INTRODUCTION

In the previous chapters on forensic epidemiology (FE) applications the focus has been on disputes arising in the course of civil litigation, typically in which an allegation of negligent behavior is the basis for the legal action. In this chapter we focus on how FE concepts and methods are applied in the context of a criminal prosecution.
Causality in criminal cases is often undisputed because of the high degree of association between the alleged exposure and the outcome of interest. The temporally proximate nature and high degree of lethality of the methods used to commit homicide (firearms, blunt trauma, sharp instruments) typically leaves little room for consideration of competing causes of injury and death. As an example, when death is the outcome and the exposure is a gunshot wound (GSW) to the head that was sustained moments before the exhibition of signs of injury (unconsciousness followed by cardiorespiratory arrest), there is no need for an expert forensic medical assessment of the cause of the death. The fact that penetrating trauma to the head is associated with a more than 90% death risk is widely understood and accepted (Siccardi et al., 1991). The chance that a competing cause of death acted on a decedent who died directly after sustaining a GSW to the head is so small that it is not worth considering in most circumstances. Even with a causal relationship that is obvious, however, we still have to keep in mind the basic underlying principle of the practice of FE, which is that causation cannot be observed. Thus, even in the prior example it is still possible that the decedent died due to an untraceable and 100% fatal poison that killed him just prior to sustaining a survivable GSW. A forensic pathologist who finds a bullet in the brain of the decedent will stop looking for a cause of the death, because it is, of course, impractical to consider an alternative cause of death that is so nearly (but not completely) implausible.

In some cases, however, death and injury investigations applicable to the prosecution or defense of a criminal action are aided by the use of epidemiologic data or concepts. In this chapter we present four case studies demonstrating a range of applications of FE methods to the investigation of probabilities associated with disputed issues in criminal cases. In all but the last case the application of physics (ie, biomechanics) plays an important adjunctive role in the assessment of the probabilities of interest.

In the first case study, the circumstances surrounding a crash-related death are described. The issue investigated with FE methods was the position in the vehicle (driver or passenger) of the surviving and intoxicated occupant. The second case involved the death of a pedestrian struck by a motorcycle, with the investigation focused on the speed of the motorcycle at impact. The third case concerns the investigation of the most likely cause of a skull fracture observed in an infant, in which it was alleged that the injury history provided by the father was so improbable that the likely alternative explanation was that the injury was the result of intentional violence. In the last case an epidemiologic investigation of hospital data was undertaken to estimate the probability of causation attributable to maternal gestational cocaine exposure in a full-term delivery of a stillborn baby. Although these cases are varied in nature and the type of analysis performed, there are many other circumstances in which an FE analysis may provide reliable insight into an important question arising in a criminal matter. Like the civil cases described in Chapter 11, Traffic Injury Investigation, Chapter 12, Traffic Injury Investigation: Product Defects, Chapter 13, Product Defect/Liability Investigation, and Chapter 14, Medical Negligence Investigations, the analyses are primarily dictated at the assessment of causal relationships, although this is a bit difficult to see in some of the case studies.
CASE STUDY #1: IDENTIFICATION OF THE SEATING POSITION (DRIVER vs PASSENGER) OF AN EJECTED OCCUPANT IN A VEHICULAR HOMICIDE INVESTIGATION

