

## Biological and Chemical Hazards of Forensic Skeletal Analysis

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**ABSTRACT:** In the course of conducting forensic analysis of human skeletal material, anthropologists are exposed to a number of biological and chemical hazards. This paper reviews the primary concerns in terms of infection or exposure. Handling of human tissue provides an avenue through which bloodborne pathogens may be transported. Scene recovery also includes a set of hazards through exposure to human, animal and soil vectors. Basic personnel protection and laboratory procedures should be established for the protection of all personnel involved in this work.

**KEYWORDS:** forensic science, hazardous materials, skeletal analysis, forensic anthropology, physical anthropology

Nowhere in the subdisciplines of anthropology are the risks to health higher than in forensic anthropology, where the techniques of human skeletal analysis are applied for the purposes of addressing medicolegal questions. First, these risks include exposure to potentially infectious material from the body and body fluids. Second, involvement in scene investigation and recovery of the remains may necessitate working in areas where animal and insect vectors may transmit pathogens. Third, some anthropologists use chemical treatments in the preparation and preservation of forensic material requiring specific handling to insure safety as well as integrity of the evidence. Fourth, forensic anthropology brings practitioners into countries torn by battle as well as disease. The anthropologist risks not only an unstable political situation, remnants of war such as unexploded missiles and land mines, and a wide array of endemic infections. Finally, the hazards to others under our guidance, especially students and laboratory workers, challenge the anthropologist to face health and safety issues.

The increasing institutional concern over exposure to hazardous material, newly enacted environmental health and safety regulations, and instructor personal liability for injury to workers and students necessitate that forensic anthropologists be fully aware of the biological and chemical dangers which we may encounter in our work. In this paper, we review hazards which are grouped in two broad categories: (1) biological hazards from contact with human blood and other bodily fluids and tissues or at sites of recovery of remains; and (2) chemical hazards from chemicals used in cleaning, preserving or embedding bone and other tissues. Procedures for the safe handling and disposal of such hazards also are presented.

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### Bloodborne Pathogens and Other Dangers of Body Tissue Exposure

Skeletal biologists, including forensic anthropologists, are exposed to dangers from soft tissue, blood and bodily fluids in a number of settings. Detailed dissection of muscular tissue is often essential in order to link morphological features of the skeleton to functional differences in locomotion, manipulation or posture and investigate the interaction between soft and hard tissue. Removal of already dissected tissue reveals underlying skeletal morphology for research or teaching. Forensic anthropologists frequently work with extensive quantities of unpreserved soft tissue in various stages of decomposition. Whatever the state of the human remains, the potential for exposure to pathogens in the tissue or body fluids must be acknowledged.

In 1992, the Occupational Safety and Health Administration (OSHA) enacted its Occupational Exposure to Bloodborne Pathogens regulations for healthcare workers (1). This set of regulations is designed to minimize exposure to infectious agents within blood and other potentially infectious material (OPIM). These fluids include almost all bodily derived fluids with which exposure is not common, but can be extended if substances, such as urine, are contaminated with blood or vomitus. Exposure is defined as occurring due to (1) a wound resulting from a blood or fluid contaminated object, (2) splash of blood or other bodily fluid onto an open wound or area of dermatitis, or (3) contact with blood or other bodily fluids with mucous membranes of the eyes, nose or mouth.

The pathogens of chief concern to the forensic anthropologist when in contact with human remains are human immunodeficiency virus (HIV) and hepatitis B virus (HBV). Other pathogens encountered with the remains or during scene recovery include non-HBV hepatitis, tuberculosis, Creutzfeldt-Jakob disease, herpes, smallpox, arenaviruses, filoviruses, and viral hemorrhagic fever.

Since the human remains presented for forensic anthropological analysis often are of unknown background, the risks of infection also are unknown. The cases seen by forensic anthropologists include those individuals who are often at highest risk for infectious conditions. Drug use and poverty have been frequent factors in many of the lives of the deceased whose bodies are presented for autopsy. In one study of forensic cases at autopsy, 32.6% had serological evidence of a significant viral infection and about 84% of known drug users were found having at least one viral infection (2). Bodies are often brought for analysis prior to completion of testing which may reveal advanced infections. Furthermore, many diseases are transmissible prior to the development of antibodies which form the basis of the primary tests for infection. Universal measures to reduce exposure to the pathogen, therefore, are warranted.

### *Human Immunodeficiency Virus (HIV)*

Since the early 1980s, much of the public concern about disease exposure has focused on the AIDS epidemic. Human immunodeficiency virus (HIV), the culprit in the onset of acquired immunodeficiency syndrome (AIDS), has been retrieved from blood, semen, vaginal secretions, lymph nodes and brain cells of infected persons. This disease has a long latency period, up to 16 years or longer during which time the victim can be virtually asymptomatic (3).

Autopsy samples have reported frequency of HIV positive individuals of about 6% (2–4). Among forensic autopsy series, however, few individuals showed full-blown AIDS (5). Instead, more than 90% of the HIV-infected individuals died from unnatural causes including heroin intoxication, suicide and homicide and were generally asymptomatic of infection at the time of death.

