase the amount of chemical vapors and gases generated by the automatic processor. An engineering report written shortly after the facility had been constructed stated that the dilution ventilation in the darkroom was only about 5 ACH. Further evidence of the inadequacy of the ventilation system was reported approximately one year after installation of the new processor. An incident report filed by a clinic staff member complained of a strong processor chemical odor throughout the clinic. Two years later an industrial hygienist was notified of the problem and investigated. The ensuing investigation resulted in a renovation bringing the facility into compliance with AIA and manufacturer’s requirements.

DISCUSSION

Chemical Hazards

Automatic radiographic processing equipment contains tanks for developing solution, fixing solution, and rinse water.\(^1\) Developing solutions are chemicals used in the reduction of silver bromide ions. These solutions also contain chemicals that control the processing speed, a preservative and a hardening agent. Fixing chemicals include a neutralizer, a clearing agent to remove undeveloped silver bromide ions, a preservative, and a hardening agent. There are a number of constituents that may cause health effects: acetic acid, diethylene glycol, glutaraldehyde, hydroquinone, potassium hydroxide, sodium sulfate, phenidone (1-phenyl-3-pyrazolidone), aluminum sulfate, and ammonium thiosulfate. The products are used in differing concentrations and combinations, depending on the brand and manufacturer of the automatic radiographic processing equipment. Although each of these chemicals may present some health risk, the hazards of primary chemicals of concern are described below.

Glutaraldehyde is an aliphatic dialdehyde with an odor threshold of 0.04 ppm in air. It is available most frequently as a 2 percent or 50 percent aqueous solution. The primary use of glutaraldehyde in most health care settings is in the high-level disinfection of heat-sensitive equipment. In medical imaging, glutaraldehyde is primarily used as a hardening agent to prevent films from sticking together. However, an environmental assessment should verify that it is not also being used as an instrument disinfectant or as an environmental surface germicide.

The American Conference of Governmental Industrial Hygienists (ACGIH\(^\text{®}\)) initially adopted a ceiling level for glutaraldehyde of 0.05 ppm in 1976 and raised it to 0.2 ppm in 1979.\(^5\) However, occasional reports of adverse health effects at levels below 0.2 ppm resulted in their lowering the ceiling level back to 0.05 ppm. Skin sensitization and allergic contact dermatitis after occasional exposure have been documented. Gannon et al. confirmed that exposure to glutaraldehyde resulted in occupational asthma in seven hospital workers, including one radiographer.\(^6\) They documented positive reactions to a challenge test of 0.017 ppm. Hydroquinone (HQ), or 1,4 benzenediol affects the eyes, the respiratory system, skin, and central nervous system. The ACGIH threshold limit value (TLV\(^\text{®}\)) is 2 mg/m\(^3\) as an eight-hour
time weighted average (TWA) and the National Institute for Occupational Safety and Health (NIOSH) recommends this level as a 15-minute short-term exposure limit (7,8). Due to its low volatility in processing chemicals, it has not been suspected as a respiratory sensitizer. However, because automatic radiographic film processors are heated, there will be some increase in volatility. In terms of skin contact, a worst-case one-hour dermal exposure of a 0.005 mg/kg human absorption was estimated. (9) Although the potential for HQ to cause human cancer in unknown, it is a dermal sensitizer, and repeated application may cause leukoderma, which is defined as an absence of pigment, partial or total, in the skin. Also, a case of exogenous ochronosis, a condition characterized by pigmentation of cartilage and sometimes skin, with allergic contact dermatitis was reported. (10) This provides further evidence of a potential for an allergic response from repeated exposures to HQ. Because there is a potential for dermal allergic response and some increased volatility due to heating, it is inappropriate to rule out HQ as a contributor to health effects in medical imaging personnel.

Mixing of processor chemical components also causes the release of sulfur dioxide from decomposition of sulfite. Sulfur dioxide, a potent respiratory irritant with an ACGIH TLV of only 2 ppm, is moderately soluble and may cause a persistent cough. (8) Chronic exposure may result in bronchospasm and has been suggested as playing a role in chronic obstructive pulmonary disease. (11)

Ammonia, a highly soluble respiratory irritant, is another potential byproduct from the breakdown of processing chemicals. The primary effect of ammonia, due to its high solubility, is irritation of the upper airways. (11) The potential health effects from synergism between chemical mixtures and byproducts are unknown.

Radiology employees may also have exposure to other chemicals used as cleaning agents and germicides, for example, detergents, quaternary ammonium compounds, iodophor or phenolic-based germicides, and alcohol. Contact dermatitis is the primary risk associated with these products. Detergents and other surface cleaners or germicides may be strong irritants, and contact with alcohol may defat the skin. Phenolic-based germicides may also cause systemic effects since exposure may result in adsorption through intact skin.

**EQUIPMENT AND DESIGN CONCERNS**

Medical imaging darkrooms tend to be cramped and poorly ventilated, as is the case in these case reports. Automatic processors generate heat to hasten the film development and drying process. The design of automatic processors is such that operators must come in close contact with chemicals while removing and cleaning film cross-over rollers and processor racks. Furthermore, caustic chemicals are used to clean medical imaging tanks. Manufacturers usually recommend daily cleaning of crossover rollers and weekly cleaning of large racks.

