REVIEW ARTICLE

Forensic Pathologist Testimony, Part 1: Common Questions and Considerations

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ABSTRACT

Introduction: Forensic pathologists are the only medical specialists who routinely testify in courts of law as part of their occupation. As such, one element of their training involves learning how to testify responsibly and competently. Individuals qualified as experts are permitted to offer opinions in order to assist the triers of fact. **Results:** We review the forensic pathologist's primary role as an expert witness which is to lay out concepts clearly, methodically, and objectively, in medicine, pathophysiology, toxicology, and injury, to convey these concepts with understandable, plain language, and to explain how certain evidence, physical, medical, and historical, supports their conclusions and/or presents limitations. **Discussion:** We discuss various components about testifying in court, some common expert questions posed to the forensic pathologist, and what concepts and facts they might consider when answering them. We do not offer a prescription as to how one should answer these questions specifically, but rather we provide a single resource that summarizes some of the key issues that may arise in court for the forensic pathologist.

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INTRODUCTION

Forensic pathologists are the only medical specialists who routinely testify in courts of law as part of their occupation. Most job descriptions for forensic pathologists include this requirement. Unlike lay witnesses ("fact witnesses"), who can testify only to facts and observations, forensic pathologists (FPs) are permitted to offer expert opinions, the most common of which are those involving cause and manner of death. Still, there are other opinions that may be of interest to the attorneys involved in a given case. These other opinions are based on a myriad of concepts, separate and apart from the cause of death alone, concepts learned over time through medical and forensic training, experience, and by watching other experts testify. In that vein, the forensic pathologist's primary role as an expert witness is to lay out these concepts clearly, methodically, and objectively, in medicine, pathophysiology, toxicology, and injury, to convey them with understandable, plain language, and to explain how certain evidence, physical and historical, supports their conclusions and/or presents limitations. They do this in the posture of a physician teacher and a neutral arbiter of the facts. Due to the adversarial nature of judicial systems, FPs are called to court typically by only one party involved in a legal action. The forensic pathologist, however, speaks for the decedents more than anyone else in the courtroom regarding the circumstances and sequelae surrounding their death and dying, as opposed to being a witness for an attorney, per se. Even though typically called by the prosecution, medical examiner forensic pathologists are neither advocates for the prosecution nor adversaries of the defense. Rather, forensic pathologists are independent expert witnesses whose opinions are the same regardless of the party calling them to testify. As such, the FP's primary role surrounds education and communication, not advocacy or displays of emotion. Ideally, they represent a voice of reason and science, and above all, they tell the truth and admit to their limitations when necessary.

We discuss here common expert questions posed to the forensic pathologist and what to consider when answering them. We do not specifically propose how someone should answer these questions, but rather provide a single resource that summarizes the key issues (with support from the legal and forensic pathology literature) that arise in court for the forensic pathologist. Novice forensic pathologists typically have an expected degree of trepidation around testifying and it may even deter some students from pursuing a career in forensic pathology. While not intended to be comprehensive, we hope that this resource will help to allay some of those concerns and provide a general understanding of what questions may be asked in court and what considerations might be taken into account when providing answers to those questions under oath.

We are aware of the potential to use this publication to impeach witness testimony. We can foresee the possibility of it being misunderstood, misused, or even weaponized at a trial. Therefore, as a preemptive strike, we add this caveat: *We cannot anticipate every variable and contingency that may exist in a specific case, one or more of which could reasonably contradict some of the proceeding points. Forensic pathologists are rarely able to be 100% certain of an opinion, as doing so implies that there are no other (reasonable or unreasonable) possibilities. With that in mind, the use of the following is best tempered by viewing it through the prism of experience, the recognition of nuance and context, physical and investigative, the expectation of occasional outliers, and the specifics of each case. There is rarely a one-size-fits-all paradigm that applies to forensic pathology practice.*

DISCUSSION

Qualification of Expert Witnesses: What to Know

In some jurisdictions, a judge must qualify an expert witness to give opinion testimony. Although the judge's sanction is not required in all jurisdictions, a process of expert qualification usually takes place. In some instances, the legal parties may "stipulate" to the expert status in order to make the process more efficient or do so for strategic reasons. Often, the attorney calling the expert wants to demonstrate to the jury why they (the jurors) should consider this person an expert. There is no standard list of requirements for

experts. In general, however, there are three components to being deemed an expert witness: the subject matter is of a scientific or professional matter that is beyond the scope of the average juror, the field itself is one that is generally accepted as reliable within the relevant scientific or medical community, and the witness has sufficient skill, knowledge, and/or expertise in that field to appear to be helpful to the jury in its search for the truth. Common qualification questions for forensic pathologists include:

- What is your occupation?
- By whom are you employed?
- How long have you been so employed?
- What are the duties of the Medical Examiner/Coroner?
- What is your education and training in this field?
- What is pathology?
- What is forensic pathology?
- Are you licensed to practice medicine? In which states?
- Are you certified by a specialty medical board to practice forensic pathology?
- What is an autopsy?
- Approximately how many autopsies have you performed, observed, or supervised?
- Approximately how many autopsies of (firearm, sharp, thermal injury) have you performed, observed, or supervised?
- Have you been qualified before as an expert in the field of forensic pathology in a court of law?
- Approximately how often and in what courts?
- Have you ever been denied qualification as an expert in forensic pathology?
- What material did you review in conjunction with this case?