A potential difficulty for fact finders in vehicular homicide prosecutions arises from the lack of reliability and precision associated with injury pattern evidence. Occupant injury patterns are often used in a vehicular homicide investigation to help determine where an occupant was seated during a collision, as some injuries are more commonly associated with a driver’s position than a passenger’s position, and vice versa (Freeman and Nelson, 2004). The difficulty occurs when there are differing expert interpretations of the significance of the injuries. As an example, one expert may claim that a chest abrasion observed in a decedent could have been caused only by contact with a steering wheel and therefore the surviving defendant must have been in the driver’s seat at the time of the crash. In contrast, another expert may interpret the abrasion as having no such meaning. Thus, the evidence of injury, the presence of which both experts agree on, can be characterized as a positive test for steering wheel contact. The first expert interprets the positive test as having a high-positive predictive value or PPV (see Chapter 3, Methods Used in Forensic Epidemiologic Analysis) for steering wheel contact, and thus reaches the conclusion that the evidence serves as a reliable indication of the precrash position of the occupant as being in the driver’s seat. In contrast, the second expert can agree with the first expert that a chest injury is associated with a steering wheel impact, but at the same time reject the assertion that the association excludes alternative explanations for the injury (ie, the finding has low specificity for steering wheel contact). While both experts essentially agree that the injury serves as a positive test for steering wheel contact, the second expert infers a low PPV for the finding and rejects the inference that it is reliably associated with steering wheel contact. A fact finder is thus left with two differing interpretations of the meaning of piece of evidence, and no means of quantitatively comparing the accuracy of one interpretation to the other. In such a manner, epidemiologic concepts that are crucial to understanding the meaning of evidence are hidden in plain sight in many criminal investigations.

Injury pattern analysis (IPA) is the method, used primarily in crash injury and death investigation, in which injury patterns observed from postmortem or medical evaluation of decedents and survivors can be systematically paired with crash reconstruction, biomechanics, and epidemiologic data in order to draw inferences regarding the seating position, restraint use, ejection route, and other parameters of occupant status in a fatal crash investigation (Smock et al., 1989; Freeman and Nelson, 2004). IPA is an exemplar of FE methods, as the technique requires the probabilistic interpretation of evidence via the application of knowledge from multiple adjunctive disciplines. Presented in the following case study is the account of an IPA analysis that employed a Bayesian evaluation of the posttest probabilities associated with multiple pieces of evidence relating to the seating position of a surviving occupant of a fatal crash (Freeman et al., 2009). The use of the Bayesian posttest probability formula, described in Chapter 3, Methods Used in Forensic Epidemiologic Analysis allowed for the consideration and relative weighting of the evidence so that it could be presented to lay fact finders in a meaningful form.

The investigated collision consisted of a high-speed frontal impact of a pickup truck with a tree followed by a passenger side leading ¼ turn rollover in which the surviving occupant
was ejected and the decedent was trapped in the vehicle, and subsequently died in an ensuing fire. There was no definitive evidence regarding which of the occupants was driving, such as an eyewitness account. Because the surviving occupant was found to have a blood alcohol concentration that was three times the legal limit, the death was investigated as a homicide.

The following undisputed evidence was used to construct a posttest probability calculation that the surviving occupant was the driver:

1. The ejected occupant was found to have high-energy (comminuted and/or open) fractures of the right femur, tibia, fibula, and foot.
2. There was extensive crush to the front end of the vehicle on the driver’s side, and the driver’s side foot well was obliterated (see Figs. 15.1 and 15.2).
3. The decedent was found to have no lower extremity fractures upon autopsy.
4. There was little crush to the front end of the vehicle on the passenger side, and the passenger’s side toe pan was preserved. See Fig. 15.3.
5. The only apparent opening allowing for the ejection of an occupant was on the driver’s side, between the driver’s side door and the A-pillar (see Fig. 15.4).
6. The deployment of the airbags would have made a passenger ejection through the windshield improbable during the initial collision with the tree, and the subsequent $\frac{1}{4}$ rollover to the right would have had the effect of trapping rather than ejecting an occupant in the passenger’s seat.

This evidence was used to develop true positive and false positive rates for four “diagnostic” tests pertaining to (1) whether the ejected surviving occupant was in the driver’s
FIGURE 15.2 Photograph of the driver’s side foot well with a measurement depicting the distance from the front of the seat frame (white arrow) to the end of the foot well. There are approximately 7 inches (0.2 m) of space for the legs of the occupant.

FIGURE 15.3 Photograph of the passenger’s side foot well depicting the distance from the front of the seat frame (white arrow) to the front of the foot well; approximately 26 inches (0.66 m) of occupant leg space.