Cleaning of these tanks offers opportunity for dermal or respiratory exposure. Monthly “deep-cleaning” of a large processor often requires the worker to place the upper half of the body in an unventilated space to clean chemical deposits off the sides and bottom of the tank. Additional opportunities for dermal or respiratory exposure may occur during processor repair or spill clean-up.

In the Indian Health Service, medical imaging staff often use clinical laboratory coats and latex examination gloves for personal protective equipment (PPE), while cleaning the processor. This may be inadequate to prevent dermal contact with chemicals. Staff at small-scale medical imaging departments often manually mix batches of chemicals each month, creating ample opportunities for exposure to toxic chemicals.

**HEALTH CONCERNS**

In addition to the two cases discussed in this article, other case reports of occupational respiratory disease and dermatitis have been reported among medical imaging personnel and photographic developers. (6,12–15) Using a respiratory symptom survey, Smedley et al. found that radiographers reported more workday-related lower respiratory tract symptoms (wheeze, cough, chest tightness, dyspnea) and other symptoms (dizziness; headache; soreness of mouth, throat, and eyes) than a comparable group of physiotherapists. Although the prevalence of wheeze in the two groups was similar, the one-year period prevalence of asthma was higher in the radiographers. (7) In addition to the chemical hazards discussed previously, other potential respiratory hazards are latex allergy and irritant-associated vocal cord dysfunction. (16,17) Latex allergy is recognized as an emerging hazard in health care. However, in these case reports, this hazard was evaluated and found not to play a role in these employees’ complaints.

The appropriate evaluation of symptomatic individuals’ suspected exposure to medical imaging chemicals should include (1) a detailed history and physical examination; (2) an assessment of possible exposures; and (3) confirmatory diagnostic testing. The history should include questions about the onset of symptoms, their temporal relationship to specific job tasks, any preexisting conditions (such as asthma), and use of PPE. The comprehensive physical examination should note particularly any rashes and pulmonary signs or symptoms. Confirmatory diagnostic testing for asthma may include serial peak expiratory flow measurements, pre- and post-shift spirometry, and/or methacholine challenge. Provocative challenges in an exposure chamber are rarely done because of safety considerations, as well as difficulty in simulating the exact exposure. Serologic tests for specific IgE may be useful, but in most cases these will not be available.

In some cases, the physician may need to distinguish between a diagnosis of asthma and reactive Airways Dysfunction Syndrome. (7) In cases of suspected irritant or allergic contact dermatitis, patch testing may be required. (8) In some cases, the clinical evaluation will identify a set of conditions that produces symptoms, but not a particular chemical exposure. Even so, the
A physician should, in communication with the worker and the employer, be as specific as possible regarding possible restrictions and job accommodations. The physician should enumerate the types of substances and the exposure routes to be avoided. For example, employers need to know whether substances are airborne or contact hazards in designing appropriate interventions.

The environmental investigation should focus on potential design and equipment installation problems. It is important to assess the type(s) of mechanical ventilation, the volumes of air exchanged, the source and amount of makeup air, and the discharge location of exhausted air. Air sampling has many uses such as establishing baseline levels for chemicals of concern such as glutaraldehyde, exposure monitoring for regulated chemicals, or for follow-up after the completion of engineering changes. However, ambient and personal sampling may not be useful for workers with a chemical sensitivity, because these individuals may react to exposure levels considerably below the ACGIH TLVs. Furthermore, negative air samples may give a false impression of safe conditions.

Another potentially serious problem in the investigation of work-related chemical sensitivity cases is that supervisors and administrators may disbelieve health complaints from affected workers. The sensitized individual may be accused of malingering because other workers report no symptoms and the affected worker may have reported no problems in the past. Initially the cases described above were disbelieved; however, in the second case, intervention in the form of removal of the affected employee(s) from exposure may be successful in preventing the development of severe, irreversible disease.

There are a number of effective solutions to prevent or control occupational respiratory disease in medical imaging employees. The most effective means to reduce exposure to toxic chemicals in medical imaging are proper equipment installation and adequate ventilation.

Ventilation

It is imperative that the darkroom ventilation meets the current AIA guidelines of a minimum rate of 10 ACH, measured as air exhausted. The darkroom should be under negative pressure, and all air should be exhausted directly to the outside away from any supply inlets. AIA recommends that the exhaust duct discharge be at least eight meters away from any supply inlet. Sufficient make-up air is required to assure proper operation of the system. If there is a possibility of vapor accumulation, that is, if chemical tanks are located inside the darkroom, the exhaust blower should be wired to run continuously. The primary purpose of general ventilation in the darkroom is removal of excessive heat and moisture, and trace amounts of vapors and gases. If there are significant sources of toxic chemicals in the room, local exhaust ventilation is needed.