Having clear answers and appropriate definitions formulated in advance of these questions being asked is a reasonable expectation and responsibility of any forensic pathologist preparing to testify. Similarly, like any other matter involving potentially high stakes, excellent preparation, in general, with a thorough review of the relevant case materials, is considered standard practice, and thoughtful consideration and anticipation of the issues and questions that may arise from both sides is strongly advised.

FIREARMS

Courtroom questions related to gunshot wound deaths typically involve range of fire, the lethality of a given wound (eg, was it potentially fatal by itself?), the likelihood of activity and/or consciousness after having sustained a wound, the direction of the bullet track in the body, the potential positions of the shooter relative to the decedent, and the sequence of gunshot wounds, if there are more than one.

A specific range of fire may be provided if the wound has soot, stippling, a muzzle stamp, etc Forensic pathologists do not themselves typically test fire firearms in cases where the firearms are available (in homicides, they are often not recovered), and so physical evidence on the body and/or clothing are generally accepted as the basis of such estimates. If the entrance wound or clothing has none of these gross markers, the range of fire is best deemed as indeterminate or as "no evidence of close or intermediate range of fire." Some may call all such indeterminate wounds "distant," but this does not consider the possibility that there may have been intermediate targets (eg, a pillow) that filtered out the gunshot residue. In addition, subsequent chemical and microscopic analysis of the clothing may further clarify the range of fire. One must be careful not to testify to a greater certainty than there really is and be mindful of the potential variations in one's determinations.

An opinion may be given about the degree of potential lethality and how long a person may have been able to remain conscious and/or purposefully mobile (the latter to be differentiated from involuntary movements, such as those associated with seizure activity) following an injury. Survival, including length of consciousness and/or physical activity, will vary with the

location and the extent of the injury, and sometimes, with the health of the decedent. In fact, most people who sustain a gunshot wound injury, do not die from it.[1] In reality, specific injuries seldom cooperate fully with attempts to determine their survival interval with precise reliability. Vasospasm, attempts at external compression and therapeutic interventions, internal tamponade, elevated blood pressure (eg, from fear, pain, stimulant drugs), the morphology of the injury, the extent of the injury, and the health of the decedent all may vary from case to case and affect the survival intervals disparately. It is generally accepted, however, that gunshot wounds that damage the spinal cord, brainstem, or both cerebral lobes of the brain will cause a person to immediately collapse, even if they remain transiently conscious (eg, lower spinal cord injuries). There are also instances of low velocity gunshot wounds to one cerebral lobe in which the person remained conscious.[2] Similarly, there are well-documented instances of people sustaining a perforating gunshot wound of the heart in which the person is still able to run half a city block or more before collapsing. This is explained by the fact that the brain is capable of about 6–10 s of potential consciousness after cardiac standstill, during which time a person may be able to maintain enough blood pressure/oxygenation to remain conscious and execute substantial and purposeful movement, even after a gunshot wound of the heart leads to myocardial fragmentation.[3]

The direction of a wound track in the body is given with reference to the standard anatomic position (the body standing straight up with the arms at the side and the palms facing forward). Unless there is a ricochet or deflection, the entrance, exit/lodgment, and firearm will be connected by a straight line. Stated differently, the direction of the bullet track in the body gives the relative position of the gun to the body. This description may be misinterpreted to mean that the body was in the standard anatomic position when shot. This is not usually the case and, in fact, in most circumstances, the position is not known. This construct tends to work better for torso injuries because its motion is more restricted, unlike the head and extremities, which are less limited in their potential positions, movement, and locations relative to the torso. Moreover, when multiple gunshot wounds are involved, the actual position of the body may change between shots fired. In some instances, such as when the torso was twisted or flexed at the waist when the shot was fired, it may be difficult or impossible to establish a straight line through the body in the standard anatomic position.

