2 Medicolegal Autopsies and Autopsy Toxicology

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MEDICOLEGAL AUTOPSIES

DEFINITION OF MEDICOLEGAL AUTOPSIES In the broadest sense, a medicolegal autopsy generates an evidentiary document that forms a basis for opinions rendered in a criminal trial, deposition, wrongful death civil suit, medical malpractice civil suit, administrative hearing, or workmen’s compensation hearing. Because any autopsy report can become such a document, all autopsies could be considered medicolegal. However, for the purposes of this chapter, a medicolegal autopsy is more narrowly defined as an autopsy that is performed pursuant to the provisions of a medical examiners coroners act of a state.

FORENSIC PATHOLOGISTS, MEDICAL EXAMINERS, AND CORONERS Ideally, medicolegal autopsies should be carried out by trained forensic pathologists—that is, experts in the physical effects of mechanical, chemical, baro-, and electrical trauma. Although the shortage in this country of board-certified members of this specialty has eased in recent years (1,2), many general pathologists still perform medicolegal autopsies.

In the States and Territories of the United States, medical examiners (22 states) or coroners (11 states) are in charge of death investigation systems, and in 11 states, both systems operate (3). In general, medical examiners are appointed by state or county governments, and are required to be physicians, pathologists, or forensic pathologists, depending on locale. Coroners are elected, and, in general, the only requirement is to be a registered voter. Forensic pathologists are employed as medical examiners and, in the more populous coroner jurisdictions, as coroners’ pathologists.

ACTIVITIES RELATED TO MEDICOLEGAL AUTOPSIES Particularly challenging are death investigations involving blunt impact to the head or neck, infant deaths, postoperative deaths, and drug-related deaths. Investigation of this last group has become easier with the advent of sophisticated methods of analysis, as mentioned later in this chapter. Medical examiner autopsies sometimes are requested by next-of-kin who are dissatisfied with the medical care that was rendered to a decedent. Life insurance companies also rely on medicolegal autopsies. Finally, both plaintiff and defense attorneys in the medical malpractice field and hospital risk managers prefer to have autopsies in as many deaths as possible.

ERRORS IN MEDICOLEGAL INVESTIGATION In many instances, a seemingly trivial error can have unforeseen disastrous consequences. Every pathologist who works in this field should benefit enormously by reading and rereading the examples given in Moritz’ classic paper (4).

Although nonforensic pathologists generally understand the purpose of the descriptive (objective) part of the autopsy report, they have little or no training in opinion formation. The essentials are set forth in the following paragraphs.

DEFINITIONS OF DEATH First, one must understand the terms “cause of death,” “manner of death,” and “mechanism of death.” The cause of death is the disease or injury that sets in motion the physiologic train of events culminating in cerebral and cardiac electrical silence. “Carcinoma of the Pancreas,” and “Gunshot Wound of the Head with Perforation of the Skull and Brain” are underlying causes of death. “Bronchopneumonia” and “Pulmonary Embolism” are immediate causes of death, being in almost all cases the consequence of underlying injuries or diseases such as Alzheimer’s disease or femoral neck fracture.

The manner of death is a pseudo-judicial classification of deaths dating back to Norman England, when the property of suicide victims was seized by the Crown. The four manners of death are natural, accident, suicide, and homicide. Natural deaths are caused exclusively by disease. Accidents are deaths in which trauma causes or contributes to the cause of death, and the harm inflicted is not intentional. A homicide is death at the hands of another person, with intent to cause harm. Suicide is the intentional unnatural death of one’s self, by one’s self.

The mechanism of death is the physiological derangement set in motion by the causes of death that leads to the cessation of cellular electrical activity. Common mechanisms of death are ventricular fibrillation, adult respiratory distress syndrome, and cerebral edema. When clinicians use the term “cause of death,” they usually mean the mechanism of death.

The cause and the mechanism of death are interrelated and one may explain the other. For example, an autopsy reveals atherosclerotic heart disease, and the toxicological studies reveal concentrations of benzodiazepines and opioid narcotics somewhat above the therapeutic ranges. If the history is that of a man who was alert, oriented, and who suddenly collapsed in view of witnesses, one may infer a ventricular arrhythmia as the mechanism and atherosclerotic heart disease as the cause of death. If, for the same set of findings, the history is that of a man who became somnolent, gradually comatose, and then had a diminishing tidal volume followed by respiratory arrest, and then a brief period of persistent cardiac activity, then one may infer that the mechanism is respiratory depression and the cause of death is intoxication by the effects of the drugs.

In a criminal proceeding, opinions must be to a reasonable degree of certainty. This means that there can be no other reasonable possibilities—that is, the opinion is beyond a reasonable doubt. Speculation is not allowed. For example, it is conceivable that the defense attorney and the pathologist in a case might be on the next space shuttle, but such a possibility is obviously speculative.

In a civil proceeding, the opinion by an expert is to the standard of probable—that is, more likely than not. Under this standard, one need not eliminate competing reasonable possibilities. It is necessary only that the competing possibilities be less likely than the favored one. Speculation is not allowed in civil proceedings either.

For death certificates, the required degree of certainty is not well-defined, but is generally understood to require a more-likely-than-not probability. In a homicide, the death certificate should meet the standard of reasonable medical certainty. Otherwise, the death certificate might be used to impeach one’s trial testimony.

In the formation of opinions, three principal errors are often made.

First, a pathologist seizes onto one particularly interesting finding but ignores equally compelling evidence that points to a contrary explanation. Unwarranted criminal or civil suits may result. Moritz described this approach as the substitution of intuition for a scientifically defensible interpretation (4).

Second, errors are caused by the failure to appreciate the distinctions between various degrees of opinion and probability. Thus, a mere reasonable possibility is introduced as if it were a probability, or a speculative idea is presented as a reasonable possibility.

Third is the failure to appreciate the unspoken underlying assumptions. In the absence of facts, they point to one opinion or another and guide pathologists in the right direction most of the time. For instance, a pathologist conducting a second autopsy must start with the rebuttable presumption that the findings of the first autopsy are correct. Likewise, in the absence of facts, or in the presence of conflicting facts, a decedent is entitled to the rebuttable presumption of a natural death for the purpose of the formation of the final cause-of-death opinion. This is perfectly compatible with an initial investigative presumption of homicide because this ensures a careful investigation. A violent death creates the rebuttable presumption of an accidental manner, as opposed to suicide or homicide.

Numerous sources describe the technical aspects of medicolegal autopsies (5–8).