HIV appears to have a limited lifespan after the death of the individual. It is rapidly inactivated by chemical and physical agents (6), including bleach, alcohol, paraformaldehyde, hydrogen peroxide, and Lysol. Heating to 56°C for 10 min is also effective at inactivating the virus. In sterile conditions, such as in uncontaminated blood smears, the virus may remain viable for a considerable period (weeks to months). In most contaminated conditions, however, HIV rapidly degrades and loses viability, although it is reported that cultures were successfully obtained from organs and tissues even eight days after death (7). Similarly, HIV has been found to retain infectivity more than 14 days in liquid suspension at room temperature and in sewage, tap water and seawater for up to 11 days (8).

Risk of HIV infection is relatively low for health care workers. Infection risk due to a needle prick is estimated at 0.3% to 0.5% (9,10). Aerosol transmission of HIV, such as may occur during autopsy, has not yet been documented and the risk is probably minor due to the relatively large size of the virus particle. Given the typical length of time since death, the contamination by bacterial and other agents and the natural processes of decay, the HIV risk to the forensic anthropologist of HIV infection is extremely low. The extent of degradation and contamination, however, cannot be assessed by visual inspection alone and universal precautions are needed (11). Special care should be taken in the transport of remains to prevent loss of body fluids. Any tissue samples taken from the remains where HIV may still be viable should be fixed in formalin or ethanol. Spills of blood or body fluids can be cleaned with a bleach solution since HIV is inactivated by a 1% bleach solution in only 2 min (12).

### *Hepatitis*

Viral hepatitis consists of a group of illnesses which are produced by viral particles traveling through a variety of modes. Some (Hepatitis A and E) are transmitted through feces and known as infectious hepatitis while others require more direct contact and are known as serum hepatitis (Hepatitis B, C, D, and G). Incubation periods and duration of the illnesses also vary with some forms appearing within two weeks while others may be delayed by six months.

Hepatitis B is a continual hazard for the forensic anthropologist. Risk of hepatitis B infection rather than HIV drove health care workers to push for OSHA regulation of bloodborne pathogens. Infection is manifested as random necrosis of liver cells and inflammation with clinical symptoms including weakness, drowsiness, anorexia, discomfort and fever. Damage induced by this virus increases susceptibility to other liver ailments which can prove

fatal. The long incubation period of 6 to 24 weeks often masks the association between the event of infection and the onset of symptoms (13).

Hepatitis B virus is associated with increased morbidity and mortality among mortuary workers due to high frequency among the deceased and longevity of the virus. Li et al. (2) report frequency of HBV at about 23% in their autopsy series, roughly equal in males and females. Risk of infection from a needlestick or splash is between 6 and 30% when the source material is derived from an infected subject (14). This is about 100 times more transmissible than HIV and reflects both higher volume of infectious particles in the blood with HBV as well as ability to be transmitted by aerosol due to the smaller size of the viral particle (15). HBV can be inactivated by a 1% bleach solution within 10 min (12).

Hepatitis C and D can produce chronic liver damage (16,17). Both forms are often found among intravenous drug users and HCV has been reported at a frequency of 19% among forensic autopsy subjects (2). Transmission of hepatitis C and D through percutaneous exposure has been documented. Risk of HCV infection by needlestick is estimated to be 2 to 3% (18). In one case a cardiac surgeon infected a number of patients with HCV without remembering any puncture wounds or cuts during the operation (19). Hepatitis G is transfusion-associated and presumably contractible through inadvertent contact during autopsy although no causal relationship between infection and actual hepatitis has been shown (20).

In contrast to serum hepatitis, hepatitis A (21) and E (22) are transmitted through fecal material. Possible avenues of infection for the anthropologist may be through contact with fecal material during examination and later inadvertent transfer to the mouth. It also may become a factor in scene recovery of human remains when those remains may be in contaminated water or mud. Risk increases when working in developing countries where conditions may foster transmission. It is essential that preventative measures are taken such as proper vaccines being administered before contact, appropriate cleaning of hands prior to eating and, of course, refraining from partaking in food, drinks or cigarettes during the examination of remains.

### *Tuberculosis*

Tuberculosis (TB), an infectious bacterial disease, was once a major global killer and remains so in developing countries. A recent upsurge of TB rates in industrialized nations among urban residents, drug users and the homeless, combined with the appearance of therapy-resistant strains of the pathogens, demonstrates that TB poses a significant danger to workers exposed to human material. This disease is transmitted by airborne droplet nuclei of 1 to 5  $\mu\text{m}$ , typically generated by coughing or other respiratory efforts of the infected person (23).

The risk of exposure is particularly high among those who are involved in histological preparation from fresh material and in autopsy (24). In a recent case study in which a patient was misdiagnosed and no respiratory precautions taken, about 12.5% of the health care workers involved in his care later showed signs of exposure (25). In contrast, all of the vulnerable autopsy personnel involved in the examination of his remains later tested positive. It is probable that oscillating saws are primarily responsible for distributing infectious particles into the air (25,26).