One is not able to determine the decedent's body position and location without an additional reference point. For example, if an exited bullet is found lodged in the floor directly under the exit wound on the back, one may then reasonably conclude that the decedent was lying supine on the floor when shot. A shored exit also may support this conclusion.[4]

One cannot estimate the height of the shooter as people may hold and fire a gun in a variety of positions relative to their own body. Furthermore, the person being shot may be crouching, bending, falling, etc., or may be in a location that is physically above or below the shooter (eg, in a stairwell). Reaction times may also vary. Studies have shown that a body can turn 180° in as little as 0.53 s.[5] In these instances, investigative details may further inform answers to hypothetical questions regarding body positions. Finally, steep bullet tracks in the body may reflect several possible scenarios. Examples include shooting up or down in a stairwell or the injury being sustained when the decedent was falling to or on the ground.

"Consistent with" is a term commonly used by forensic pathologists when they are being presented with a hypothetical question in court, one that is based on introduced evidence or testimony on record (the forensic pathologist's or other witnesses'). It essentially means that something is reasonably possible, only with reference to the specific hypothetical scenario presented. It does not, however, indicate that the said scenario is how the events definitively occurred. Although "possibilities" usually carry less weight in court, these opinions may be used to help corroborate or refute witness statements. For example, if a close-range wound was identified at autopsy, a witness statement indicating that the shooter was across the street when the gun was fired would be *inconsistent* with the physical findings. By contrast,

a probability indicates more likely than not (see Part 2 of this series).

Finally, rarely may the sequence of gunshot wounds be deduced. One such example where it can be is when there is a specific fracture pattern of the skull resulting from two gunshot wounds. Known as Puppe's rule, if there is a radiating fracture of gunshot wound A that terminates at a linear fracture caused by gunshot wound B, one may reasonably conclude that gunshot wound B preceded gunshot wound A.[6,7] Assessing the amount of hemorrhage in a wound track to opine as to the sequence of gunshot wounds has limitations, depending on the case.

Sharp Force

The force needed to cause a sharp injury is a common subject of inquiry in court. The extent of sharp injury will depend upon the sharpness/pointedness of the object, the force of the cutting or stabbing movement, and the object and/or structures penetrated (eg, cotton blouse, leather jacket, skin, bone).[8–15] It would take less force to penetrate the skin with a razor-sharp chef's knife, for example, than with a butter knife.

Sharp injuries that are potentially rapidly fatal include those that penetrate major blood vessels, vital organs, or body cavities. Due to their vascularity, numerous sharp injuries of the scalp and/or face can also be fatal, including open wounds of the oral cavity and nose, both of which can lead to respiratory compromise through hemoaspiration.[16,17]

One phrase commonly described in textbook discussions of sharp wounds is "defense injuries".[18–24] When consciously aware, most people will reflexively sacrifice their hands and arms in order to protect more vital structures during a violent encounter with a sharp object. Therefore, it is not unusual to see sharp injuries of the hands and/or forearms or arms in a decedent dying from sharp force injury inflicted by another.[18–24] At trial, these typically nonfatal injuries should *not* be referred to as "defense" injuries any more than the decedent should be referred to as the "victim," both terms associated with implicit judgment. Identifying the offender versus the defender is a question for the jury to consider and ultimately answer. Alternatively, one could refer to such wounds as sharp injuries consistent with the decedent grabbing at a knife, if applicable, or of the upper (and/or lower) extremities becoming injured in the setting of a violent encounter during which a knife was being wielded. Notably, and importantly, however, the very nature of these wounds most supports consciousness/purposeful movement by the decedent at the time that they were sustained, an understanding that may have bearing on the interpretation of the circumstances of the death.

The holder of the knife also may sustain sharp injuries on their hands (sometimes referred to as so-called "offense wounds").[24,25] These may occur during a struggle over the knife or when their hand slips down the handle of the knife, causing it to come into contact with the sharp edge of the blade, sometimes creating a characteristic incised wound to the lateral index or medial fifth (pinkie) fingers, depending on the grip type. This may also occur with knives that do not have a guard/hilt, when the knife is forcefully thrust into the body and contacts a hard surface (such as the scapula), and/or when the knife is particularly bloody/slippery. This abrupt stoppage of the knife may result in the grasping hand sliding down onto the blade.[24,25]

Similar to gunshot wounds, the sequence of sharp injuries can rarely be definitively determined from the physical findings alone. It is also difficult (if not impossible) to definitively ascertain the handedness of the holder of the knife based on the location/distribution of the wounds on the decedent alone. For example, there may be a temptation to conclude that the stabber is right-handed if the decedent has stab wounds of the left chest, but this conclusion requires numerous assumptions. This same pattern may be caused by a left-handed person if they are thrusting the blade in a backhanded motion or if they are on top of the person facing the decedent's feet and stabbing downward, among other scenarios.[26,27] Finally, the direction of the movement of the blade that produces a typical incised wound similarly cannot be determined based on the morphology of the wound.