**PRONOUNCEMENT OF DEATH** Failure to ascertain that death has in fact occurred has on occasion led to serious embarrassments and repercussions. The findings supporting a pronouncement of death are briefly recapitulated here. With few exceptions—for example, mitochondrial poisoning by cyanide—the vast majority of deaths are met by either a rapid cardiac mechanism or a slow central nervous system mechanism (9). Many findings are self-evident. Ordinary citizens recognize a putrefied body as being dead. Most police patrolmen recognize dependent lividity and rigor mortis. Emergency medical technicians and paramedics will usually recognize early dependent lividity in bodies that have not yet developed rigor mortis, and will opine death without resorting to a cardiac monitor. However, a still, cool body with no livor requires the demonstration of the absence of cardiac electrical activity before death is confirmed.

In practice, by the time the medical examiner arrives at the scene, enough time has elapsed that livor will be present. Medical professionals such as nurses who actually observe deaths uninterrupted by resuscitation efforts will observe the following:

1. Cessation of respiration. As a slow death approaches, the person frequently breathes in gasps. Intervening apneic periods rarely last for more than 30 s; their presence can be ruled out by extending the examination over a 10-min period.

2. Cessation of circulation. In slow deaths, the lack of a peripheral pulse does not necessarily denote cardiac arrest, and the heartbeat does not necessarily cease as soon as breathing stops (10). In contrast, in persons with a rapid cardiac death, ventricular fibrillation or asystole leads to immediate cessation of blood flow to the brain and immediate cessation of the pulse. Cessation of respiratory efforts, voluntary muscle activity, and consciousness all follow within 13 s.

**DEATHS FROM NATURAL CAUSES** Not all medicolegal autopsies deal with violent or unnatural deaths. For example, in two major medical examiner districts in Florida, 45 and 44% of deaths investigated, respectively, were found to be from natural causes wherein death occurred suddenly, unexpectedly, or in an unusual manner (11). Atherosclerotic and hypertensive vascular diseases in their cardiac and cerebral manifestations were the most common diseases causing natural deaths (12). One cannot necessarily conclude that the manner of death was natural merely because a natural disease was demonstrated, because the natural disease may be an immediate cause of death that resulted from an underlying traumatic cause of death. Table 2-1 provides a checklist of natural diseases that can be the sequelae of mechanical or chemical trauma.

**EVALUATION OF THE SCENE AND CIRCUMSTANCES OF DEATH** Investigation of the scene where the body was found may provide critical environmental evidence, allow the preservation of medicaments, and allow the medical examiner to take witness accounts that are crucial to interpreting the autopsy findings. A body thought by police to have bled from a homi-
Table 2-1  
Some Common Natural Diseases and Their Possible Violent Antecedents

<table>
<thead>
<tr>
<th>Disease</th>
<th>Possible underlying injury, acute or chronic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Central nervous system</strong></td>
<td></td>
</tr>
<tr>
<td>Meningitis; cerebral abscess</td>
<td>Fracture of skull, jaw, facial bones; injuries to middle ear, nasopharynx, air sinuses; infection introduced by surgical, anesthetic, roentgenologic, chemotherapeutic, diagnostic procedures</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>Cerebral contusion enlarged by alcoholic coagulopathy, masquerading as hypertensive bleed</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>Blunt impact to head or neck; laceration of vertebral artery</td>
</tr>
<tr>
<td>Subdural hematoma</td>
<td>Blunt impact to head from fall</td>
</tr>
<tr>
<td><strong>Cardiovascular system</strong></td>
<td></td>
</tr>
<tr>
<td>Coronary artery insufficiency</td>
<td>Emotional or strenuous physical effort related to occupation, or threat of assault</td>
</tr>
<tr>
<td>Ruptured heart valve; aortic aneurysm</td>
<td>Strenuous physical effort or blunt impact</td>
</tr>
<tr>
<td>Congenital anomalies</td>
<td>Teratogenic drugs</td>
</tr>
<tr>
<td>Seizure disorder, “Vasovagal attacks”</td>
<td>Shock; fright</td>
</tr>
<tr>
<td><strong>Respiratory system</strong></td>
<td></td>
</tr>
<tr>
<td>Pneumothorax; subcutaneous and mediastinal</td>
<td>Traumatic intubation, artificial ventilation with bag-mask, aspiration of foreign body, SCUBA diving, premature putrefaction in the setting of sepsis</td>
</tr>
<tr>
<td>emphysema; hemopneumothorax</td>
<td>Trauma, immobilization</td>
</tr>
<tr>
<td>Pneumonia; pulmonary embolism</td>
<td>Exposure to radiation; drugs; asbestos; industrial exposure</td>
</tr>
<tr>
<td>Pulmonary fibrosis; mesothelioma; pneumoconiosis</td>
<td></td>
</tr>
<tr>
<td><strong>Alimentary system</strong></td>
<td></td>
</tr>
<tr>
<td>Ruptured vissus; perforated ulcer; peritonitis; intestinal obstruction</td>
<td>Impact to abdominal wall; burns; strenuous physical effort; foreign bodies by mouth or rectum, or left at laparotomy; diagnostic or therapeutic endoscopy; paracenteses; peritoneal dialysis</td>
</tr>
<tr>
<td><strong>Fulminant toxic hepatitis; massive hepatic necrosis</strong></td>
<td>Exposure to drugs; poison, anesthetic agents; pesticides; shock</td>
</tr>
<tr>
<td><strong>Genitourinary system</strong></td>
<td></td>
</tr>
<tr>
<td>Renal tubular necrosis; papillary necrosis</td>
<td>Poisons; drugs; heavy metals; burns; shock; dehydration</td>
</tr>
<tr>
<td>Cystitis; pyelonephritis; ruptured bladder; ruptured uterus; ruptured ectopic pregnancy</td>
<td>Impact to abdomen; abortion; injudicious instrumentation</td>
</tr>
<tr>
<td><strong>Hematopoietic and reticuloendothelial system</strong></td>
<td></td>
</tr>
<tr>
<td>Hemolytic anemia</td>
<td>Incompatible blood transfusion</td>
</tr>
<tr>
<td>Aplastic anemia; agranulocytosis; thrombocytopenia; leukemia</td>
<td>Drugs; poisons; pesticides; industrial and laboratory chemicals; antibiotics</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td></td>
</tr>
<tr>
<td>Malnutrition; failure to thrive</td>
<td>Negligence; parental cruelty; eccentric or unusual religious beliefs</td>
</tr>
<tr>
<td>“Crib death”</td>
<td>Accidental or homicidal suffocation</td>
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Criminal wound may be putrefied with pulmonary purging, dead from apparent natural causes. In this situation, an opinion by a medical examiner at the scene prevents an unnecessary full-scale criminal investigation.

Physicians responsible for investigating scenes of violent death should foster police policies directed toward the end of ensuring that nothing in the vicinity of the body is disturbed before their arrival. The uninstructed patrolman will instinctively remove a firearm from the body of a suicide. On the other hand, such a policy need not be transmitted to the fire department. A well-trained fireman will pull a freshly dead, viewable body off a pile of smoldering tires, making identification easy, whereas a well-trained detective will not disturb the scene. If the medical examiner arrives at a death scene before the police technicians and detectives, masterly inactivity is required until they are ready for the body to be disturbed. In busy jurisdictions, the medical examiner is summoned after detectives have arrived, preliminary statements have been taken, and crime scene technicians have completed measurements and photographs in the vicinity of the body. In jurisdictions with few homicides, the medical examiner will often be summoned immediately by the first uniformed police officer to arrive at the scene.