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The true and false positive rates were used to arrive at an estimate of the posttest probability that the survivor was the driver using the following equation for posttest probability:

$$P(\text{driver}|\text{tests}) = \frac{(P(\text{driver}) \times \text{(true positives)})}{(P(\text{driver}) \times \text{(true positives)}) + (P(\text{passenger}) \times \text{(false positives)})}$$

The equation was simplified by the fact that the pretest probability of driver versus passenger seat position for the survivor was assigned an “indifferent” value of 0.5, and thus ($P(\text{driver})$) and ($P(\text{passenger})$) were the same and canceled each other out. The resulting equation was for positive predictive value:

$$P(\text{driver}|\text{tests}) = \frac{\text{(true positives)}}{\text{(true positives)} + \text{(false positives)}}$$

In the same way that the comparative risk ratio (CRR) can be converted from a ratio to a percentage probability, the posttest odds are converted as follows:

$$\text{Posttest odds} = \frac{\text{(posttest probability)}}{1 - \text{(posttest probability)}}$$
When viewed as tests of the precrash position of survivor, the true and false positive rates for the following four pieces of undisputed evidence from the fatal crash investigation were as follows:

**TEST #1—PRESENCE OF A FRACTURED LOWER EXTREMITY OF THE EJECTEE**

This was considered a test for the probability the ejected survivor was in the driver’s seat, based on the high degree of crush to the foot well at this position and corresponding high risk of lower extremity fracture. This probability was estimated to range from 0.85 to 0.95 based on previously published epidemiologic data (Augenstein et al., 2005). The false positive rate used for Test #1 was the probability that the survivor would have suffered the same fracture if he had been occupying the passenger seat, given the lack of crush at this position. This probability was estimated to range from 0.56 to 0.63 based on an analysis of National Automotive Sampling System-Crashworthiness Data Sample (NASS-CDS) data (see further description of this database in Chapter 11, *Traffic Injury Investigation*).

**TEST #2—THE LACK OF A FRACTURED LOWER EXTREMITY IN THE DECEDENT**

Test #2 is the mirror image of Test #1, but because of the mutually exclusive nature of the “who was driving” scenario the evidence can, in essence, be counted twice. The true positive rate of Test #2 is equal to the probability that the decedent would not have sustained a fracture had he been seated in the passenger seat position. This value is the complement of the false positive rate (ie, the specificity) for Test #1, or a range of 0.37 to 0.44 (derived from $(1 – 0.63)$ to $(1 – 0.56)$). The false positive rate of Test #2 was based on the probability of no lower extremity fracture had the decedent been in the driver’s seat. This range of values was the complement of the true positive rate of Test #1, or 0.05 to 0.15 (derived from $(1 – 0.95)$ to $(1 – 0.85)$).

**TEST #3—THE DEFENDANT WAS EJECTED**

The estimated true positive rate used for Test #3 was 0.5–0.75 based on the investigation findings that indicated the driver’s side as the most probable ejection route (see Fig. 15.2). The false positive rate used for Test #3 was the probability that the ejectee could have been ejected from the passenger seat of the vehicle, estimated to be 0.05–0.15. This probability is given a very low value because the reconstruction of the collision events produced no identifiable route through which the passenger could have been ejected. It could reasonably be argued that it is even lower, if not outright implausible.
TEST #4—THE DECEDENT WAS NOT EJECTED

As was the case with Test #2 relative to Test #1, Test #4 is the mirror image of Test #3. Thus, the true positive rate used for Test #4 was the complement of the false positive rate (0.85–0.95), which represented an estimate of the probability of no ejection given passenger seat position. The false positive rate was the complement of true positive rate (0.25–0.75), which was the probability of no ejection if the defendant had been in the driver’s seat.

From the discussion above the true positive rates of the tests were estimated be in the following ranges:

Test #1 = 0.85–0.95
Test #2 = 0.37–0.44
Test #3 = 0.5–0.75
Test #4 = 0.85–0.95

The false positive rates were estimated as follows:

Test #1 = 0.05–0.15
Test #2 = 0.56–0.63
Test #3 = 0.25–0.5
Test #4 = 0.05–0.15

For the posttest probability calculation, only the lowest true positive and highest false positive values were used to in order to minimize the probability of a Type I error (see Chapter 3, Methods Used in Forensic Epidemiologic Analysis) and maximally favor the defendant, as the analysis was performed for the prosecution. The posterior probability that the defendant was the driver which calculated from all of the probabilities as follows:

\[ P(\text{driver}|\text{tests}) = \frac{(0.85 \times 0.37 \times 0.5 \times 0.85)}{(0.85 \times 0.37 \times 0.5 \times 0.85) + (0.15 \times 0.63 \times 0.5 \times 0.15)} = 0.949645 \]