Unless the knife (or its broken tip) is still in the body, the forensic pathologist does not typically assert from the autopsy findings alone that a specific knife definitively caused a particular wound. Forensic pathologists do, however, commonly testify that a particular knife, based on its physical characteristics, was capable or incapable of causing the wound (ie, "consistent with" or "inconsistent with" the wounding pattern). This reasoning takes into account the understanding that the length of a stab wound defect on the skin surface may be longer than the blade is wide (due to a combination of stabbing and cutting and/or the relative movement of the body and/or knife while the knife is still in the body, such as may occur during a violent struggle) and that the depth of the stab wound may be shorter (blade is not inserted to its full length) or longer (due to the compressibility of certain tissues) than the blade is long. When the sharp edge of a serrated knife blade is scraped across the skin, it may result in numerous fine, linear, parallel superficial incised wounds/linear abrasions that may be generally compared in pattern and periodicity with the putative serrated knife. That said, when not scraped across the skin, a serrated knife usually creates discrete cut or stab wounds that are indistinguishable from a non-serrated knife.

One may be able to distinguish a singled-edged knife from a double-edged knife based on the morphology of the wound.[28–30] One sharp angle and one "blunted" end may be seen on opposite ends of a stab wound defect on the skin surface or in some subjacent organs (eg, the liver) as a result of stab injury with a single-edged knife. Some knives may have blades that have two sharp edges (double-edged knives) for a portion of its length, a single sharp edge for another portion, and no sharp edge for a third portion. Therefore, the same knife may be capable of producing one or more defects with the morphology of a single-edged knife, a double-edged knife, and/or a non-sharp-edged weapon depending upon the depth of penetration of each wound.

One area of inquiry that may arise in court involves the hypothetical question asking about the likelihood of a single, deep stab wound of the anterior torso having resulted from the decedent running into the knife.[18,31] If the blade has a considerable upward or downward track in the body, one may be able to answer this hypothetical with a "no." For example, to explain a stab wound having a steep downward track in the body through a "collision" mechanism, the decedent would have to have run up/moved or jumped upward into the knife to sustain this injury, provided they were standing on the same surface and facing the holder of the knife. If the track of the wound is roughly horizontal, however, then running into a blade may be physically possible, but depends on the specifics of the case, the morphology and depth of the wound, and the structures penetrated.[8–15]

Due to its structure and elasticity, the skin is second only to teeth, bone, and cartilage with regard to the amount of force required to breach it.[32,33] The surface area of a knife tip is so tiny that unless contact is made with enough inward force *and* stability, the tip may be deflected, creating only a superficial wound. When there are multiple stab wounds, the question of inadvertent injury/falling onto the knife is not as likely to arise or even be relevant. Finally, while there are studies that quantitate such forces, when asked about how much force would have been necessary to cause a given stab wound, a qualitative (eg, "considerable force," "enough force to penetrate…") rather than a quantitative answer, based on the concepts outlined above and depending on the specific wound, may be the most accurate one to offer.[8–15,34]

Incised wounds are caused by the movement of a sharp object across the body, not into it, tip first, as is the case with stab wounds. In terms of wound morphology and distribution, a multiplicity of sharp, sometimes gaping wounds (incised and stabbed) distributed widely and sometimes haphazardly are consistent with relative movement of the body to the knife, typically denoting consciousness and a struggle. A tight cluster of homicidal stab wounds with a similar orientation (ie, horizontal, vertical, oblique) and direction, by contrast, may indicate incapacitation at the time of their infliction (eg, unconsciousness, restraint, death).

Finally, it is common for the forensic pathologist to be faced with questions regarding the mechanism of

death in sharp force fatalities (or any other fatality), to which they may opine about both the length of the potential survival interval and of purposeful activity. The most common mechanism by which sharp force trauma causes death is through hemorrhage, whether exsanguination, hemoaspiration, tamponade, tension hemopneumothorax, or some combination of these. Rarely, cardiac air embolism contributes, particularly with deep incised wounds of the neck involving venous injury. The forensic pathologist should be prepared to define certain concepts, such as exsanguination and total blood volume, to describe evidence of hypovolemic shock and to convey that most deaths resulting from untreated acute, substantial blood loss typically ensue in minutes, rather than in hours or days (see "Mechanisms of Death" in Part 2 of this series).