The position of the body, the distribution of blood lost by the victim or the assailant, or objects in the neighborhood of the body may offer important clues for the reconstruction of the fatal events, especially in cases of blunt impact or bludgeoning, and in cases of industrial accidents. Scene investigation is much more apt to yield clues as to the approximate time of death than
is the autopsy (see below) and may help in the estimation of the interval that may have elapsed between injury and death.

Pathologists without training or appreciable forensic experience should not hesitate to secure help from statewide law-enforcement agencies. Homicide detectives and crime-scene technicians from large police departments are familiar with death-scene investigations; patrolmen and detectives from small police jurisdictions usually have very limited experience in this area.

Pathologists who do not examine the site where the body was found must rely on the written or oral reports of the circumstances of death, and photographs or illustrating sketches, if they are available. A forensic autopsy should not begin before the known circumstances surrounding the death have been reviewed. However, the quantity of information available in homicides is generally much less than that available in accidental and suicidal deaths, because the person with the best and most complete information is usually the killer, who in most cases has not made a statement at the time the medical examiner is conducting the scene investigation.

**ESTIMATION OF THE TIME OF DEATH**  The postmortem interval is determined by asking the police investigator when the decedent was last known to be alive and when the decedent was found dead. An opinion can be given with assurance that the subject died in that time frame. Because the onset of the signs of death varies widely, the physician can only in some cases opine that death occurred more toward one end of that time spectrum than the other. The physical signs that may help in this regard are described in the following paragraphs.

**Livor Mortis (Postmortem Lividity)**  After cessation of circulation, the blood drains to the most dependent vessels, and becomes deoxygenated. The external manifestation of this process is the appearance of a faint pink erythema of the dependent skin surfaces, visible after 30–60 min in bright light in Caucasians, and later with poor lighting or when the skin is pigmented.

As the blood continues to pool under the influence of gravity, a distinct purple appearance develops on the dependent surfaces. Up until roughly 12–24 h after death, the liver can be blanched by pressing a finger or instrument against the skin surface. Livor is usually absent at pressure points, such as the skin over the scapulae and buttocks in a supine body.

Then, as blood pigment migrates extravascularly, the lividity becomes fixed. In a body whose position is changed before the onset of fixation of livor, the blood will shift to the newly dependent areas. If the livor has become entirely fixed, it will not shift, and the pattern of the livor will be inconsistent with the position of the body.

**Rigor Mortis (Postmortem Rigidity)**  The maintenance of a loose, supple quality in muscle fibers requires energy in the form of adenosine triphosphate and glycogen. The low-energy state of muscle fibers is manifested by stiffness. In dead bodies, the stiffness is customarily termed rigor mortis. The strength of the rigor is entirely dependent on the mass of muscle; grading rigor as weak, moderate, and strong is a useless exercise. Thus, muscular young men who are dead have impressively strong rigor mortis that is difficult to break, whereas a frail elderly woman with little muscle mass seems to have weak rigor mortis. More important to note is whether the rigor is present or absent, and if present, whether it is oncoming, fully developed, or passing.

Rigor mortis ordinarily makes its first appearance 2–4 h after death. Its detectable appearance is hastened by antemortem depletion of muscular energy stores. Thus, vigorous physical activity or convulsions immediately before death can result in the almost instantaneous onset of muscle stiffening. Rigor may begin at identical times in two bodies, but will be apparent earlier in the body with the greatest muscle mass. It becomes fully developed in roughly 4–10 h. The onset and passing of rigor are hastened by high ambient temperatures, and delayed by cold ambient temperatures. This is most often manifested by the maintenance of rigor in bodies maintained under refrigeration. Rigor begins to fade simultaneously with the onset of putrefaction. Rigor is easily and reliably ascertained by attempting to open the mouth by pressing on the mandible. In the extremities, especially the upper limbs, rigor often has been broken prior to transportation of the body because elbows, hips, and knees had to be straightened.

**Algor Mortis (Postmortem Cooling)**  The rate of cooling of a dead body is dependent on the temperature gradient between the body and the environment; the body mass in relation to its surface area; the rate at which air or water moves across the body surfaces; and the extent to which insulation is afforded by shelter, clothing, and adipose deposits. This multiplicity of variables results in wide variation in the rate of cooling. Published tables and formulas for estimating the postmortem interval generally take into account only the temperature gradient. Such formulae seem to enjoy popularity in cool climates where most people die indoors in structures with indoor heating and fairly uniform temperatures. In Florida, where outdoor deaths occur throughout the year, the formulas are largely ignored. The author’s practice is to palpate the torso with the back of the gloved hand, and to estimate whether the body is warm, cool, cold, or at ambient temperature. In most cases, warm bodies are recently dead; or hyperthermic from sepsis, cocaine intoxication, or neuroleptic medication, or from obesity. Cool bodies of adults usually are dead for some time and often have livor or rigor mortis.

**Stomach Contents and State of Digestion**  Under normal conditions, the stomach empties a medium weight meal in approx. 3 h. Emptying time is delayed by a heavy meal. Significant cranio-cerebral trauma can delay gastric emptying for days. Carbohydrate foods such as potatoes and bread are readily dissoluted by swallowed salivary amylase. Vegetable matter and meat are recognizable for a few hours. Mushrooms seem to stand up to gastric juices the longest.
In a homicide for which the time of injury is not known, the gastric contents not needed for toxicologic analysis can be strained and rinsed to facilitate naked-eye identification of food matter. The information gained can be correlated with investigative information to help establish whether or not the decedent was alive at certain times or present at certain meals.

**Autolysis**  Within 3 or 4 h after death, the corneas begin to cloud. This effect is most useful in determining whether or not death was very recent. The degree of cloudiness is of no real use. Corneal clouding is extreme in burned bodies, in which the corneas have been baked. Such high temperatures tend to render all irises a cloudy blue, regardless of the initial color.

Skin slippage, or postmortem blistering, is a sign of autolysis that develops simultaneously with putrefaction. But under subtropical sun, or if the skin is near a heat source, slippage can be evident within a half hour after death.

