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Neurobiology of Trauma

Julie Valentine, MS, RN, CNE, SANE-A; Linda Mabey, DNP, APRN, PMHCNS; and Leslie Miles, DNP, APRN, PMHNP

“Traumatic stress has a broad range of effects on brain function and structure, as well as on neuropsychological components of memory.”
(Bremner, 2006, p. 455)

Key Points in This Chapter

- The neurobiology of trauma can affect the functioning of the brain with lasting consequences.
- The body’s hormonal response to trauma affects the encoding of memory.
- Acute stress disorder (ASD) can result following trauma and can develop into post-traumatic stress disorder (PTSD) if symptoms last for more than 1 month.
- Trauma can cause immediate symptoms, such as tonic immobility and dissociation, and may lead to chronic symptoms of depression and anxiety.
- Exposure to trauma can cause physical health problems.
- Evidence-based psychotherapy treatment options following traumatic exposure are available.
- Providing compassionate, nonjudgmental care to victims of trauma helps their healing process.
Nurses work with many individuals who have suffered trauma as well as those who have inflicted trauma on others. Often, those who perpetrate crimes have been victims of trauma themselves. It is important to understand what occurs physiologically to the person who has experienced trauma and its aftermath. This chapter discusses the neurobiology of trauma, the repercussions of experiencing trauma, and interventions to improve the lives and functioning of traumatized individuals.

**Defining Trauma**

Trauma can be defined in a variety of ways, including bodily injury, a catastrophic occurrence, and psychological and physiological reactions to an overwhelmingly negative event. For the purposes of this chapter, *trauma* refers to an actual or threatened event that begins with the stress response but continues to negatively impact psychological and physiological functioning.

Exposure to traumatic events is common in the United States:

- The seminal National Comorbidity Study (NCS) reported that 60% of men and 51% of women experienced a traumatic event in their lifetime (Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995).

- The most frequently encountered traumas involve a life-threatening accident, a natural disaster, or witnessing a traumatic event that happens to someone else.

- Over half of the individuals who experienced trauma reported more than one type of traumatic exposure.

*Post-traumatic stress disorder (PTSD)* is a mental disorder frequently associated with exposure to trauma. Although not all individuals exposed to traumatic events develop PTSD, a sizable proportion do, about 29% in the NCS sample. Of the various kinds of traumatic exposure surveyed by the NCS, individuals who faced assault, physical or sexual, were the most likely to develop PTSD (Kessler et al., 1995). Rape, a particularly violent form of assault, is a potent risk factor for PTSD (Ballenger et al., 2000; Tjaden & Thoennes, 2006). The higher
incidence of rape and interpersonal violence in women may contribute to the higher prevalence of PTSD in women (American Psychiatric Association [APA], 2013).

Four neurobehavioral symptom clusters are characteristic of PTSD:

■ Intrusive symptoms, including distressing memories and dreams
■ Avoidance of reminders of the trauma
■ Hyperarousal
■ Negative alterations in cognition and mood

In addition, sufferers often experience flashbacks of the event, nightmares, increased startle reflexes, and emotional numbing. These symptoms are associated with “high levels of social, occupational, and physical disability, as well as considerable economic costs and high levels of medical utilization” (APA, 2013, p. 278). If individuals develop PTSD from trauma exposure, they are at high risk for developing an array of additional mental disorders, including depression, bipolar disorder, anxiety disorders, and substance disorders (APA, 2013).

**Diagnosing Trauma’s Effect on the Brain**

The ability to evaluate the effects of trauma has expanded in the past two decades. Prior to the 1990s, the impact of trauma could only be detected by observing the behaviors and psychological distress that resulted from it. Functional magnetic resonance imaging (fMRI) and positron emissions tomography (PET) now allow scientists to study what happens in the brain in response to trauma. Although individuals will have differing reactions and consequences from trauma, all responses are generated by brain activity. PET scans and fMRIs map the activity and brain circuitry involved in the central nervous system’s traumatic response.