Asphyxia

Criminal asphyxial deaths commonly include, but are not limited to, smotherings and/or neck compressions (strangulations). Since a dominant mechanism of death in neck compression is an interruption in the cerebral circulation due to sustained and considerable vascular compressive forces, the death may not result solely from (systemic) asphyxia per se, but rather from local (cerebral) ischemia and stasis. Facial, conjunctival, and mucosal petechiae, injuries of the skin of the neck, lower face, anterior and/or posterior strap muscle and soft tissue hemorrhage(s), and fracture(s) of the skeletal structures of the anterior neck may be seen in some combination with neck compression deaths. These findings are not uniformly found in all cases and are not, in sum, required to make a diagnosis.[35–37]

Petechiae do not result from hypoxia/hypoxemia per se, nor are they invariable in all asphyxial deaths. Certain asphyxial modalities (eg, neck and chest compression) are more commonly associated with their development, however, predicated on their mechanical vascular pathogenesis. This is in contrast to other homicidal asphyxial deaths (eg, smotherings), which do not usually involve sustained vascular compression, so are not expected to be associated with petechiae as a typical sequela. In other words, petechiae, as an isolated finding, are nonspecific and, therefore, their interpretation requires contextualization, as do many findings in forensic practice.[38]

Inquiry related to the necessary duration of fatal neck compression and the length of the conscious interval that precedes unconsciousness and death often arises in court. Compression of the neck is expected to lead to unconsciousness in several seconds if both carotid arteries are simultaneously and fully compressed. Compression of both carotid arteries will usually result in loss of consciousness in approximately 10 to 15 s.[37,39] If, on the other hand, only the jugular veins are compressed (requiring less applied force than that for carotid artery occlusion), consciousness may be maintained for a minute or so prior to the supervening unconsciousness, and the eruption of facial and conjunctival petechiae is more likely.[38] The latter represents a common scenario in homicidal strangulations, given the typical struggle and movement that often take place during the conscious interval, with the resultant difficulty in maintaining complete occlusion of both carotid arteries during that time.

Compromise of the airway and normal respiration, either by compression of the trachea, forceful gagging, water submersion, posterior and upward pressure on the tongue base (with occlusion of the posterior pharynx in a neck compression or gagging), inversion and various forms of inflicted positional asphyxia, and/or concomitant smothering and/or chest compression, typically result in unconsciousness in minutes. As an analogy, consider how long an average person can hold their breath before losing consciousness. In general, the body can tolerate hypoxia better than ischemia. Consider also that, during this time, a person may be involved in a violent exertional struggle, be under the influence of one or more substances, and/or be experiencing a sympathetic fight or flight reaction, all of which may affect oxygen reserve and stamina and/or their ability to robustly fight against their perpetrator, the latter particularly relevant when depressant drugs are involved.

So, how long must the compression be maintained on the neck in order to cause death? When faced with this common question, it is advisable, and likely the most

accurate, to respond with *units* rather than with specific *numbers* (is it 3 min? 4 min? 5 min?), as asserting a definitive number can quickly move into arbitrary and capricious territory. Rather, it is fair to say that considerable pressure typically needs to be maintained *and* uninterrupted for some time (a number of minutes) *after* the victim becomes unconscious and prior to the death supervening.

If death were contemporaneous with the loss of consciousness, no one would be successfully resuscitated after a potentially fatal cardiac arrhythmia. Death is defined as the *irreversible* stoppage of the heart and lungs or functioning of the entire brain, including the brainstem. A study in 1943 revealed that with complete cessation of cerebral circulation, the participants lost consciousness in 4–10 s.[3] All the subjects had regained consciousness within 30 to 40 s after restoration of circulation. In 11 subjects, the periods of acute arrest of cerebral circulation were for as long as 100 s. All of these were "well tolerated" and followed by "rapid and uneventful recovery" once the compression was released. Therefore, in order to cause death by neck compression, in most instances, it is fair to say that the compressive forces are reasonably expected to be maintained for greater than 100 s *after* loss of consciousness, on average. When they exist and are not reasonably explained by the body's postmortem position, facial, conjunctival, and mucosal petechiae, confluent hemorrhages, and plethora provide objective and measurable physical evidence in support of continued circulation during sustained venous only compression, even in the setting of moderate to advance coronary artery disease. To be clear, however, these findings are not uniformly observed and depend upon the specific application of force, whether there was a continuous or intermittent application, and the forcefulness of the compression (eg, complete and forceful fatal bilateral carotid occlusion often results in a relatively pale-faced victim).[40]

A carotid sinus mechanism has been proposed in court to explain death by neck compression (with rough sexual intercourse, for example). In reality, it is a vanishingly rare mechanism/cause of death in a healthy person and is more theoretical than factual. Pressure on the carotid sinus is even a common medical technique to treat certain tachyarrhythmias.[41] With facial/conjunctival petechiae and plethora in a decedent left in a supine position (proof of continued circulation to the head), one can effectively rule out the theory of a sudden arrhythmic death due to a carotid sinus mechanism. Blood pressure/circulation to the head during sustained chest or neck pressure is needed to produce petechiae. The carotid sinus hypothesis infers a stoppage of the heart, which, in turn, stops circulation and, in doing so, would preclude the development of petechiae and plethora.