**Putrefaction**  Putrefaction is caused by the migration of bacteria from the gut into the blood, where they multiply, consume the blood, and produce a variety of gases as metabolic products. The volume of gases produced can be enough to float bodies that have been tied down with iron weights. In most cases hydrogen sulfide is produced. This gas combines with the iron in hemoglobin and myoglobin to produce black-green discoloration of the blood, viscera, and cutaneous livor. The earliest visible effect of putrefaction is often blue-staining of the skin of the right lower quadrant of the abdomen, over the cecum, and black staining of the inferior aspect of the right lobe of the liver, adjacent to the hepatic flexure of the colon. Because putrefaction follows the blood, it is most pronounced in areas of dependent lividity, where it first manifests as ruddy and then green-black marbling, also termed venous suggillations. With fully developed putrefaction, the face and genitalia become grotesquely swollen with gas, the eyes bulge, the skin acquires extensive green-black discoloration, and a foul putrid odor becomes evident. The body cavities are filled with putrid gases under tension, which escape with a rush when the cavities are opened. The soft tissues and viscera are softened, darkened, mottled, and riddled with gas bubbles.

Exsanguination removes the principal nutrient source for bacteria and greatly retards putrefaction. In temperate climates, putrefactive changes begin to be evident roughly 3 d after death. In subtropical climates, they can be evident within 24 h. Putrefaction is hastened by obesity, because the viscera are insulated from cooling; and delayed in infants, whose bodies cool rapidly.

**Mummification**  When the body cools rapidly, the warmth needed to sustain putrefactive bacterial growth is denied. The ears, nose, lips, toes, and fingers, and in extreme cases, the calves and forearms shrivel and darken as the water content evaporates from the tissue. This change is of little use in determining the postmortem interval. Mummification is more common in children and small-framed adults, and in a cold or dry environment.

**Adipocere**  This substance is a rancid semisolid product of fat decomposition. Adipocere is found most often on bodies which have decomposed without having been exposed to air. Its presence is not useful in determining postmortem interval.

**Entomologic Evidence**  Dead bodies attract flies, which lay eggs, particularly near the eyes, nostrils, mouth, genitalia, and wounds. The eggs hatch into larvae, which are popularly termed “maggots.” Maggots consume soft tissue, leaving behind bone, cartilage, gristle, and some but not all of the dermis. The maggots molt one or more times, going through stages of development termed “instars,” and finally crawl off the body to pupate in nearby soil. The maggots are eaten by other insects. When the soft tissues have been largely removed and the partly skeletonized remains have dried somewhat, beetles move in to consume the cartilage, gristle, and dried dermis. The order of their appearance depends on the local fauna present at that particular time of year. Maggots mature more rapidly in warm weather. A forensic entomologist can make these interpretations, but generally requires baseline data for the local area, including the time of appearance of local species, and data on temperature ranges. An entomologist can narrow the date-of-death window down to a few days in some cases, whereas the forensic pathologist working with the signs of decomposition can only give broad estimates of numbers of weeks or months in cases of advanced decomposition.

**Chemical Evidence**  Mathematical formulas have been devised to estimate the postmortem interval from the concentration of nitrogenous compounds in cerebrospinal fluid, and from potassium in vitreous. In practice, the formulas produce wider time frames than are provided by acquiring from the police the times last known alive and found dead, and are of academic interest only (13,14).

**IDENTIFICATION OF THE BODY**  A Polaroid photograph of the face is useful for the purpose of identification of a viewable body by friends or relatives. Burned bodies often have one or two printable fingers, and may be identifiable by dental comparison or comparison of antemortem and postmortem somatic roentgenographs. Dismembered bodies that are recovered piecemeal require the separate identification of the major elements. The head can be identified by dental comparison or plain roentgenographs, which portray the unique outlines of the frontal sinuses. The upper extremities can be identified by fingerprinting. The torso can be identified by chest, abdominal, and pelvic roentgenographs, if antemortem films exist. Virtually any part of the body can be used for a DNA match. Serologic studies, performed by the crime laboratory, can differentiate human from animal blood or tissue.

Fingerprinting may become difficult if the skin is shriveled, macerated from immersion, or charred. If there is no ridge elevation, but the pattern is visible, the whorl pattern can be photographed with a macro lens. If there are ridges, but the fingerprint pads do not roll well because of maceration or desiccation, the fingerprint pads can be built up with injectable compounds, including formalin, found on the shelves of all funeral directors with embalming facilities.

Blood typing will be done by the crime laboratory in cases of serologic interest, such as bludgeonings. In criminal cases with no immediately perceived serologic interest, such as homicidal gunshot wound deaths, it has been the practice of the author’s office to have the crime laboratory do preliminary typing, and prepare a blood stain on filter paper. The paper is then stored long-term at room temperature, and the tube of blood is discarded according to local policy.
Sex determination can be made from most skeletal remains from the contours of the pelvis and skull. Age determination can be based on evaluation of epiphyses, laryngeal and sternocostal cartilages, sacral, hyoid, and cranial bone sutures, and the condition of joints and teeth. Stature is reconstructed by anthropologic measurements and formulas (15,16).

THE FORENSIC AUTOPSY PROTOCOL To ensure that all details, no matter how irrelevant, are captured, the protocol can be dictated concurrently with the progress of the autopsy. However, many experienced pathologists make notes on a body diagram and dictate the external and internal examinations only after the completion of the internal examination. This style tends to produce a concise, well-organized prose narrative.

If the protocol is dictated directly at the time of examination, and there are no handwritten notes, it should be promptly typed and proofread. If notes have been made, the need for a prompt proofing is still apparent for lengthy protocols with multiple gunshot wounds, or combinations of injurious modalities, such as impact, strangulation, and stabbing. The most common error made by experienced pathologists is the transposition of the words “left” and “right.”

Because it is the testimony that is offered into evidence at trial, and not the autopsy report, mistakes in the protocol can be corrected at any time. However, the concerned attorneys must be notified immediately of any change that affects an opinion. If a change is cosmetic, it is sufficient to notify the attorney who has called the pathologist, just before the pathologist takes the witness stand. The attorney can choose whether to elicit testimony concerning the change on direct examination, or to ignore it. The subjective and objective sections of the protocol should be clearly separated from each other. The subjective portion comprises the cause of death opinion, the diagnoses, and the prose summary and opinion if there is one. The objective portion comprises the macro- and microscopic descriptions.

The gross protocol should contain objective descriptions with which no reasonable, trained pathologist would disagree. No revision of the gross description should be necessary after the microscopic slides are reviewed and further medical history and investigative information becomes available. Diagnostic terms may be used if the diagnosis will never be in question. For instance, if the lungs have obvious bronchopneumonia, and it is clear that the diagnosis will not be changed by subsequent microscopic studies, the end of communication is best served by including the term “bronchopneumonia” in the description of the lesion.

The opinion section, which includes the cause-of-death opinion, the line diagnoses, and any prose opinions, should be clearly labeled as opinion. The opinions contained in this section are based on all the available information, including medical history and circumstantial information. Unlike the data in the gross protocol, which should never change, the opinions can change if there are changes in circumstantial and historical information on which the opinions are based.