Thus, the odds that the decedent was the driver were:

\[ \text{Odds(}\text{driver}|\text{tests}) = \frac{0.949645}{(1 - 0.949645)} = 19 \]

These posterior odds indicate that, using the data most favorable to the defense, the ejectee was at least 19 times more likely to have been the driver versus the passenger.

The sequence of the lower extremity injury mechanism and ejection are illustrated in Figs. 15.5–15.9.
While the preceding analysis was limited somewhat by the fact that some of the data were adapted from a previously published paper, the paper did provide a description of vehicle damage and thus could reasonably serve as a basis for comparison to the investigated crash. Most importantly, the posttest probability calculation was performed using the true and false positive values that least favored a correlation between occupant position and ejection and lower extremity injury risk (also known as a “safety” analysis), reducing the chance of Type I error.

FIGURE 15.5  Right side view of the pickup and tree just prior to impact. Preimpact speed was reconstructed to 55 mph (88 km/h).

FIGURE 15.6  The point of maximum engagement with the tree and maximum crush to the front of the pickup. Both airbags have deployed. It is at this point that the foot well of the driver is crushed toward the driver (see Fig. 15.2), presenting increased risk of lower extremity fracture. The foot well on the passenger side is preserved (see Fig. 15.3).
FIGURE 15.7  Top view of the same point in the crash sequence shown in Fig. 15.6. Both occupants have shifted to the left of the vehicle interior because the truck is beginning to roll toward the passenger side.

FIGURE 15.8  Top view as the truck continues to roll toward the passenger side and the driver is ejected from the opening between the door frame and the A-pillar.
Like the first case study this second case illustrates the application of epidemiologic methods and data to medical, biomechanical, and crash reconstruction investigation findings from a fatal crash in order to assess a discrete issue. The case concerned the death of a 13-year-old female pedestrian who was walking on the sidewalk in a small village with three friends. The decedent was the furthest from the road, and to the right of her friends. She was struck from behind and killed by a Yamaha dirt bike operated by a teenaged male. The motorcycle was a very powerful two-stroke motorcycle that was not legal for street use, and thus not equipped with a headlight or turn signals.

Fig. 15.10 is a figure of the crash scene, with the preimpact approach direction of the motorcycle indicated in the lower right-hand aspect of the picture. The two blue X’s indicate the general area in which the decedent was struck, and the red X is the estimated point of final rest for the decedent. The motorcycle is depicted in Fig. 15.11.

The witnesses to the crash (the three friends) recalled that they heard the motorcycle behind them as it entered the sidewalk area, and they turned to see what was making the noise. They turned back and kept walking, assuming that the motorcyclist was entering the driveway to the parking lot, which was approximately 100 feet (30 m) behind them. It was noted by the investigating officer that the driver of the motorcycle lived in the village where the crash occurred, and he had been seen riding the bike illegally on the street previously (the motorcycle was not street legal).
FIGURE 15.10  See text for description of the annotations.

FIGURE 15.11  The involved motorcycle, a Yamaha 450 cc two-stroke dirt bike.
There was no dispute as to how the death occurred. The motorcyclist initially claimed that prior to the collision he was driving on the road and traveling in the same direction that the girls were walking, when he lost control of the motorcycle, resulting in the bike traveling up onto the sidewalk and the subsequent collision. He claimed to have been traveling at 12 mph (20 km/h), which was an important issue for how the defendant might be charged criminally. If it could be proven that the defendant was, in fact speeding, then the level of criminally negligent behavior would warrant a more serious criminal charge.

The three witnesses indicated that after the impact the driver stayed upright for a few meters before falling off of the bike. The bike fell over and slid approximately 100 feet (30 m) to final rest, leaving gouge marks in the sidewalk for the last 23 feet (7 m). The decedent was projected at least 10 feet (3 m) forward by the impact.