Forensic pathologists also may be asked to testify in a criminal case involving the survivor of a strangulation attempt.[42,43] This usually involves the forensic pathologist's familiarity of the range of signs and symptoms an individual might experience following such an encounter, including hoarseness and neck pain, and an explanation to the jury about the pathophysiology of neck compression, including a discussion of the various risks of forcefully compressing a person's neck (eg, stroke, vascular and/or airway injury or occlusion, compressive hematomas, etc).[44–46]

As a final note, on occasion, particularly with decomposed bodies, the forensic pathologist is faced with both explaining the meaning and defending the diagnosis of "asphyxia, not otherwise specified" or "homicidal asphyxia" as a cause of death in a *homicide*. The cause and manner of death in such fatalities are typically determined as a diagnosis of both exclusion (autopsy) and inclusion (investigative circumstances). That is to say that, even in the absence of structurally demonstrable fatal asphyxial injury (as may be absent in a smothering with a soft object or bag), all other reasonable causes have been effectively excluded by autopsy (ie, the death is insufficiently explained by autopsy alone); moreover, the compelling circumstances and/or the condition in which the decedent was found are clearly suspicious, if not overtly criminal (eg, bound, gagged, dismembered, wrapped in a bag, buried, etc), leading the forensic pathologist to only one reasonable conclusion.[47,48] Still others of these clearly criminal deaths may need to be certified as "homicidal violence of undetermined type" if the remains have been altered (burned, dismembered, etc) or are otherwise limited or incomplete

(skeletonized, decomposed, animal predation, etc). Some forensic pathologists may prefer to certify the cause of death in such cases as "undetermined." The certification of the cause of death is part of the art of medicine and not a pure scientific process. That said, we believe that one should not deny reality in the name of objectivity. In rare instances, a case with compelling circumstantial information may even be certified as a homicide without a body or with only scant remains (eg, burnt or skeletonized remains).[49]

Intoxications

Forensic pathologists may be asked to testify in criminal proceedings against sellers of illicit drugs that result in a death even when certified as an accidental drug intoxication.[50,51] Drug and alcohol-related testimony, however, is more commonly elicited in traumatic homicides, when it surrounds issues of the potential antemortem effects of various substances on behavior or abilities, rather than in their lethality, per se.[16,52]

Forensic pathologists often testify about the common effects of certain classes of drugs but cannot predict with precision how in a particular person, a drug, at a specific concentration, would have affected them. A myriad of often unknowable variables intervenes, including, but not limited to, drug tolerance, host enzymatic efficacy, liver and renal function, gastric contents, drug interactions, and the time course over which drugs were used and metabolized relative to the death, including the survival interval. These and other potential variables make such specific individual behavioral and physiologic assertions fraught with inaccuracy.

That said, ethanol is the relative exception to this rule in that one may offer some opinions about the potential extent of intoxication, given the existence of extensive data on this specific substance. A helpful and often used testimony approach compares the blood alcohol concentration (BAC) of the decedent with a reference point of 0.08 gm%, which is the legal upper limit for operating a motor vehicle in most jurisdictions. For a BAC of 0.16 gm%, for example, one could say, as a general comparison, that it is "twice the legal limit for operating a motor vehicle." One could also make specific ethanol calculations to offer an approximation of the number of "drinks" (ethanol equivalents) that would have needed to have been consumed over a given time frame to achieve a certain blood alcohol concentration (eg, one equivalent of ethanol will raise the BAC 0.02 gm% in a 70 kg man and it will be metabolized at a rate of 0.015 gm% per hour). Comparison of the BAC with the vitreous alcohol concentration also provides information about whether the individual was pre- or postabsorptive at the time of death.[53–56] All this said, while one may testify as to the extent of the potential intoxication in general terms, one cannot describe with precision how it would have affected a specific individual, given host variability. A blood alcohol concentration may help, however, to corroborate or refute a witness's description of the person before death.

Concentrations of licit drugs may be described as subtherapeutic, therapeutic, or potentially toxic/fatal, but it is generally advisable to avoid the term "fatal concentration." Separate from the many host variables, such as individual tolerance, there are a variety of other factors related to the postmortem milieu (eg, postmortem redistribution, putrefaction, etc.) that need to be considered when interpreting drug and alcohol concentrations.[57–65] For this reason, it is important not to view postmortem concentrations as equivalent a priori to the antemortem/clinical concentrations listed in reference books and scientific articles, unless one is referring to the antemortem (hospital) blood that was tested.