A nurse who is caring for a patient who has experienced significant trauma should remember that people are not only shaped by a lifetime of experiences (who they are) but also acutely impacted by the effect the current trauma has on their brain.
functioning (what has happened to them). This awareness helps the nurse accept each patient as a unique person doing the best he or she can to manage his or her distress.

The following sections explore various neurobiological factors that influence an individual’s response to trauma, as well as how the brain reacts to traumatic events.

How Genes and Environment Influence Trauma

In the normal day-to-day course of events, the brain processes experiences and retains information that is important to ensure not only survival but also growth and development as human beings. A significant amount of the information that contributes to the survival and development of human beings is transmitted through the collective human genome. In the process of transcription and translation, genes control the production of amino acids, the protein building blocks essential to human life.

It is beyond the scope of this chapter to discuss in detail how genes are constructed and function. However, it is important to know that gene expression—whether a gene is “turned on” to produce its amino acid product or “turned off” to not produce its product—is not a one-way process of genetic inheritance. Rather, unique personal experiences also influence how individual genes are expressed. How a person responds to trauma is not dependent upon a linear culmination of inherited factors, temperament, personality, and environmental influence; it is contingent upon the interaction of multiple environmental and genetic factors. For example, recent research examined how specific inherited forms of the serotonin transporter and corticotropin-releasing hormone receptor genes combined with a history of early childhood adversity to produce a greater susceptibility to depression when adults are faced with acute stress (Starr, Hammen, Conway, Raposa, & Brennan, 2014). Serotonin and cortisol are important players in mood and stress regulation, and a particular form—or allele—of their transporter genes affects their function negatively. Traumatic childhood experiences do not always produce depression in adults who face acute stress. A genetic vulnerability in the serotonin and cortisol systems appears to combine with two environmental insults, childhood adversity...
and adult stress, to confer a susceptibility to depression. Although not all stress can be classified as trauma, all trauma involves stress.

**How Trauma Affects Brain Development**

The human brain develops in an orderly sequence over time and is not mature until early adulthood. Even then, the brain remains quite “plastic”; that is, new connections between nerve cells continue to develop throughout life. This is both a blessing and a curse. It is a blessing because if the brain suffers a physical injury, such as a stroke, the brain can recruit undamaged areas to help the individual regain many functions that may have been lost due to the brain injury. It is a curse in the sense that when a trauma occurs, the individual may have the experience “etched” into his or her brain without psychological or physiological resolution. When this occurs, the experience is replayed, including all of its sensory aspects, when triggers ignite the trauma system. The same memory systems that help a person survive now turn against the person.

The brain develops in a bottom-up direction, with reptilian brain being the most primitive. Located in the brainstem, this is the part of the brain that regulates basic bodily functions, such as breathing, eating, and sleeping. Close in proximity to the reptilian brain is the limbic system. The limbic system is a series of structures whose functions include alerting us to danger; interpreting stimuli as frightening or fun, motivating or boring; as well as memory encoding. Together the reptilian brain and limbic system constitute what trauma specialist Bessel van der Kolk refers to as the “emotional brain” (2014, p. 57).

**How the Limbic System and the Amygdala Contribute to Trauma**

Certainly not all stress is a result of trauma. However, the stress response is an important initial reaction that can be triggered by a traumatic event. The limbic system is particularly important in how we respond to our environment and is constantly changing in response to internal and environmental stimuli, including threat. Yesterday you may have had no reaction to a picture of an alligator. However, after you encountered one on the golf course in Florida today, the
same picture may now elicit sheer panic. This reaction is the result of a cascade of brain activity, including the activation of an almond-shaped limbic structure called the *amygdala*. It is part of the body’s alert system and is stimulated when something noteworthy in the environment triggers its response. In a sense, the amygdala says, “I need to remember this!” Figure 3.1 depicts a model of the brain.