Forensic anthropologists must consider themselves vulnerable, probably having increased exposure due to the segment of the population from which most cases are derived. While at present

the frequency of tuberculosis is low to moderate, the lack of recognition of this disease even in cases where respiratory disease is suspected is frightening. One study suggested that 54% of the series of recent autopsies in which TB was present had been undetected by the attending physicians due to atypical presentation and unfamiliarity of the doctors with the manifestations of this disease (27). Since TB is one of the opportunistic infections which may occur secondary to HIV infection, simultaneous transmission of both pathogens may occur. There is little known about the duration of viability of the tuberculum bacilli after the death of its host. Experiments with culturing TB from infected late 19th century museum material were unsuccessful (P. Sledzik, personal communication).

#### *Creutzfeldt-Jakob Disease and Associated Prion Diseases*

Creutzfeldt-Jakob Disease (CJD) affects the central nervous system and is often manifested in confusion, sensory disturbances, neurological deterioration, and eventually coma. The epidemiology of this disease is confused by its multi-origin capabilities. It apparently originates spontaneously in some individuals while, in others, is due to particle transmission. Hereditary predisposition may also be involved and in yet others environmental factors have been postulated. The primary culprit appears to be minute proteins, called prions, capable of replication and transmission between species (28–30). The prion particle is a glycoprotein which normally exists harmlessly on the cell's surface. If, however, it is converted post-translation into a protease-resistant form, it may become infectious. This conversion may occur spontaneously or may be due to contact with an introduced converted particle.

The disease is rapidly fatal after onset. Although rare, it is believed to be harbored in a larger segment of the population than previously thought. CJD related deaths are more commonly recognized among the elderly. In the U.S., 5.9 deaths per million persons are attributable to CJD (31). Human incubation times have been shown to be up to 20 years. Bloodborne transmission is possible by surgical instruments and from infected brain dura-mater (32). CJD remains infectious even after exposure to heat and formaldehyde (33). Neither autoclaving nor immersion in 5% sodium hypochlorite has been proved insufficient to eliminate infectivity [32]. The pathogens appear concentrated in the central nervous system and adjacent tissue such as found in the eyes, with only moderate to low levels found in lymphoid tissue, internal organs, dura mater, cerebrospinal fluid, bone marrow, and peripheral nerves. Prion concentrations in the bone, blood and musculature are minimal or nonexistent (34).

Forensic anthropologists should be aware of the risks and take precautions to avoid transmission during examination procedures. The infective status of the deceased cannot be readily assessed. Reliance on the sterilizing effects of formalin preservation or autoclaving is unwarranted. In one example, a chimpanzee was infected by electrodes used 18 months earlier on a woman with CJD. In between these events, the electrodes had been cleaned three times and repeatedly sterilized with ethanol and formaldehyde vapor (35).

#### *Herpes*

Herpes simplex viruses infect along the axonal route from peripheral sites of infection (36). There are two basic forms, HSV-1 and HSV-2. Although not restricted to bodily regions, lesions from HSV-1 tends to be more common in the mouth while HSV-2 lesions tend to be genital. These viruses can lie in latent state

within the nerve cells of the ganglion, a condition which may endure for the remainder of the person's life. Rates of infection are high among certain high risk groups such as the immunosuppressed and those who have multiple sex partners. The rates are also high in many developing countries reaching about 90% of all young adults. Even among the affluent of developed nations seropositive rates can be as high as 60% after the third decade of life.

Direct contact is needed for transmission. In most cases active ulcerative lesions are the primary source of transmission. Viral particles may also be shed in saliva or from the skin in asymptomatic individuals, although at a much lower rate than from the lesions. Outbreaks in hospitals have been reported although appear to be traceable to failure to wear gloves, breakage of gloves or failure to wash hands (37,38). While no information is available as to its persistence following the death of the host, universal precautions such as gloves and faceshields should prevent the contact to mucous membranes or abraded skin necessary for transmission.

#### *Smallpox*

Smallpox is induced by the variola viruses and is primarily confined to humans (39). The natural transmission is rapid and appears to require close contact with a symptomatic person. Mortality rates vary between 16 and 30%. The last known natural case of the disease was reported in 1977 and, in 1980, the World Health Organization declared this disease eradicated. Today only small samples are maintained in two laboratories and WHO plans to destroy remaining stocks on June 30, 1999 (40). One reason for the hesitation in destroying the samples has been the possibility that the disease could resurface from infected material stored in human remains (41).

In that there have been no cases since the last natural transmission, it is highly unlikely that smallpox will be readily transmissible from dead tissue. Examination of scabs from known infected persons revealed very little virus after 30 days (42). Darkness extended the viral survival although rarely beyond three months. Similar studies reported by Zuckerman (43) showed destruction of the virus in scabs within one year after collection. In a single case, however, it was retrieved in laboratory conditions after over a year at room temperature (42). Forensically, there is little reason for concern over smallpox infection. For those anthropologists involved in archaeological excavations of smallpox victims in areas with permafrost, inoculations should be considered (43).