Identifying features must be recorded in detail for bodies that are unidentified “John Does.” In contrast, a brief mention of iris color, hair color and distribution, facial hair, and significant scars is adequate for bodies for which identification is not in question. For instance, this author is satisfied to describe the lengths of scars as small, medium, and large in relation to the involved body regions for identified bodies.

Descriptions of endotracheal tubes, central venous catheters, and other devices of therapy are best clustered in a single paragraph that has both the external and internal aspects of the descriptions of the locations of the devices. For instance, “An endotracheal tube runs from the mouth to the trachea.” The observations in this paragraph need not be repeated in the external and internal sections of the report.

Finally, the protocol should contain another separately titled section for all the external and internal data on any penetrating wounds, such as gunshot wounds and stab wounds (17). I use the same device for blunt impact wounds, with separate sections for head and neck, torso, and extremities. The wound descriptions are not repeated in the customary sections for external examination and internal examination.

Measurements are made metrically or in the English system, depending on the purpose to which the measurements will be put. Lesions caused by disease and anatomical measurements of interest only to physicians should be measured metrically. Wounds can be measured metrically or by the English system, at the discretion of the pathologist. The author measures wounds metrically, unless the wound is patterned, and is being matched to an impacting object that was manufactured to English system specifications. However, the old axiom that wounds must be measured in inches no longer holds; jury pools now contain citizens educated in the metric system.

In the United States, distances between wounds and anatomic landmarks such as the top of the head, the median sagittal plane, and the soles of the feet should be recorded in inches because police investigators will be using feet and inches to measure the distances between bullet holes in walls and floors.

In the USA, body length and weight should be in the English system, because the parties who use this information are most often attorneys. Readers of the autopsy report who must perform physiologically oriented calculations based on body weight or length will be capable of converting the English measurements to metric measurements.

Measurements should be preceded by a qualifying adjective to indicate whether the number is actually measured, or is estimated (e.g., “A measured 1200 mL of dark red clot is in the left pleural cavity,” “A measured 85 grams of clot is in the subdural space on the left side,” “An estimated 100 mL of liquid blood is in the retroperitoneal soft tissues,” “An estimated 50 grams of the heart weight is attributable to increased epicardial fat”). Blood accumulations in the retroperitoneal or mediastinal soft tissues must be estimated because they cannot be measured by any reasonable means.

For organ descriptions, terms such as “Normal,” “Unremarkable,” and “Within normal limits” may be used, but a reviewing pathologist will have more confidence in the report if the normal organs are briefly described, e.g., “The myocardial cut surfaces are the usual red-brown.” The written description of external wounds should be supplemented by sketches on pre-printed diagrams and by photographs. Suitable diagrams of the external surface anatomy, the skeleton, dentition, and
organs are available from the Armed Forces Institute of Pathology. Diagrams are particularly useful in jogging the memory while reviewing old cases, because they depict the wounds not as the camera saw them, but as the pathologist perceived them.

The availability of roentgenographs varies with the equipment and personnel of the facilities in which autopsies are conducted (see Chapter 12). In addition to roentgenographs for the detection of foreign objects in penetrating wounds, the author routinely takes chest roentgenographs to detect venous air embolism in all victims of traffic crashes who are dead at the scene or around the time when they arrived at the hospital, and all victims of penetrating neck trauma. The common portals of air entry are dural sinuses lacerated by skull fractures, and penetrating wounds of the jugular and subclavian veins (18).

It is useful to have an internal scale near a lesion being photographed to get a sense of scale, but the internal scale cannot be used to measure the lesion in the picture, owing to the distorting effect of photographing a curved surface. Attorneys have at times raised the question of what lesions might be obscured by the scale, so it is good practice to have a companion photograph without a scale or other objects.

THE CHAIN OF CUSTODY In all criminal or noncriminal cases, medicolegal or hospital-derived, the chain of custody of the body should be documented by a record that includes the names of the transport driver, the log-in technician, the log-out technician, and the driver for the funeral home to which the body is released; and the dates and times of each transfer. Care must be taken that no one tampers with the body without authorization. If possible, a lock should be put on the cooler in which the body is kept.

Likewise, a record of the chain of custody must be kept of physical evidence such as bullets, hair and fingernail exemplars, trace evidence, and toxicologic specimens. (For the chain of custody of toxicologic evidence, see also below under “Autopsy Toxicology.”) Such material should be saved in containers labeled with the case number, the name of the deceased if known, the date the specimen was impounded, the name of the deceased if known, the medical examiner.

Bullets can be inscribed on the base or nose, but not on the sides. Any mark or symbol serves to take a bullet out of the legal category of fungible items. Pathologists in court frequently recognize their bullets not by the faded, tarnished marks made months before, but by the writing on the evidence envelope or by comparing the bullet to photographs taken of the bullet before it was sealed in the evidence envelope. The author routinely photographs all removed bullets with a macro lens.

THE EXTERNAL EXAMINATION When available, clothing from victims of gunshot wounds and pedestrians struck by vehicles that fled the scene should be examined for soot and gunpowder, and transfer of paint and trace evidence, respectively. Victims of bludgeoning, brawls, and strangulation should be examined for transferred hairs and fibers before the body is stripped and cleaned. Clothing can be examined at the scene and placed into police custody, or transported on the body to the autopsy facility and re-examined in good light, at the discretion of the pathologist. For apparent natural deaths, the clothing can be stripped by the autopsy room technicians, and retained for later examination by the pathologist in the unlikely event that it becomes necessary.

The inspection of the external body surfaces and orifices should be sufficient to detect old suicidal wrist scars, partial finger amputations, needle tracks, conjunctival petechiae, cutaneous contusions, and open wounds of the hair-bearing aspects of the scalp. However, when the hair is thick and tightly coiled, perforations of the scalp are easily obscured. Cutaneous contusions are made less evident by skin pigmentation.

Roentgenographs Head, chest, abdominal, and pelvic roentgenographs should be taken before the internal examination in unviewable bodies, because they may be needed for identification purposes. If an unviewable body has decomposed severely and thus, trauma cannot be precluded with confidence, then roentgenographs of the extremities should be prepared also.

Chest roentgenographs should be obtained in cases of motor vehicle accidents with head trauma, and in victims of stabbing of the neck, to detect venous air embolism from torn dural sinuses, unless the victim has lived long enough to have had spontaneous circulation of blood. For the detection of pneumothoraces, see under that heading in Part II and below under “Internal Examination.” Pelvic roentgenographs are helpful in traffic fatalities, because they are more sensitive than the autopsy in detecting pelvic fractures. Chest roentgenographs are not needed to detect rib fractures because the autopsy is more sensitive in this regard. Likewise, roentgenographs are less sensitive for the detection of skull fractures than is direct observation after reflection of the galea and stripping of the dura. Cervical roentgenographs will show cervical dislocations that are obvious at autopsy, but are inferior to posterior neck dissection in detecting lethal craniocephalic derangements in which there is no residual static dislocation.