**Figure 3.1 A depiction of a brain model.**

The amygdala fires whether the experience is exquisitely lovely or decidedly dreadful and sets the process of encoding the memory in motion. Its firing can occur even before the brain is consciously aware of the significance of the stimulus. For example, when you startle because you see something in your path, your amygdala has sent the alert that the object may be a threat. A moment later, your frontal cortex, whose job is to evaluate and make reasoned judgments, sends the message back to the amygdala that “it is just a stick,” and the amygdala ceases its threat alert. The experience of trauma can “over-sensitize” the
amygdala, causing it to fire alert responses when there is no current danger, but instead activating memory traces of past trauma, often somatic or sensory in nature. This occurs because trauma memories are not stored in a discrete area of the brain but are encoded into neural networks connecting various emotions, body sensations, and cognitions associated with particular memories.

In the complex process of memory encoding, the amygdala plays a significant role, as do the hippocampus, hypothalamus, and anterior cingulate (Wheeler, 2014). The hippocampus is critical in inhibiting the amygdala, forming distinct memories and constructing the personal narrative that forms the autobiographical sense of self. The hypothalamus functions as a type of command center and exerts its influence through the hypothalamic-pituitary axis (HPA). It interacts with the amygdala and the endocrine system. A signal from the amygdala brings the hypothalamus on board to play the critical role of regulating the body’s response, including blood pressure, pulse, and glucose availability. Additionally, the hypothalamus stimulates the release of cortisol through its discharge of corticotropin-releasing hormone (CRH). This hormone activates the pituitary gland to release cortisol from the adrenal glands. Cortisol stimulates glycogenolysis, releasing the glucose needed to respond to a threat.

Many of the mental and physical health problems associated with PTSD are in response to the overstimulation of the hypothalamic-pituitary axis (Wheeler, 2014). The anterior cingulate is involved not only in the regulation of the autonomic and neuroendocrine systems but also in the cognitive and emotional responses to stimuli. As explained by Wheeler, “This structure helps decide which emotional information to pay attention to and assists in processing emotion arising from the limbic system by recruiting other areas of the cortex to respond to emotions” (2014, p. 71). Although the limbic system is the key player in a person’s response to stress and trauma, other brain structures, including the cerebellum, locus coeruleus, cerebral cortex, orbital medial prefrontal cortex, insula, corpus callosum, and right and left hemispheres, are also involved. In essence, trauma impacts the entire brain.
Understanding the Psychological and Physical Effects of Trauma

The majority of individuals do not develop PTSD following trauma, but experience short-term reactions. Time-limited trauma responses include:

- **Acute stress reaction**: An acute stress reaction occurs up to 48 hours after trauma exposure and may include symptoms such as nightmares, anxiety, aggression, and mood disturbances (Bryant, Friedman, Spiegel, Ursano, & Strain, 2011).

- **Acute Stress Disorder**: If the individual's symptoms are severe and remain after 2 days, the person may be experiencing Acute Stress Disorder (ASD).

  ASD can develop from witnessing, directly experiencing, or even hearing about a trauma. First responders, including firefighters, police, and healthcare workers, are vulnerable to this disorder due to their job exposure to trauma. Recurrent and intrusive memories of the event, disturbing dreams, flashbacks, sleep disturbances, exaggerated startle response, and feeling “unreal” about one's environment or self are common manifestations of ASD. Individuals with ASD are often unable to recall aspects of the trauma.

  ASD is a result of the same neurobiological cascade as PTSD, but in ASD the disorder is temporary and resolves within a month of the traumatic exposure. If ASD symptoms last for more than 1 month, the diagnosis changes to PTSD (APA, 2013). Approximately half of trauma survivors with ASD develop PTSD (Bryant, 2010).

It is important for nurses to understand and remember that there are no right or wrong reactions to trauma, as there is significant variability in behaviors. Some patients cry uncontrollably while others may become non-responsive or emotionally labile. During trauma, a hormonal flood is released, triggering the fight, flight, or freeze response. While some individuals fight or flee during trauma, others freeze, a response known as tonic immobility. Sexual assault victims often experience tonic immobility, causing an inability to run, fight, or yell (Campbell,
Tonic immobility can be triggered when an individual experiences a terrifying, traumatic situation resulting in extreme fear (Abrams, Carleton, Taylor, & Asmundson, 2009; Campbell, 2012). Nurses should reassure patients who have experienced tonic immobility that their freezing or immobility reactions were normal, because many individuals blame themselves for not reacting to the trauma by taking action. The hormonal response to acute trauma may also result in peri-traumatic feelings of detachment, decreased awareness, hyper-awareness, or memory loss. Nurses must adopt a nonjudgmental attitude toward how patients respond to trauma, recognizing that trauma response is highly variable.