#### *Pathogens Encountered During Scene Recovery*

In addition to the biological agents encountered while working with human remains, other potential pathogens may be contacted during recovery operations. Universal precautions should be taken to avoid exposure to the pathogens producing these diseases and to the vectors which harbor and transport them. Additionally, forensic anthropologists should have a knowledge of symptoms and transmission routes of these diseases and should prepare in the event of contact.

In recent years, a new family of viruses has emerged, the Filoviridae, which cause rapid-onset, severe hemorrhagic fever and often death in humans (44). Death often occurs within 7 to 16 days, usually from shock and severe blood loss. There are no treatments except prevention and treating complications of the disease. The family contains Marburg and Ebola, which have come to prominence through actual or fictionalized outbreaks. Marburg was first

identified in Europe after laboratory workers became infected from monkeys from Africa (45). Ebola was identified in 1976 after outbreaks in Zaire and Sudan killed well over 50% of all infected individuals. A reemergence of Ebola in Africa in 1995 left 244 people dead and a mortality rate of 77% (45).

Both Marburg and Ebola are transmissible through bloodborne contact, and are thus a concern to the forensic anthropologist working in areas where such diseases may emerge and when working on remains where soft tissue is still present. Feldmann and Klenk (45) cite the preparation of bodies for burial as a major risk factor for contracting Ebola. Infection also can occur through respiratory transmission (46). No studies on the longevity of the viruses are yet available.

An additional concern for the forensic anthropologist comes from members of the family Arenaviridae including Lassa; Junin; Machupo; Lymphocytic choriomeningitis virus (LCMV); and Guanarito. All can cause rapid-onset hemorrhagic fever, often leading to death (47). Forensic anthropologists are at risk through exposure to direct contact with blood or secretions from an infected person or the animal vector (e.g., rodents) when working in field conditions (47,48). Bloodborne infection has been demonstrated for Lassa. Improper sterilization procedures and person-to-person contact has led to outbreaks. Such risk probably applies to the other diseases of the family. Aerosols may be involved at low humidity where the virus has been shown to be stable.

Two of the primary sources of infection in the more isolated regions in which many human remains are recovered include components of the soil itself and a variety of insect and rodent vectors. Fungal infections are a commonly encountered danger. In the United States, these include primarily *Histoplasma capsulatum* found in the Midwest (49,50) and *Coccidioides immitis* found in the Southwest (51). Histoplasmosis usually results from exposure to inhaled dust in areas contaminated by bat or bird excreta. Coccidioidomycosis or "valley fever" results from infection from fungi located in the soils of arid regions. It often afflicts archaeologists, hunters, farmers, and construction workers but has also shown recent outbreaks associated with earthquakes and climatic changes (52,53). Most fungal infections are asymptomatic in the majority of cases but for 10 to 40% of cases, flu-like symptoms or more severe respiratory distress may occur. Those who are immune-compromised are most susceptible.

Ticks are a common vector for disease. Lyme disease is produced by *Borrelia burgdorferi* spirochetes carried by ticks, primarily species of *Ixodes*. The larvae and nymphs feed on small rodents and birds while the adults feast on deer or other larger mammals including humans (54,55). The spirochete appears to move within the tick during the first two days of feeding and primary dissemination occurs during the third day as the tick salivates into the attachment site. Monitoring of body surfaces for ticks and prompt removal is essential. Clothing which limits access by ticks to easily monitored areas is also helpful.

One of the most significant deadly diseases encountered during scene recovery in the United States is hantavirus. Hantaviruses, disease agents known to cause hemorrhagic fever, are transmitted by rodents. Like other hemorrhagic fever-causing viruses, hantaviruses can cause high fever, headache, muscle pain, and sometimes edema and hemorrhaging leading to death. It is likely that the viral agent is endemic to certain areas of Europe and Asia, and has remained so for centuries (56). A North American form, known as the Sin Nombre virus (SNV), appears to primarily affect the pulmonary system rather than having the renal focus of the Eurasian forms. SNV has a mortality rate which is ten-fold higher

than found in the Old World (57). Epidemiological research revealed that this disease is endemic among many American rodent populations producing human victims in at least 21 states (58).

Hantaviruses are transferred to humans through direct contact with soils laden with rodent excreta (including urine, saliva, and feces), although aerosol transmission is suspected in some cases (56). Person-to-person transmission or infection through contact with infected tissues appears highly unlikely (59). No evidence is yet available on the longevity of this pathogen outside the host.

Frequently rodent nests are investigated in the course of scene investigation as they are a frequent repository for small skeletal elements and associated cultural items such as jewelry (60). Since this disease was identified in soldiers of the Korean War, anthropologists may come in contact with this disease in the soils or packing materials associated with the bones of Korean war dead.

Other disease are also potential hazards during scene recovery due to the presence of endemic conditions within local populations and colleagues, contaminated water, or insect and animal reservoirs. A wide range of diseases are represented within this group with a variety of transmission modes, latency periods and virulence and includes viral hemorrhagic fever, malaria, human granulocytic ehrlichiosis, and human T-lymphotrophic virus type I.