Photographs Photographs of external wounds should be taken with a 35 millimeter camera. Pathologists customarily use Ektachrome or Kodachrome transparency film for three reasons: the slides are small and store easily, there is no need to develop prints, and they are suitable for projection at lectures. Police customarily use print film, and develop the prints only if a court appearance is anticipated. Some pathologists and police photographers now use digital cameras.

THE INTERNAL EXAMINATION A postmortem examination should include examination and removal of the thoracic, abdominal, pelvic and neck organs, and the intracranial contents. So-called limited autopsies, which omit the opening of the skull, examination of the neck organs, or examination of the chest or abdominal organs, permit only limited opinions to be made, and are merely specimen retrievals. An autopsy conducted pursuant to statute should never be limited. It is often preferable to have no postmortem examination at all than to be responsible for an examination that cannot answer the anticipated questions.

The standard Y-shaped incision will permit a thorough examination of the anterior neck organs, and removal of the tongue (6). After retracting skin and muscles of the anterior chest, a pleural window should be created to detect pneumothoraces by scraping the intercostal muscle off the external aspect of the parietal pleura. This should be done on both sides of the anterior aspect of the chest, usually near the third ribs.
In cases of third and fourth degree burns, it is usually necessary to make a European-style midline incision to the chin, because the tissue is contracted and indurated. For the same reason, the testes must often be removed through scrotal incisions in these bodies. This is not a problem for the undertaker because these bodies are not viewable.

Layerwise examination of the anterior neck structures is desirable in all cases, and is accompanied by sequential in situ photograpy in cases of suspected strangulation. Layerwise examination of the posterior neck structures is required for traffic fatalities in which there is insufficient trauma elsewhere to account for death, or in which there is an unexplained laceration of the brainstem, or hemorrhage in the prevertebral fascia. Posterior neck dissection is necessary to rule out craniovertebral derangement in cases of suspected suffocation in traffic accidents, and is recommended in all infant deaths that occur outside the hospital. The pathologist opening an infant spinal canal for the first time may be surprised to find that the delicate and loosely supported epidural venous plexus has become so hypostatically congested that the blood has extravasated into the loose fibrofatty tissue of the epidural compartment. The absence of sprain hemorrhages in the supporting ligaments and muscles of the vertebral column permits the exclusion of the diagnosis of true epidural hemorrhage.

For special procedures for the diagnosis of arterial and venous air embolism or pneumothorax, see under these headings in Part II.

The method of evisceration should be the one with which the pathologist is most comfortable. Some experienced forensic pathologists remove thoracic and abdominal organ blocks prior to dissection (see Chapter 1) but others remove organs in sequence (Virchow’s technique), with equally good results. Many crucial observations can be made only during the evisceration. Therefore, it is important for the pathologist not to delegate the evisceration procedure. If this is neglected, an attorney might convince the judge, the jury, and the press that the autopsy was actually performed by the technician, and that the doctor merely looked at removed specimens. The helper in these cases may be called to testify, because the observations that were passed on to the pathologist are hearsay.

The order of examination of the organs is not critically important. The pathologist who does only occasional autopsies should use the same order consistently so that no change of dissection techniques is necessary. Some pathologists prefer to dissect the heart first, arguing that the most important findings in an apparent cardiac death should be brought to light first. The author’s preference in such cases is to dissect the heart last, to decrease the time interval between the observations and the recording of these observations.

EMBALMING For the autopsy pathologist, embalming is much to be desired in an exhumed body, but much to be avoided in a fresh body. Embalming involves two phases.

Arterial embalming involves the introduction of a catheter into a common carotid artery, usually the right, following which the blood vessels are flushed with embalming fluid. If the embalmer observes that the embalming fluid is not perfusing an extremity, he will expose the brachial and femoral arteries as necessary. Poor perfusion generally results from luminal obstruction by postmortem clots. In the United States, arterial embalming fluid is generally a mixture of methanol, formaldehyde, and red dye.

Obviously, embalming creates challenges for the toxicologist. After the arteries have been thoroughly flushed, there is no usable blood available. Ocular fluid, bile, and urine are available as liquid specimens, but will have artificial concentrations of methanol appearing in the gas chromatograph. Technical problems abound in these situations.

Arterial embalming produces soft formalin fixation and artifactual pink coloration of the tissues. It produces artifactual effusions in the body cavities, and hardens intravascular clots.

At the same time, it induces contraction of the tunica media in the walls of blood vessels, which then contract around any post-mortem clots, producing an appearance similar to or indistinguishable from that of a distending thrombus.

Trocar embalming involves the introduction of a sharpened hollow metal pipe through the abdominal wall. The trocar is used to aspirate any liquids and to inject cavity embalming fluid; this fluid has no dyes, and usually has more methanol than does the arterial fluid. After trocar embalming, the liver, stomach, mesenteries, and loops of bowel have numerous perforations. The lungs and heart generally have fewer perforations, depending on the diligence of the embalmer. The tissue along the perforations is firm and gray, unlike the tissue fixed only by the arterial embalming fluid. The perforations of the diaphragm and pericardial sac produce communication paths among body cavities. The body cavities can contain substantial formalin collections mimicking effusions. More troublesome are real effusions and blood collections that are diluted by the embalming fluid. Fixed feces is often found floating in the peritoneal fluid.

The practice of permitting arterial embalming before an autopsy is mentioned only to discourage it. At the Mayo Clinic, where the autopsy suite includes an embalming room, the neck organs are removed after arterial embalming has been accomplished, which facilitates the work of the embalmer. Embalming before examination of the neck organs should not be permitted for medicolegal autopsies.

EXHUMATION AND OTHER SPECIAL PROCEDURES Recently exhumed bodies differ from the embalmed bodies described above only by the presence of colorful growths of mold on the skin surfaces. The internal findings are similar to those of yet-to-be-buried embalmed bodies. Long-buried bodies have variable degrees of decomposition, and can be virtually skeletonized. Many special procedures, from “Abortion” to “Strangulation” are listed in Part II in alphabetical order of the condition.

AUTOPSY TOXICOLOGY Most autopsies in which toxicologic analysis is performed are conducted pursuant to statute, toward the end of determining the cause of death. For additional details, see Chapter 11.
that is helpful to further a toxicologic investigation, once poisoning is suspected (see Table 2-2). Of particular interest is the time interval between the alleged intake of the poison and the death of the decedent (20). Figure 2-1 shows that this time interval may be too long or too short to make death from a specific poison likely.