Forensic pathologists are commonly asked questions reasonably related to toxicology training when they appear in legal proceedings as expert witnesses. At a minimum, forensic pathologists receive *interpretive* (and limited methodologic) toxicology training during their fellowship training year. They are further tested on such material as part of the board certification process in order to be deemed an expert in their field. Forensic pathologists may, however, still feel compelled to defer to a forensic toxicologist for certain toxicological questions that they deem outside of their knowledge base (such as questions about analytical methods).

The American Academy of Forensic Science Standards Board (ASB) is an ANSI-accredited Standards Developing Organization with the purpose of providing accessible, high-quality, science-based, consensus forensic standards. In 2019, ANSI/ASB published the best practice recommendations for *forensic toxicologists*, "Guidelines for Opinions and Testimony in Forensic Toxicology".[52] Some of these apply to the practice of forensic pathology. For example, they state that one should not perform extrapolation calculations for drugs other than ethanol and should not calculate the dose of a drug based on a postmortem blood concentration. They go on to assert that an expert should not address behavioral manifestations based solely upon a drug concentration and that they should also not opine as to the effects of a drug or combination of drugs in a specific individual without knowledge of the contextual evidence in a given case.[52]

National forensic pathology guidelines advise that all drugs having a similar or synergistic role in causing death be included in the cause of death statement.[66] Per the Burrage decision, prosecutors who try drug dealers for deaths caused by their product need to prove "but for" causation. This can be challenging in certain deaths that are caused by a multi-drug intoxication.[50] It may appear arbitrary to select only fentanyl as the cause of death when the decedent also had alprazolam, ethanol, and oxycodone in their blood. Fentanyl may be (and likely is), in fact, the dominant/most potent drug in certain instances and may, of course, cause death by itself, but in a given case, can one state to a reasonable degree of medical/scientific certainty that the fentanyl would have caused death without the additional or synergistic effects of the other drugs? In addition, the expert should be aware of the potential pitfalls of relying upon the postmortem concentration alone to offer an opinion on the putative role of fentanyl in a given death. For example, one study reported a fentanyl blood concentration of over 300 ug/L in a living man who was arrested for operating a motor vehicle while impaired.[67] Context and exclusion of a more compelling causes come into play in most deaths that are deemed drug-related.

For persons dying from trauma, but in whom intoxicants are detected, the intoxication is usually not included on the death certificate. With rare exceptions, forensic pathologists do not try to explain *why* people are shot or accidentally crash a car for death certification purposes, unless otherwise necessary. A person may have been under the influence of alcohol or cocaine when they died from the gunshot wound of the head (or the blunt injury from the motor vehicle collision), and this information may be of interest to certain stakeholders and even have relevance in future legal proceedings, but the alcohol and cocaine, per se, played no *physiologic* role in the death; in other words, in such traumatic deaths, the decedent would have died from their injuries whether intoxicated or not.[68]

Head Injury (General)

Questions about lucid intervals and mechanisms of injury may arise with deaths from blunt injury of the head. Ultimately, fatal head injuries may cause immediate incapacitation via diffuse axonal injury/concussive effects or brainstem injury, or be associated with a lucid interval from an expanding extra-axial hemorrhage (eg, subdural or epidural hemorrhage) or from malignant brain swelling.[69,70] Depending on its length, a lucid interval may present a hypothetical scenario in which there could have been more than one potential circumstance involving other people who may have had an opportunity to cause the injury.

A depressed skull fracture is evidence of a focal application of force that is inconsistent with a simple fall to a flat, resistant surface, which, by contrast, would be expected to cause a linear skull fracture, if any. Contrecoup cerebral contusions typically occur with a moving head impact to a stable, resistant surface, as may be seen with a fall or a push to the ground, whereas coup cerebral contusions are caused by a blow to the mobile head. A true coup cerebral contusion does not have an immediately overlying skull fracture; when such an underlying fracture exits, the contusion is more accurately identified as a fracture contusion.[69,71]

Infant Head Injury

The complexity of infant head injury and its associated testimony exceeds our scope, however, a few points will be highlighted.[72–75]

The diagnosis of abusive head trauma (AHT) is not based *solely* on the so-called "triad," which includes retinal hemorrhages, extra-axial intracranial hemorrhage, and brain injury. These findings may be seen in instances of non-abusive trauma as well.[72,76] This is a situation in which the forensic pathologist uses contextual information to further clarify the injury and interpret how it likely occurred.[77] In some instances, there are numerous additional, often nonfatal, but clearly inflicted patterned injuries, such as grab mark contusions or an excessive or unusual distribution of wounds, sometimes of varying ages, that place the head injury in a clearer context, viewing the head injury within the larger backdrop of "the company (of injury) it keeps."

The more challenging cases are those involving isolated head findings (eg, a small, non-space-occupying subdural hemorrhage, retinal hemorrhages, and/or encephalopathy), where the infant became unresponsive in the presence of a single caregiver. In these scenarios, the forensic pathologist must be able to recognize "anatomic-anamnestic disharmony," in which the history of events provided by the caregiver does not fit with the autopsy findings and their expected pathophysiology and symptomatology, and there is no other reasonable explanation other than inflicted trauma.