### Chemical Exposure

In addition to the hazardous biological agents, procedures in the laboratory often involve exposure to chemical hazards. Toxic chemicals cause damage to living cells with exposure to only minute amounts. Rates of absorption, metabolism and elimination vary by substance, by individual, by individual level of exertion, and by the mode of entry. Chemicals can affect the body in a number of ways, sometimes mimicking effects of endogenous substances while other times incapacitating or destroying tissues they contact. The entry route is most often through the respiratory tract and irritation damage can occur from the nasal passage through to the pulmonary alveoli. Skin and eye contact also may allow entry as can inadvertent consumption of toxic chemicals. Other laboratory substances may present hazards due to flammability or explosive characteristics.

Preventative measures depend on limiting the duration of exposure and the concentration of the chemicals. This combination is the "rate of exposure" (61). The body usually attempts to eliminate those substances accumulated during the course of exposure. Some such as formaldehyde are rapidly eliminated while others can be highly resistant. Even those which do not accumulate can produce significant damage at the sites where the metabolism and elimination occurs, particularly in the liver and kidneys. The chronic effects may have a latency period of many years. These consequences may be carcinogenic or mutagenic and linking individual cases to periods of exposure can be extremely difficult.

Laboratories vary in the number and amounts of chemicals they use. Thin-sectioning materials such as "hobby-store" resins may be relatively innocuous while other embedding materials, such as methyl methacrylate, are not only carcinogenic but also liable to explode. Bodies for examination may be embalmed or be preserved in chemicals to slow down the process of decay. Specialized training in the preparation, handling and storage of these materials is essential. Similarly, facilities for containment and plans for spillage should be in place. In this paper, chemicals associated with cleaning and preserving of remains will be discussed explicitly. Other chemicals should be investigated through the appropriate supporting documentation and institutional environmental health and safety officers.

### *Cleaning of Skeletal Material*

Common laboratory procedures dictate cleaning skeletal material in a couple of different fashions. These often separate along the lines of whether bones are chemically preserved or not. Nonpreserved remains are often treated with a solution of Alconox detergent and water or ammonia. Neither solution will inactivate biological agents effectively. For cleaning preserved remains, an extremely caustic solution of sodium carbonate, sodium hypochlorite, sodium hydroxide and water is often used (62). This solution is then heated to a low boil with the specimen for about 2 h. The combination of high heat with cleaning solution will most likely inactivate biohazardous materials. This substance is, however, corrosive to both the bones and the anthropologist and should be prepared and handled with caution. All work must only occur within the confines of a fume hood and with appropriate face and hand protection. Other suggested cleaning fluids for preserved material include 3% hydrogen peroxide soaks for 24 h. Although this has been found to be less than successful on preserved material, it does make an excellent degreaser of nonpreserved material. Disposal of contaminated fluids must be accomplished through authorized agencies.

### *Formaldehyde*

Formaldehyde (HCHO) is a colorless although pungent gas present in a wide variety of manufactured products but its sterilizing properties make it an important component of the embalming process. Formaldehyde appears commonly as formalin, a mixture containing 30 to 50% formaldehyde and 10 to 20% methyl alcohol in water (63). When cases involving exhumed bodies are examined, exposure to formaldehyde becomes a problem for the anthropologist. Similarly, decomposed bodies may be treated with formalin powders in order to inhibit putrefaction.

Formaldehyde overexposure is known to cause irritation of the eyes, nose, throat and skin and, in some individuals, allergic reactions and asthma (64–66). Concentrations as low as 0.5 ppm may cause irritation to the upper respiratory system of some sensitive individuals but for most eye irritation is apparent at 1.0 ppm with nose and throat becoming affected at 2.0 to 3.0 ppm. By 3 to 5 ppm the response may increase to tearing and become intolerable. When levels increase to 10 to 20 ppm, there is often difficulty in breathing and burning in the nose and throat. At levels of 25 to 30 ppm there is usually severe respiratory tract injury leading to pulmonary edema and pneumonitis. Exposure to 100 ppm may be fatal. With prolonged exposure, sensitivity in odor recognition and eye irritation tends to diminish so that the warning signs of overexposure are lost. This substance is linked to cancers of the lung, nasopharynx and oropharynx and nasal passages in humans.

Contact with the eyes can result in corneal damage, leading to blindness. Soft contact lenses can absorb formaldehyde vapors and concentrate them against the eye, leading to ocular damage. Wearers of soft contact lenses should wear glasses on days working with or around formalin-preserved material. Since formaldehyde dissolves the natural oils in the skin, exposure can lead to excessive skin dryness and dermatitis.

Both federal and state regulations regulate the tolerated levels of exposure. New OSHA regulations drastically reduce permissible exposure limit (PEL) which includes both the short-term as well as the long-term exposure. These are based on current information and may not predict long-term consequences nor individual sensitivity. The time weighted average (TWA) limit is 0.75 ppm as an 8-hour average. This limit may be exceeded for short periods as

long as the 8-hour average is maintained. The short term exposure or ceiling limits (STEL) are somewhat higher at 2.0 ppm and indicates the maximum exposure permitted for even short periods. The National Institute for Occupational Safety and Health limits are even more stringent. Formaldehyde produces a pungent odor usually noticeable at about 0.5 to 1 ppm, already close to the maximum allowable levels.