Among other injuries, the decedent sustained a massive skull base fracture (ring fracture—see Chapter 6, Forensic Pathology) with associated fatal central nervous system injury, along with a right femoral neck fracture and an upper thoracic spine fracture. The fractures to the skull base and the femur fracture are depicted in the 3D CT scan reconstructions depicted in Figs. 15.12–15.14. These reconstructions illustrate the utility of this technology for clearly showing the orientation of bony injuries resulting from high-energy trauma.

FIGURE 15.12 Postero-inferior view of the skull demonstrating complex fractures of the skull base.
As described in the first case study, an IPA investigation was helpful to understand the injury biomechanics of the collision. The cutaneous injury pattern observed in the right lower quadrant of the decedent’s back was matched to the structure, geometry, and height of the right front brake lever and housing. See Figs. 15.15 and 15.16.

The smooth and contiguous injury pattern almost certainly resulting from impact by the brake lever suggests that the driver was not using the front brake when the motorcycle struck the decedent, as the pattern from the two fingers on the brake lever would likely have been evident (the brake type was designed for two-finger use).
FIGURE 15.14 Anterior view of pelvis demonstrating right femoral neck fracture.

FIGURE 15.15 Posterior view of the decedent’s torso and right upper extremity. The widely distributed reddening is postmortem livor (see Chapter 6, Forensic Pathology). The injury pattern seen in the circled area is a near-perfect match for the right front brake lever and housing (see Fig. 15.16).

III. APPLICATIONS OF FORENSIC EPIDEMIOLOGY
IMPACT SPEED ANALYSIS

There were two types of evidence used to assess the impact speed of the motorcycle. The first and most reliable was the distance traveled by the motorcycle after impact, which was approximately 100 feet (30 m). A motorcycle sliding on pavement will lose speed at a relatively consistent rate because of the friction between the bike components and the roadway (known as the friction coefficient or drag factor) (McNally). If the distance that the motorcycle has slid is known then a standard “slide-to-stop” calculation can be used to estimate the pre-slip speed of bike.

The formula for this calculation, assuming that the final speed of the bike was 0, is

\[
\text{Pre-skid speed} = \sqrt{2 \times \text{road drag factor} \times \text{distance of skid}}
\]

The result is in feet or meters per second, which can be converted to mph or km/h.

Taking into account the distance that the motorcycle traveled during the skid (100 feet (30 m)), and using a middle value for the coefficient of friction for the motorcycle on the paved sidewalk (0.5), the calculation yielded a preimpact speed of 38 mph (62 km/h), or around three times the speed claimed by the driver of the motorcycle. In the calculation there was no accounting for the energy lost (ie, slowing) when the motorcycle struck the decedent, and thus the preimpact speed was likely greater than just the skid to stop calculation result. Depending on the degree of engagement between the bike and the decedent, the impact could have added an additional 3 mph or more (5 km/h) to the impact speed.
In keeping with the safety analysis approach described in the first case study, assumptions most favorable to the defendant were further examined. Had the motorcycle began to slide while traveling only 12 mph (20 km/h) as claimed by the defendant, and using the lowest published drag factor for a sliding motorcycle, the postimpact travel would have been only approximately 13 feet (4 m), nearly 90 feet (27 m) less than what was observed. This is such a large disparity from what was observed at the scene that it is reasonable to conclude, even assuming a relatively high degree of inaccuracy or error in the measurements or reported distance estimations and an unrealistically low coefficient of friction for the entire slide distance that it is a physical impossibility for the subject collision to have occurred at less than 30 mph (50 km/h).

The second analysis of the impact speed of the motorcycle (made somewhat moot by the reconstruction findings matched to the evidence) was based on an analysis of epidemiologic data, relative to the injuries observed in the decedent. As a demonstration of the forces typically associated with just the decedent’s skull fracture (ie, ignoring the additional presence of the femur fracture), data were accessed from the NASS-CDS database (described in Chapter 11, Traffic Injury Investigation).