**CONTAINERS** To prevent contamination of specimens by cleaning or embalming agents, previously unused polyethylene or glass containers are preferable in most situations. With time, highly volatile compounds such as the accelerants used by arsonists will diffuse through polyethylene and escape the container. Glass containers are susceptible to breakage during transport. If glass containers are to be used, they must be washed with dichromate. Dichromate can activate the glass surface and cause adsorptive loss or low concentrations of drugs and metabolites. In the laboratory, this type of adsorptive loss is reduced by silyzation, silanization, or siliconization of the glassware prior to use. The pathologist should always be present if a funeral director obtains tissues for toxicologic study.

The label for each specimen container should state the date the material was secured, the name of the decedent, the case number, and the name of the organ or liquid sample. Samples added to containers with preservatives should be inverted several times to disperse the preservative through the sample. Samples should be kept refrigerated before and during transport to the toxicology laboratory. After analysis, deep-freeze

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**Table 2-2**  
Investigative Information Useful for Suspected Poisoning Cases

<table>
<thead>
<tr>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date deceased was last known to be in good health</td>
</tr>
<tr>
<td>Date and time last known to be alive</td>
</tr>
<tr>
<td>Date admitted to hospital</td>
</tr>
<tr>
<td>Date and time pronounced dead in hospital, or</td>
</tr>
<tr>
<td>Date and time found dead</td>
</tr>
<tr>
<td>Date, time, and content of last meal</td>
</tr>
<tr>
<td>Prescribed drugs (append medication record if indicated)</td>
</tr>
<tr>
<td>Known drugs of abuse</td>
</tr>
<tr>
<td>Suspected drug of ingestion</td>
</tr>
<tr>
<td>Symptoms: nausea, vomiting, diarrhea, constipation, thirst, loss of weight, jaundice, blindness, cyanosis, shivering, hallucinations, convulsions, pupillary dilatation or contraction, delirium, drunkenness, sweating, unconsciousness</td>
</tr>
</tbody>
</table>

*Adapted with permission from ref. (19).*
storage is preferable to refrigeration. In the future, weighing and freeze-drying may permit storage of specimens at room temperature.

**ROUTINE SAMPLING OF TOXICOLOGIC MATERIAL**

In the author’s office, it is usual practice in all autopsies to save 50 mL each of central blood, bile, urine, liver, and brain, plus available femoral vein blood up to 50 mL, and all retrievable vitreous. Approximately half the blood is placed in containers with sodium fluoride as a preservative. Sodium fluoride inhibits both bacterial growth and serum esterases which hydrolyze cocaine postmortem. If commercially available gray-top Vacutainer® tubes are not used, 250 mg of NaF can be added to 30 mL containers.

**Urine** Urine is aspirated with a syringe through the dome of the bladder after the peritoneal cavity has been opened. If the bladder is nearly empty, it can be secured by hemostats before incising the dome to facilitate aspiration of the bladder lumen under direct vision. Toxicologists often prefer urine as a specimen for enzyme-multiplied immunoassay technique (EMIT) and enzyme-linked immunosorbent assay (ELISA) drug screening, because it can be analyzed without extraction. NaF as a preservative is optional; as an inhibitor of cocaine hydrolysis NaF is unnecessary, because the immunoassays detect cocaine metabolites rather than parent cocaine.

**Blood** Central luminal blood is preferred to cavity (pleural, pericardial, or peritoneal) blood. Central (“heart blood”) specimens are aspirated from any chamber of the heart, or from the intrapericardial thoracic aorta, pulmonary artery, or vena cava. However, for a growing number of analytes, most notably tricyclic antidepressants, peripheral blood is preferred over central blood. Peripheral blood is aspirated by percutaneous puncture before autopsy, from the femoral vein or the subclavian vein. The author prefers the femoral approach in order to avoid any question of artifact in the diagnosis of venous air embolism. Peripheral blood can be obtained by a technician as soon as the body is received. If cocaine intoxication is likely, it is highly desirable to obtain this specimen in a tube with NaF as soon as possible, in order to inhibit postmortem hydrolysis of cocaine. The term, “cavity blood” is used for blood ladled or aspirated from a hemothorax, hemopericardium, hemoperitoneum, or from the pooled blood left in the common cavity after removal of the heart and lungs. Cavity blood analyses should be supplemented by peripheral blood, vitreous, or solid tissue analyses, because of the real possibility of contamination from gastric contents.

**Vitreous** Vitreous is an excellent specimen for alcohol and drug analysis. The protected location in the orbit renders the fluid less susceptible to putrefaction than blood, and the problem of site-dependent variation in concentrations in blood specimens is avoided. Two to three mL of vitreous from one or both eyes is gently aspirated from the lateral angle of the eye with a 5 mL clean syringe. The tip of the needle should lie near the center of the eyeball. The procedure is illustrated in Chapter 7 (Fig. 7-1). Forceful aspiration must be avoided because it may detach retinal cells, which cloud the specimen and give spuriously high potassium values. Before dilution, the chemist must invert the specimen 10 or 12 times to ensure thorough mixing.

**Gastrointestinal Tract** After removal of the stomach, duodenum, pancreas, and esophagus, the gastric contents are squeezed out through the esophagus, or through an incision in the stomach, into a 1-L container. A representative 50-mL specimen is satisfactory for the toxicologist, unless the stomach contents have a nonuniform slurry of solid and liquid elements, in which case a higher volume is desirable. If the solid elements seem to be fragments of medicaments, then nearly all the contents should be saved for the toxicologist, except for what is needed to strain and inspect the material to identify food matter. In suspected suicides, in which death may have followed ingestion by several hours, it can be useful to ligate a length of jejunum before removing it and draining it into a specimen container. The jejunum in such circumstances may have a higher concentration of analyte than the stomach.

The establishment of toxicity in adults cannot be done from analysis of gastric content; investigative information and analysis of tissue or body fluids are needed. Analysis of gastric content may help to establish suicidal intent and to investigate poisoning in infants. In infants, screening of gastric contents also can be used to save the limited quantities of blood for quantitative analysis.

**Cerebrospinal Fluid (CSF)** The practice of removing CSF (see Chapter 6) by suboccipital or lumbar puncture is mentioned only to discourage it. Although pathologists certainly vary in their skill levels, and some can make a clean puncture more often than not, even in the best hands blind punctures often produce blood-lined tracks that render the interpretation of posterior neck and vertebral dissections problematic. Vitreous, like CSF, is a low-protein erythrocyte-free substitute for blood, and is preferred in most situations. If CSF must be drawn, it is best taken from the cerebral cisterns after the skull has been opened is such a fashion that the leptomeninges are relatively intact and the CSF has not run out. The situation most often calling for a CSF specimen is the meningitis autopsy with no urine available for a latex agglutination test for bacterial antigens.

**Bile** Bile is aspirated by needle after the abdomen is opened and before the organs are removed. Because the mucosa of the gallbladder is lush and easily becomes ensnared in the needle tip, it is helpful to aspirate with gentle vacuum, and to use the free hand to milk the gallbladder. Bile is a useful substitute for blood when the analyte of interest is an opiate or an alcohol. In rapidly fatal opiate intoxications, the offending opiate may be detectable only in bile.