### **Preventative Plans and Measures**

Every laboratory should have written preventative plans in place for the handling of biological and chemical hazards and require all workers, students, volunteers and investigators to read and understand these plans. These plans include descriptions of all tasks, levels of precaution, response to exposure or contamination and preventative measures as well as appropriate protective actions needed. All tasks should be examined for their potential to exposure. Even if personal protective equipment is used by the workers, situations in which a breach of these would result in exposure must be considered potentially dangerous situations. Personal liability is involved for all who maintain or supervise students or workers in the use of laboratory chemicals and all precautions must be in place to support the legal responsibility as well as the moral one.

### *Protection of Personnel*

Direct protection of personnel is perhaps the “frontline” of the precautions against exposure to a number of hazards including both bloodborne and chemical. These are designed to construct barriers between the material being handled and the living tissues of the worker while still allowing the person to work with the material.

All laboratories should have ample supplies of latex or other gloves for all workers. Gloves should be frequently checked for leakage as one study reports about 8.3% failure rates during autopsy (67). It is often preferable to double-glove when working with particularly messy material, known infected individuals, or when sharper material including broken bones may tear at the gloves. Longer gloves or arm protectors may also be appropriate. Standard latex gloves provide only about 15 min of protection when handling formaldehyde. Heavy corrosion resistant gloves often are needed for handling of chemicals. Puncture-resistant mesh gloves are also available and may be useful when working with remains entangled in torn metal such as occurs in auto, plane and train crashes.

It is estimated that as many as 17 to 25% of workers develop allergic reactions to latex, the most common form of laboratory hand protection. Symptoms usually are seen as a mild rash but bouts of asthma or respiratory shock have been recorded. Allergies appear to increase with continued exposure and are more common in those with pre-existing skin conditions (68). Hypoallergenic gloves, such as those of nitrile or vinyl, can be used by those who suffer latex allergies or cotton liners may serve to prevent contact between the latex glove and skin.

Lab coats, masks, goggles, and face shields should be appropriate for the level of exposure. During normal exposure, workers should wear cotton or polyester lab coats. Once soiled, these should be placed in clearly labeled containers and held for routine laundering by an agency certified for this type of work. Disposable, non-permeable garments such as Tyvek suits should be available when higher exposure is expected. Dress should include garments which provide coverage of the legs (i.e., trousers rather than shorts) and closed-toed shoes.

With infectious material or chemical exposure, more stringent precautions may be needed. Filtering of all air inhaled by the workers can be accomplished by respirators. Air is drawn through a filter or set of filters specifically designed to trap the particles or chemicals with which the investigator is working. Adequate supplies of appropriate filters should be on hand as each has a limited use life. Respirators consist of either a full-face or half-face covering which is airtight. Powered air-purifying respirators are also available. Prior to fitting, each person must have a respiratory check to ensure that their respiratory function is sufficient to allow correct function of the respirators. Each person must be individually fitted and tested for correct size and seal of the respirator. Tests include ability to establish and maintain a seal while breathing normally, moving the head, and talking. Since these must be in contact with skin, facial hair or jewelry may be a problem. Once fitted, most respirators will allow exposure up to ten times the permissible exposure limits (64).

Although light surgical style facial masks may also be used in some laboratory settings, these are not an adequate substitute for a respirator when working with potentially infectious or toxic material. For example, in the face of tuberculosis infection, surgical masks have proven insufficient and properly fitted respirators with high-efficiency filters are required by OSHA (69). Formaldehyde also dictates the use of respirators with formaldehyde specific filters if adequate ventilation such as vented autopsy tables cannot be established. Respirators with appropriate filters may be the best means of avoiding exposure to fungal pathogens during scene recovery. Working in respirators can be tiring and may shorten the total work time.

All forensic anthropologists, workers, and students with repeated contact with human material should be vaccinated against the range of infectious agents. All personnel should have an adult basic immunization series. Immune globulin (aka gamma globulin) injections prevent infection with Hepatitis A for a period of about two years, although injections are now difficult to obtain. Tetanus boosters should be updated regularly (about every two years), and after percutaneous injury. Vaccines against Hepatitis A, B (see below), C, and D are also available and should be obtained if appropriate. Hepatitis D requires concomitant hepatitis B virus infection so vaccines against the latter can be effective preventative measures. For those anticipating work on smallpox victims where there may be frozen or otherwise preserved virus, vaccines should also be obtained for this disease.

Inoculations against Hepatitis B, in a series of three injections over a six-month period, protect against the virus with a 90 to 98% effectiveness. Long-term assessments suggest that vaccines are able to mount an immune response up to ten years after vaccine (70) although booster shots after this period are usually recommended (71). This vaccine is prepared from recombinant DNA eliminating risks of contamination from other pathogens. The vaccine must, by OSHA regulations, be available without charge to all workers exposed to blood or other potentially infectious material and this preventative measure is an excellent investment for the anthropologist and all students involved in handling human remains. Occupational exposure will often guarantee the willingness for health insurance or university health services to cover the cost for non-employed personnel. Indeed, it has been recommended that immunization become universal. Periodic testing for maintenance of immune response is also warranted and booster shots may be required at about 10-year intervals. Those who decline vaccinations should indicate so in writing and these records

must be maintained by the laboratory. It must be understood that they may, at a future date, reverse their decision.