The parameters of the search performed for the present case were as follows: all data were accessed for all occupants 10–25 years of age with a skull base fracture coded as “severe” (AIS 4+) or greater, injured in a passenger vehicle that was involved in a crash, but with no vehicle rollover and no ejection of the occupant. The crash also had to have been reconstructed for impact-related speed change to be included in the analysis. The purpose of the analysis was to find circumstances in which a skull base fracture resulted from a quantified intravehicular impact, as the speed change of the vehicle would be the approximate speed at which the occupant would collide with components in the vehicle interior, and provides the best estimate of impact severity associated with the injury.

Ideally the analysis would have been performed on pedestrian impacts, but no such database containing information on impact speed versus fracture risk was available.

The results of the analysis were as follows:

There were an estimated 7285 occupants with the injury of interest during the years queried (1995–2012). The average speed change at which the injury occurred was 32 mph (53 km/h). Only 2.5% of the injuries occurred in crashes with a less than 12 mph (20 km/h) speed change.

From these data it could be concluded that skull base fractures like the one seen in the decedent are unusual at occupant impact speeds of 12 mph (20 km/h) or less. If the additional impact energy required to cause both the skull fracture and the femur fracture were to be accounted for, it is likely that there would be an even smaller proportion of injuries occurring at similar speed changes.

As a final point to be included in the investigation of the cause of the fatal crash, the fact that the witnesses turned and looked at the motorcycle and then turned back and kept walking suggests that initially the bike was not perceived as a threat. This fact pattern suggests that the driver was traveling slowly when he mounted the sidewalk and the girls saw him, and then he accelerated toward the girls to reach the impact speed. A bike as powerful as the subject Yamaha would be able to accelerate to the likely impact speed within a very short distance. This fact pattern tends to cast doubt on the driver’s initial explanation that he lost control of the bike prior to it leaving the roadway.
FIGURE 15.17  The lamp and the table that it was ordinarily situated on in the father’s home.

III. APPLICATIONS OF FORENSIC EPIDEMIOLOGY
This case study concerns a skull fracture sustained by an 8-month-old male infant who was in the care of his father. The child was crawling around the family room of the father’s home, and the father left the room for a short time. He heard the child begin to cry and rushed back to the room to see what had happened. He found the child in obvious distress, with a small mark at the back of his head and swelling that was rapidly forming. He also found a small glass lamp lying next to the child, unplugged. The position of the lamp on the table where it is normally situated is depicted in Fig. 15.17. Figure 15.18 is the appearance of the plug when the father examined it.

The father took the child to the emergency department of the nearest hospital where a physical examination was conducted and a CT scan of the child’s head was performed. The scan demonstrated a comminuted skull fracture to the left parietal aspect of the child’s skull with subgaleal hemorrhage (bleeding between the scalp and the skull), subdural bleeding over the surface of the brain, and bleeding within the brain from a contusion, with associated subarachnoid bleeding. Images from the CT scan are reproduced in Figs. 15.19 and 15.20.

A pediatrician who examined the child at the emergency department was shown photographs of the lamp and the table the lamp ordinarily sat on. Additionally, the pediatrician was shown a photograph of the lamp from a cell phone (investigators later took
FIGURE 15.19  Image from CT scan performed on the infant at the emergency room.

FIGURE 15.20  A 3D reconstruction of the CT scan examination performed in the emergency room, demonstrating the discrete pattern of the fracture consistent with an impact from a pointed object, with a 3 mm depressed and comminuted fracture noted.
measurements at the scene and from the lamp (see Fig. 15.21), and the weight of the lamp was measured at 2.4 lb (1.1 kg). Based on this information the pediatrician concluded that the history of how the injury occurred was “not consistent with this kind of injury” and that consequently “this kind of injury is highly concerning for inflicted injury (emphasis added).” Based on this conclusion the father was charged with child abuse. The child ultimately had a complete recovery from the injury.