Commonly, the processor tanks are located outside the darkroom in a small alcove. Unless the area is well ventilated, that is, at least 10 ACH with no recirculation, a small slot hood exhaust system should be installed in the wall above the tank. Although there are no standard designs for venting automatic processors, the ACGIH has design criteria for similar applications. One effective method would be to provide a slot hood with dimensions of 50 mm in height and as long as the processor tank is wide. The system should be capable of exhaust ventilation at a rate of 150 m$^3$/minute, at an effective distance of 150 mm from the hood. For example, a flanged hood over an 800-mm (30 inches) wide processor should be equipped with an exhaust blower capable of removing at least 600–800 liters per second (1300–1750 ft$^3$/min) of air.

The installation of equipment should comply with the manufacturer’s specifications. An exhaust duct must be connected to the film dryer to discharge contaminants directly to the outside. This exhaust duct should be constructed of smooth plastic, aluminum, or galvanized iron materials equipped with an air regulator assembly to attain maximum efficiency. One manufacturer’s specifications call for a negative static pressure between 0.75 mm and 1.0 mm of water to be maintained in the vent. Smaller radiology departments may be equipped with table-mounted automatic processors that are not equipped with a dryer vent. These units are similar to dental film processors and may require increased general ventilation or special local exhaust designs, for example, a canopy hood. Ventilation systems should be evaluated at least once a year to assure minimum air exchange rates and negative static pressures in the processor vent are being met, and an effective preventive maintenance program is necessary to assure that the system operates according to design specifications.

Processing Equipment

In some medical imaging departments, a chemical replenishment tank is located outside the darkroom. This tank is a potential source of vapor release and may require a local exhaust hood similar to that described previously. Assuring that the floating lids and tight-fitting covers are in place can minimize leakage from this tank. Installing an automixer can eliminate the need for this unit. An automixer is an effective means of reducing dermal and respiratory exposure from manually mixing chemicals. If a daylight loading processor is used (no darkroom is present) minimum space clearances should be provided (per manufacturer’s specifications), and the room should be ventilated at a rate of at least 10 ACH with no recirculation.

Design

Occupational safety and health staff should review and verify that the processing area provides sufficient space. Each manufacturer provides specifications for processor space requirements. These requirements must be followed to assure minimum clearances to maintain and service the unit. Space requirements for silver recovery or other critical functions must also be considered in the darkroom design. A particular concern is the arrangement of pipes and electrical connections to eliminate tripping hazards.
Processor manufacturers may also specify approved materials for waste piping (one manufacturer prohibits the use of copper piping and recommends only galvanized iron or polyvinyl chloride materials). The drain lines may also be a source of vapor release. If this appears to be a problem, it may be necessary to construct a “capture box,” similar to those used with ethylene oxide sterilizers, over the floor drain.

Another source of vapor release is the silver recovery unit. It is important that the lid be tightly secured and only opened in a well-ventilated area. The medical imaging department design should include the installation of a utility sink in close proximity to the automatic processor to assist in cleanup and to reduce the potential for chemical spillage during routine processor maintenance. An eyewash station, meeting American National Standards Institute (ANSI) requirements, should be installed in the department near the chemical mixing areas. An on-the-faucet eyewash unit is not acceptable if it is the same sink used to clean cross-over racks because of the potential for contaminating the eyewash unit.

**Operational Improvements**

Operational improvements must be made to minimize exposure to chemicals. OSHA’s Hazard Communication Standard must be implemented in medical imaging departments. Staff must be thoroughly educated concerning the contents of Material Safety Data Sheets for processing chemical contents and potential hazards. The feasibility of specifying a processor using a glutaraldehyde-free fixer should be considered. This would eliminate one chemical that has been demonstrated to cause sensitization. This process, however, is a new technology that may not be suitable for all single emulsion films, and may require the purchase of a specially designed automatic processor. One of the most difficult challenges is to ensure that individuals responsible for cleaning or maintaining processors wear appropriate PPE to avoid dermal or respiratory exposure. The type of PPE will depend on the type of processor and the task but may include a respirator, plastic apron, goggles, and gloves that resist chemical breakthrough. Finally, it is critical that spills are cleaned thoroughly and promptly.

**CONCLUSION**

Occupational respiratory and skin diseases are little-recognized hazards associated with medical imaging. Effective intervention requires a proactive, cooperative effort, which includes occupational safety and health specialists, physicians with experience in occupational health, ventilation engineers, and personnel specialists.

Health care administrators and managers of medical imaging departments need to be made aware of occupational disease, acknowledge employee health complaints, and take appropriate action to remove affected individuals from exposure. Cases of occupational respiratory illness are most effectively managed when a multidisciplinary team conducts the investigation. Effective action requires the involvement of occupational safety and health staff to recommend engineering and PPE interventions, clinicians to provide diagnostic and therapeutic care, personnel specialists to arrange for workplace accommodations, and medical imaging specialists to assist in recommending administrative controls and special equipment selection. These interventions are critical to help prevent serious illnesses and permanent disability.

**DISCLAIMER**

The opinions expressed in this article are those of the authors and do not represent the views of the Indian Health Service or the U.S. Public Health Service.

**REFERENCES**