Fire/Smoke

Questions may arise about whether a person was alive before the start of a fire (ie, was the fire the cause or a consequence of the death). Detecting soot deep in the airways (not just on the tongue) and/or an elevated blood carboxyhemoglobin saturation supports a diagnosis of life/breathing and circulation, even if not consciousness per se, during the fire. There are instances of flash fires, in which a person may have a "normal" or very low carboxyhemoglobin saturation, even though they were documented to be alive when the fire started.[78,79] In addition, medical resuscitation that includes oxygen therapy can lower the carboxyhemoglobin saturation by decreasing its half-life. Typically, a 50% to 60% carboxyhemoglobin saturation is enough to result in the death of an otherwise healthy person. By contrast, an individual with advanced heart or lung disease may succumb to a carboxyhemoglobin saturation of 30% or less.[80]

Such cases also may remind us of the importance of considering natural co-morbidities in violent deaths that are inadequately explained by the extent/severity of the injury. In general, if an injury is sufficient to explain the death and can stand alone on the death certificate without invoking a contributory natural condition, then it should remain so. If the disease merely hastens the certain death expected from an injury, it generally should not be included as a contributory cause. If, however, a physical altercation, for example, is insufficient to explain death without invoking an underlying disease, then the disease is best included.

Associated thermal injuries are usually less rapidly fatal by themselves, unless an immolation scenario applies, homicidal, self-inflicted, or accidental. More commonly, thermal injuries do cause death, but more typically through infection, acidosis, dramatic fluid shifts and losses, electrolyte derangements, shock, and attendant complications during hospitalization. Age, inhalational injury, and the extent of thermal injury all may affect the survival prognosis of these patients.

Blunt Injury

For blunt injuries, it is important to define for the jurors the terms lacerations, contusions, and abrasions. It is not unusual for clinicians to erroneously use the term "laceration" to describe any injury defect that needs to be sutured, including not just lacerations, but also stab and incised wounds, among others. Some blunt injuries may take on a pattern produced by a specific object (a patterned injury) and other times, the individual injuries, in isolation, have no specific recognizable pattern, but their distribution or relationship to one another tells a story about how they were most likely sustained (patterns of injury).[81,82] For example, numerous scalp lacerations of every aspect of the head (ie, nonplanar) are indicative of inflicted blows rather than a fall.

Time of Death

Time of death/postmortem interval estimates is common investigative and courtroom issues that arise in the questioning of a forensic pathologist. Nowhere in FP practice is the television crime scene investigation (the so-called "CSI-effect") more troublesome in its setting up of unreasonable expectations than it is with those surrounding our ability to determine, with exacting precision, the time of death, absent a credible eyewitness, video surveillance, or the observations of a medical professional.[16,77] Moreover, the further in time the discovery of a body is from its death, the less accurate the time of death estimate becomes. The clearest demonstration of the variation of these estimates is the disparity in estimates one may encounter (hours differences), depending upon which reference article or text is consulted.

The forensic pathologist does their best to consider all data points and answer questions about time of death as accurately as possible, but is advised to do so usually only in terms of likelihoods (when not captured on video, reliably witnessed, etc., in which case, this line of questioning will likely be moot). It is imperative to be prepared to answer these questions under oath and to know, before taking the stand as an expert witness, what ranges of time one deems consistent or inconsistent with the physical and investigative evidence of the case.

The first data point that should be established and considered is when the decedent was last (reliably or objectively) known to be alive. This is the start point in the time of death estimation process. Beyond that, the FP typically speaks in terms of ranges/units (hours, days, weeks, etc.) more than in discrete numbers, per se. Similarly, as with range of fire questions, the forensic pathologist can more easily answer questions posed to them about whether a specific hypothetical time of death is "consistent" or "inconsistent" with the forensic evidence, physical and/or circumstantial. Answering in the affirmative that something is *consistent with* a proposed time simply means that it is reasonably possible, but not necessarily definitive or the only possibility. Conversely, answering that a time is *inconsistent* means that it is not *reasonably* possible, given the evidence presented. Because criminal proceedings are predicated on the exclusion of *reasonable* doubt, this terminology has significance and relevance to the triers of fact.[16]

CONCLUSION

We describe common questions and considerations faced by the forensic pathologist at trial. We cannot anticipate every variable and contingency that may exist in a specific case and forensic pathologists are rarely able to be 100% certain. Therefore, one must always be mindful of experience, nuance and context, the role of physical and investigative findings, the occasional outliers, and the specifics of each case. No two cases are identical.

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