**Other Liquid Specimens** In hospitalized decedents, the highest concentrations of toxic substances may be found in dialysis and lavage fluids, if they have not been discarded after death.

**Solid Organs** Liver is the solid organ of choice when no liquid specimens are available. Reference values are available for the lethal concentrations of numerous types of drugs in liver tissue. Liver specimens from the right lobe of the liver are preferred to specimens from the left lobe, to avoid spuriously high concentrations from diffusion from the stomach (22). Brain tissue is useful for alcohol determinations in the absence of a useful liquid specimen.

In putrefied bodies, blood and bile are usually absent, and the only specimens available may be solid organs, such liver,
brain, and skeletal muscle. Skeletal muscle from the least decomposed extremity is preferred.

In fire deaths, arson investigators occasionally request specimens for accelerant analysis. For this purpose, lung tissue is sealed in an unused lidded metal can of the style used by paint manufacturers.

**Hair**  Hair is a useful specimen in suspected chronic arsenic poisoning, and may be useful in the determination of chronic drug abuse. Hair should be pulled from the scalp, to include the roots. A large sample, about 10 grams, should be tied in a lock to identify the root end of the specimen.

**Skin**  If it is suspected that a poisonous substance has been injected, the skin around the needle-puncture site can be excised at a radius of 2–4 cm from the injection site. If a poisonous substance might have been taken up by absorption, the skin is excised in the area where the absorption is thought to have occurred, and from a distant, preferably contralateral area as a control. Skin samples are saved with the expectation that the toxicologist will prefer to obtain the information necessary to opine the cause of death by first analyzing the customary liquid specimens.

**CHAIN OF CUSTODY**  The continuity of the custody of the specimens should be documented. A blank space on the specimen transmittal form (see next paragraph) can be used for tracking custody from the pathologist to an in-house toxicology laboratory.

**Transmittal Sheet**  Specimens submitted to a toxicology laboratory should be accompanied by a transmittal sheet and a summary of the investigative information as it is known at that time. The transmittal sheet contains case identifying information, a list of specimens, supplementary information necessary to select analytical methods, and signatures to indicate the chain of custody. It should state whether the body is embalmed or decomposed and indicate the duration of hospitalization (during which an alcohol or drug is metabolized). An example is in Table 2-3.

If a courier is used to transport a sealed container with multiple specimens from multiple cases to an outside laboratory, an additional, separate, single transmittal form can be devised that lists all the case numbers; omits specimen details; and has signature/date lines for the in-house technician, the courier, and the receiving clerk at the laboratory.

**METHODOLOGY**  Although the techniques of toxicologic analysis are beyond the scope of this book, a brief summary of current methods is in order.

**Volatile by Gas Chromatography**  The analyte most frequently tested is ethyl alcohol. Toxicologists in medical examiner offices generally detect and quantify ethyl alcohol by gas chromatography, as part of a general panel designed to capture numerous volatile compounds, including ethyl, methyl, and isopropyl alcohols, and ketones. Tertiary butyl alcohol is often used as an internal standard, because it does not occur naturally. Hospital and clinical laboratories most often use the alcohol dehydrogenase method, which measures oxidizing activity, is nonspecific and mainly of historical interest.

**Specific Drug Screening by Enzyme-Multiplied Immunoassay (EMIT)**  Drugs of abuse are commonly detected but not quantified by EMIT (Enzyme Multiplied ImmunoTechnique), in which the activities of selected families of drugs are measured by antibody interaction. The panels are selected depending on local drug-abuse patterns. Panels are available for cocaine metabolites, tricyclic antidepressants, barbiturates, cannabinoids, amphetamines, opiates, and propoxyphene. Not detectable are drugs present in parts per billion, such as fentanyl.

**Specific Drug Screening by Enzyme-Linked Immunosorbent Assay (ELISA)**  Gradually supplanting the EMIT technique is the ELISA technology, which also uses antibodies, but is capable of detecting drugs whose concentrations are in parts per billion.

**Drug Screening by Thin-Layer Chromatography (TLC)**  Although EMIT and ELISA panels detect the most commonly occurring abused drugs, they are not general drug screens. The technically simplest general drug screen utilizes the TLC so familiar to high school chemistry students. Specimens are prepared for TLC by extracting into solvents under acidic, neutral, or basic conditions, in order to bring different classes of drugs into the extraction solvents.

**General Drug Screening, Identification and Quantitation by High-Performance Liquid Chromatography (HPLC)**  Supplanting TLC is high-performance liquid chromatography, in which the chromatograph is a thin column with packing material and a liquid solvent. HPLC can be linked to a computer database of hundreds of drugs to provide spectral identification and quantification. Historically, HPLC has been used by most laboratories for assaying specific classes of drugs such as tricyclic antidepressants. A few laboratories have developed extraction methods and columns that permit HPLC to be used as a general screen. HPLC, with its cool injection ports, is often a preferred quantitative method when compared to gas chromatography/mass spectrometry (GC/MS) (see below), which uses hot injection ports in the gas chromatograph to volatilize drugs. The heat decomposes drugs such as methocarbamol and propoxyphene.

**Specific Drug Identification and Quantitation by Gas Chromatography (GC) Linked to Mass Spectrometry (MS)**  The gold standard for identifying drugs is gas chromatography linked to mass spectroscopy (GC/MS). GC utilizes a gaseous medium to separate the analyte drugs in a column. The output of the column is fed into a mass spectrometer, which breaks compounds into ionic subunits, whose weights form a bar-graph spectrum that can be specific for each compound.

**Carbon Monoxide Tests**  Carboxyhemoglobin is detected in most medical examiner toxicology laboratories by visible spectrophotometry. In hospitals, carboxyhemoglobin is frequently detected and reported in the course of routine arterial blood gas analysis. Some medical examiner laboratories use GC for the determination of carboxyhemoglobin.

**Metals**  Heavy metals can be detected by qualitative tests. For example, the Reinsch test primarily detects arsenic, and is an insensitive test for mercury, antimony, and bismuth. Quantifica-
tion and specific metal identification is done by atomic absorption spectroscopy, usually by a reference laboratory.

**Cyanide** A good screen for cyanide is the nose of a person who is capable of smelling the ion. Because only a minority of persons can smell cyanide, it is helpful to know in advance if any person in an office or laboratory can smell cyanide. Textbooks state that hydrogen cyanide gas smells like bitter almonds; forensic pathologists who can smell the compound state that it has its own specific odor, which is not comparable to any other (Davis JH, personal communication, 1984).

**SAMPLING FOR SPECIFIC TOXICOLOGIC SUBSTANCES** Pertinent procedures have been listed in Part II, under the name of the substances involved, from “Alcohol Intoxication and Alcoholism” to “Poisoning, Thallium.”

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