#### *Laboratory Management for Safety*

Laboratories capable of handling forensic cases for anthropological analysis are expensive to establish and maintain and require institutional commitment. In addition to the secured facilities needed for the maintenance of evidence, health and safety also dictates the equipment needs. Freezers must be sufficiently large to contain remains and should also be capable of maintaining temperature ranges of below 10°F. They should also be placed on emergency power circuits, preventing disastrous situations in power outages. Such temperatures prevent decay, which may be important in determining the postmortem interval. They are also important for eradicating some insects which may be disease vectors, although many anthropologists have marveled at the superb recovery powers of maggots even after long exposure to freezing temperatures.

Regulations necessitate significant improvements in workspace ventilation and special equipment for safe handling above that commonly found in anthropology laboratories. Fume hoods and vented autopsy tables are required to handle material treated with formaldehyde as well as many chemicals used in embedding tissue. Monitoring of formaldehyde levels during the performance of normal tasks should be performed to test the adequacy of the established procedures. Ventilation equipment should be periodically checked to ensure that adequate airflow is maintained. Sliding glass doors can be used to partially shield the operator, providing needed protection to the face while pouring or mixing chemicals. Since cooking of materials is frequently conducted in these facilities, the floor and walls of the equipment must be capable of tolerating relatively high levels of heat as well as being supplied with either gas or electrical outlets.

When working with autopsy or Stryker saw, precautions over the production of aerosol need to be taken. This is critical given the recent findings on distribution of infectious particles such as those for tuberculosis and hepatitis B during autopsy (15,25–26). Such preventative measures should include cloaking the areas to be cut with clear plastic with cutting occurring inside the plastic or providing appropriate respirators for all personnel in the area.

Facilities for washing hands should be adjacent to workspaces, as should emergency eyewashes and showers. These should be tested regularly to prevent sedimentation in the plumbing. Antibacterial soaps and antiseptic towelettes are useful although should not be seen as completely effective. A dispenser with single-use towels or hot-air drying equipment is also necessary. Showers should either have a self-contained collection system or be without drains to allow for retrieval of contaminated water prior to entry into the sewage system. Absorbent booms are available to help prevent dispersal of water over a wide area.

Established and acceptable methods of handling and disposal of sharp instruments such as scalpel blades and dissection pins must be enacted within laboratories. Clearly labeled, leak-proof, puncture-resistant red containers for disposal of sharps are needed in every laboratory where scalpels, needles or pins are used. Students should be instructed in the safe insertion and extraction of scalpel blades to handles. Contaminated sharps containers should be disposed of by incineration or other authorized means. Sharps should never be broken or sheared as a means of disposal. Uncontaminated sharps should be placed into clearly labeled containers, and these containers may then be placed in the regular trash. Plastic wrap

or other nonpermeable disposable material can be used to cover work surfaces but should be changed whenever contamination or potential for contamination has occurred. Decontamination of surfaces with a bleach solution (1 part bleach:9 parts water) or other germicide should be routinely practiced.

First aid materials must be readily accessible for all workers, including those who may have difficulty reaching or opening storage containers. Every laboratory should be supplied with a telephone to summon assistance and to report both exposure and contaminated environments in the event of an emergency.

One of the most effective methods of eliminating accidental exposure is through proper labeling of laboratory hazards. All laboratory entries should be marked with biohazard, chemical, or radiation hazard labels telling occupants about hazards within and restricting access to authorized personnel. Areas or containers containing formaldehyde should be clearly labeled as such and informing that this is an irritant and cancer hazard.

For all chemicals used in the laboratory, there must be corresponding material safety data sheets (MSDS) located in the lab where the chemical is located and used. These forms provide detailed information on the chemical, its identification, hazardous ingredients, physical characteristics, reactivity, flammability, routes of entry, health effects and, what to do upon exposure or spillage. Information on appropriate protective clothing and equipment is also on the MSDS. All employees, students, and volunteers should have appropriate training on how to understand MSDSs.

General rules for all workers in the laboratory include avoidance of consumption of food or beverages in laboratory areas. Smoking, already banned inside most buildings, should be prohibited as should application of cosmetics or lip balm or the insertion of contact lenses. Food should not be stored in refrigerators, freezers or other storage places used for biological or chemical storage. All such facilities should be clearly marked as unsuitable for food storage.

Disposal of waste should follow mandated procedures. Known CJD infected material should be containerized and incinerated. All instruments in contact with formaldehyde-fixed non-formic acid-treated tissue should be decontaminated, not by autoclaving, but by immersion in 2N NaOH for 1 h (34). Histology samples should be soaked in formic acid for 1 h followed by fresh 4% formaldehyde. Excess formaldehyde and formaldehyde contaminated body fluids and material must also be disposed of separately and in an authorized manner. Chemical wastes should be processed according to the federal and state regulations for each substance. Soft tissue should be stored in frozen condition in clearly labeled orange or red biohazard containers for incineration by a licensed provider.