The necessity of an FE analysis of causality was made imperative by the speculative assertion by the pediatrician regarding the cause of the injury. The pediatrician’s conclusion was in the form of a logical fallacy called the conditional probability fallacy, described in Chapter 3, Methods Used in Forensic Epidemiologic Analysis (also known as the fallacy of the transposed conditional). The pediatrician erroneously concluded that the common sense conclusion that the risk of the injury from the history given by the father was “low” (ie, it “makes sense” that such a small lamp falling such a short distance would be unlikely to cause such a significant skull fracture and intracranial hemorrhage) was used as evidence to reach the seemingly complementary conclusion that the alternative explanation, that the injury was intentionally inflicted, was high. In essence the pediatrician used the presence of the injury in the context of the history of how it occurred as a test of intentional injury in the same way the injury pattern evidence described in the first two case studies was used. The flaw in the approach is that there is no indication of the false positive rate of the test for the circumstances in which it was used.

**FIGURE 15.21** Photographs of measurements of the table and lamp performed by investigators for law enforcement after it was determined that the injury could not have resulted from an impact from the lamp.
The fallacy is avoided by first identifying the elements of an actual investigation of injury risk from a falling object, which would include a biomechanical investigation of the range of forces potentially resulting from the known physics of the event, combined with an estimation of the injury threshold of the involved tissue (if known) (see Chapter 9, *Biomechanical, Epidemiologic, and Forensic Considerations of Pediatric Head Injuries* for additional discussion of methods). The next step is to examine the probabilities associated with the alternative explanations, such that a posttest probability of unintentional (or intentional) injury could be estimated. An appropriate analysis of the probability of intentional injury would require substantially more information than the pediatrician possessed at the time that the opinion was proffered (which resulted in the arrest and charging of the father). As an example of additional information that would have been useful, the preevent probability that the injury was intentionally inflicted could have been enhanced by the knowledge that the father had a previous history of child abuse, or that he was known to be violent. Conversely, if the father had a completely absent history of violence this would tend to decrease the probability that he had suddenly become violent, absent contemporaneous evidence that this was the case.

As a practical matter, the risk of injury from the history provided by the father would be very difficult to assess. This difficulty could be overcome with a counterfactual approach; ie, by assessing the implication that the injury could not have resulted from the history provided by the father.

An investigation of the biomechanical aspects of the event began with an assessment of the physics of the falling lamp. Measurements taken at the scene and from the lamp were used to assess the kinetic energy of the lamp at the time of head impact. Assuming a minimal fall distance from the table top to the child’s skull of 18 inches (0.5 m), and 2.4 lb (1.1 kg) in weight, and using the fall height formula described in Chapter 9, *Biomechanical, Epidemiologic, and Forensic Considerations of Pediatric Head Injuries*, the head impact speed of the lamp would have been approximately 7.0 mph (11.2 km/h). The associated kinetic energy of the falling lamp would have been approximately 4 ft-lb (5.4 J). An important aspect of the analysis is to understand that it is not just the weight and speed of the falling lamp, but also the geometry and stiffness of the lamp that predicts injury. It is not difficult to understand that if the child was struck in the head by the pointed corner of the glass lamp that the injury potential of the impact would be greater than if the child was struck by a flat side or edge of the lamp. A calculation of the pressure exerted on the child’s skull by one of the corners of the falling lamp, assuming a 0.25 inch (6 mm) stopping distance, indicated 147 MPa (megapascals) of mean pressure from the impact. A comparison with the failure thresholds demonstrated in experimental study of infant skull fractures indicated that the impact had the potential to exceed the fracture tolerance of an infant skull (Margulies and Thibault, 2000).

A further factor to be considered in the analysis was the deformation of the electrical plug for the lamp (Fig. 15.18). If the plug was bent because the child pulled on the cord, which then resulted in the lamp striking him in the head, the fall energy analysis would likely be an underestimation of the upper bound of the force, and thus injury risk, of the impacting lamp as the lamp could have accelerated toward the infant’s head at a rate greater than the pull of gravity.
As a result of this analysis it was concluded that the pediatrician’s assertion that the injury risk from the lamp impact was so low that intentional injury should be considered as the most likely explanation for the child’s skull fracture and associated injuries was deemed speculative and inaccurate. Moreover, further investigation demonstrated no collateral evidence that supported a determination that the injury resulted from abuse. There were no additional injury findings indicating abuse in the child, no history of abuse or violence on the part of the father or any other caregiver, and no injury mechanism that explained the discrete skull injury other than the stated history. As a test for intentional abuse, the uninformed assertion that “it did not seem like the lamp could have caused the diagnosed injury” was neither precise nor reliable.