Evacuation plans for all laboratories should be posted in designated areas, detailing evacuation routes and places where personnel will meet in the event of an emergency evacuation situation. Emergency survival kits also are useful and should be available in laboratory units, particularly in areas where natural disasters such as earthquakes, floods and tornadoes may isolate workers.

Since training of all students and workers is an integral part of this program, regular training sessions are often required. All laboratory workers as well as the managers and principal investigators should be certified in first aid and CPR. Training sessions in bloodborne pathogens, chemical hazards and personal protections are also important. Safety records of the laboratories should be carefully maintained. Adequate computer capacity for the maintenance of laboratory records is essential. All biohazards and chemicals stored and used in the laboratory should be under inventory control so that, at any point in time, the hazard distribution can

be plotted. All instances of injury and records of the response should be included. These should be maintained for a minimum of 30 years, since the latency periods for some diseases exceed 20 years. It is important that these be preserved in a variety of storage media including a written copy. Computer records may quickly become nonrecoverable due to changing technologies.

The time demands of meeting such measures is readily apparent. Staffing by a laboratory manager who monitors safety, training and compliance of laboratory personnel, students and volunteers is essential. This person is responsible for identification of tasks by level of hazard exposure and the appropriate protective measures. They must ensure that adequate safety supplies are on hand and instructions for each task explicitly determined. This person also should maintain contact with the institutional Environmental Health and Safety office.

#### *Assessment of Biohazard Level and Appropriate Precautions*

Universal precautions, a term used to designate a basic level of preventative care, include the use of some personal protective equipment for all workers who handle soft tissue, blood or other bodily fluids. Many institutions also require such precautions with the handling of any nonarchaeological or nonpreserved material. These precautions include nonpermeable gloves. Hand washing is required after gloves are removed or when any area is contaminated. Lab coats or other overgarments should be worn. Either disposable or commercially cleaned garments are necessary when risk of gross contamination is present. Soiled clothing should be removed as soon as practical. Eye protection devices such as goggles or face shields should be used when the potential for generation of splashes or aerosol arise. Contaminated surfaces should be cleaned with a bleach solution. These items and supplies should be provided without cost to the user, forming a regular part of the laboratory budget. Relying on student purchases may result in less than full compliance due to the financial burden placed on students.

While such precautions may be sufficient for most situations, when there is increased potential hazard, additional measures should be taken. These increased measures, known as Biosafety Level 2, call for increased training of those involved, limited access to the work area, extreme precautions with contaminated sharp items and containment of splashes and aerosol. Specifically those with compromised immune systems may need to be excluded at the discretion of the director of the project. The principal investigator or laboratory manager may also need to restrict access based on vaccination status. Notices of the restricted access should be prominently posted. Personnel should double glove with disposable gloves and face protection should be used regularly. Overgarments should be worn only in the restricted area. Reusable equipment should be autoclaved. The general laboratory facilities should be easy to clean and decontaminate and effective insect and rodent control should be implemented.

When there are known conditions which are potentially lethal to those infected by the pathogens, the level of containment increases dramatically to Biosafety Level 3 and specialized laboratories with barriers and containment systems will be required. These requirements usually exceed the standards achievable in most anthropology laboratories.

#### *Emergency Procedures*

Once biological or chemical exposure has occurred, immediate precautions include washing the exposed regions with water for

about 15 min. Contaminated clothing should be removed. Eye exposure should be treated by emergency eyewash for 15 min or rinsed with saline eyewash solution. Coworkers and supervisors should be notified and the person or persons involved should seek immediate medical evaluation by a health worker familiar with CDC guidelines. Information on the extent of injury, source and health history of the contaminating subject should be noted. The injured party should be informed of the results of any findings on possible infectious conditions from the source. If willing and appropriate, the exposed individual should also have a blood test for serological status of HBV and HIV. Accident reports should be completed and submitted to the laboratory supervisor.

Inevitably some spills of hazardous materials will occur. Supervisors should assess whether spills can be handled by laboratory personnel or are of sufficient scale to require a dedicated HazMat team. Small spills of blood or body fluids and cleaning of areas contaminated by contact with soft tissue should be thoroughly cleaned by personnel who are equipped with full personal protective gear. If there are broken containers, heavy gloves are preferable and if the spill is extensive, water impermeable shoe covers should be worn. Any broken glass should be lifted by mechanical means such as a stiff cardboard, which can be discarded along with the broken item. Fluids should be absorbed by disposable materials which are then deposited in biohazard containers. Detergent solutions assist in the breakdown of proteins and lysis of cellular material. Bleach solutions complete the decontamination. A final rinse with water will limit the production of odors.

## Summary

The development of forensic anthropology laboratories and training programs extends far beyond determining the academic requirements. There are extensive demands in terms of facilities and maintenance which must be in place to ensure the adequate protection of the researchers, instructors and students. As the governmental and institutional regulations controlling such activities increase, it is contingent upon the anthropologist to keep pace in training and procedures to best protect all within his or her care.

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