As an endnote to this case study the prosecution dropped the charges against the father of the child following review of the results of the aforementioned analysis.

CASE STUDY #4: FETAL DEATH FOLLOWING MATERNAL COCAINE INGESTION

In this final case study we describe another criminal prosecution in which the pivotal issue was one of the probabilistic assessments of evidence. The underlying facts of the case were as follows.

In 2006 a 15-year-old crack cocaine-using African-American female gave birth to a stillborn fetus at 37 weeks gestation (full term). A toxicologic examination of fetal blood indicated the presence of a small and nonlethal amount of benzoylecgonine, a cocaine metabolite. Based solely on this finding the pathologist who performed the autopsy on the fetus determined that the manner of death was homicide. Based on the laws in the US state where the birth occurred, the mother was charged with first-degree murder.

An FE analysis of causal probability was undertaken, in order to assess the reliability of the inference by the pathologist that the presence of a nonlethal level of cocaine in the fetal blood was the “most probable” cause of the fetal demise. The assumption by the pathologist was that the finding of cocaine metabolite in the fetal blood served as the sole explanation for the stillbirth. The assumption ignored the well-established fact that stillbirth occurs both with and without maternal–fetal cocaine exposure, and maternal–fetal cocaine exposure occurs both with and without stillbirth. Further, stillbirth occurs disproportionately among disadvantaged and women of color (Stillbirth Collaborative Research Network Writing Group, 2011), characterizations that both are accurate descriptions for the defendant mother. Although the etiology of stillbirth in individual cases is often unclear, a number of associated factors, including poverty, single motherhood, inadequate prenatal care, maternal age, infection, obesity, diabetes, thrombophilia, fetal genetic or structural abnormalities, and umbilical cord abnormalities have been identified. Notably, the mother was also diagnosed with a thrombophilia (a tendency to form blood clots).

An analysis of the epidemiologic literature, performed as the initial step of the case analysis, indicated nonsignificant elevation of risk for stillbirth secondary to maternal–fetal cocaine exposure (Miller et al., 1995; Wolfe et al., 2005).

In the FE analysis, the relationship between maternal–fetal cocaine exposure and stillbirth was considered to be plausibly causal but potentially confounded (see Chapter 3, Methods Used in Forensic Epidemiologic Analysis) by some of the previously mentioned factors. To further
quantify the relationship a case-specific analysis of hospital inpatient birth data was performed. Data from the Nationwide Inpatient Sample Database (NIS) of the Healthcare Utilization Project of the Agency for Healthcare Research and Quality of the US Department of Health were accessed. This database is described in more detail in Chapter 11, *Traffic Injury Investigation*, Chapter 12, *Traffic Injury Investigation: Product Defects*, Chapter 13, *Product Defect/Liability Investigation*, and Chapter 14, *Medical Negligence Investigations*.

Initially, a univariate analysis of the contribution of maternal cocaine presence to stillbirth risk, along with other known risk factors, was conducted. These findings were used to construct an adjusted model of the relationship between cocaine exposure and stillbirth, using binomial logistic regression. The results of the analysis resulted in an odds ratio of 1.58 (95% CI 1.02, 2.45). This value was used as a CRR for the analysis and was converted to a probability of causation of 37%.

As a result of the FE analysis it was concluded that nonlethal maternal–fetal cocaine exposure in a case of stillbirth does not account for more than 50% of the cause of the stillbirth. The assumption by the pathologist that the presence of fetal cocaine was highly specific for the stillbirth in the individual case, and thus the manner of death was homicide rather than due to natural causes was rejected as erroneous. While the cocaine exposure could have caused the stillbirth, it could not be concluded that the exposure was the most probable cause of the stillbirth, much less that a homicide had been committed beyond a reasonable doubt, which was the relevant standard of proof for a criminal conviction in the jurisdiction where the crime was charged.

As a final note, the charges against the mother were ultimately dismissed.

References