Exposure to trauma often results in physical manifestations. A large epidemiological study, the Adverse Childhood Experiences study (ACE), demonstrated that adult health outcomes were negatively affected by childhood trauma in a dose-dependent relationship; the more types of traumatic childhood events experienced, the more negative physical health outcomes reported by adults. The negative health outcomes included increased rates of cancer, liver disease, heart disease, and lung disease (Felitti et al., 1998). The ACE study findings have been replicated (Anda et al., 2006). More recently, Sledjeski, Speisman, and Dierker (2008) explored the relationship among PTSD, number of lifetime traumatic experiences, and adverse health outcomes. They found that the more traumatic events a person experienced, the more likely the individual was to self-report chronic medical problems, including chronic pain; cardiovascular, neurologic, and respiratory conditions; as well as diabetes, cancer, and ulcers.

The burden of accruing traumatic experiences shapes the function and structure of the central nervous system. Individuals, including children, who experience repeated trauma have a brain default setting of fear and distrust that plays out in many relationships, including with healthcare providers (van der Kolk, 2014). Children who have suffered serious abuse and neglect display a predictable pattern of behaviors, including the inability to regulate emotions, difficulty concentrating, and challenges in getting along well with others. The flood of stress hormones experienced by children facing multiple adversities is also associated with physical symptoms of headaches, sleep disturbances, self-harm, unexplained pain, and oversensitivity to touch or sound (van der Kolk, 2014).
Collaborative Interventions Following Acute Trauma

In the immediate aftermath of a trauma, primary attention should be on the physical and psychological safety of the patient.

First and foremost, the patient should be in a safe location where no further trauma can occur and basic physiological needs are met. Tell the patient that she is safe. Assessment of physical injuries and necessary medical care are priority interventions.

Following meeting basic needs and physical care, it is vitally important to address the psychological needs of the traumatized patient. During and after a traumatic event, individuals feel a loss of control. Help patients regain feelings of control by informing them of what will happen next and providing choices in their care. This helps patients feel an increased sense of control and aids in establishing a therapeutic relationship. Strive to establish a caring, compassionate relationship with traumatized patients without passing judgment on their choices or experiences. Fehler-Cabral, Campbell, and Patterson (2011) found that when nurses expressed compassion, believed victims, explained care, and provided choices to victims of sexual assault, the victims reported that the nurses’ actions helped in their emotional recovery from the trauma.

To further instill a feeling of control in victimized patients, ask them permission before touching their bodies. Avoid the temptation to provide comforting touch unless the patient grants permission. It is best to ask as few questions as possible of patients immediately following trauma, as retelling the story may cause re-traumatization. Only ask necessary questions to guide healthcare delivery. Additionally, they may have impaired memory of the traumatic event, especially if it is a recent trauma. When individuals initially recount a traumatic experience, it is often in an emotionless and non-sequential way (Herman, 1997). The passage of time helps to solidify memories and ascribe feelings to the experiences (Campbell, 2012; Herman, 1997).
After establishing an atmosphere of safety and trust with the patient, complete a thorough assessment, noting the presence of the following symptoms (Veterans Health Administration [VHA]/Department of Defense [DoD], 2010):

- Physical (exhaustion, hyperarousal, somatic complaints)
- Emotional (anxiety, depression, guilt, hopelessness)
- Cognitive (amnesia, dissociation, hypervigilance, paranoia)
- Behavioral (avoidance, problematic substance use)

All trauma victims should be assessed for suicidal thoughts, self-harm, ASD, and PTSD from previous traumas. Feelings of guilt are highly prevalent in victims of trauma, especially in cases of sexual assault and interpersonal violence. Openly express to patients that they hold no responsibility for the actions of others; instead, they need to understand that they are victims of a crime. Support systems and coping resources should always be explored with patients. Hospitalization may be necessary if a victim is suicidal, psychotic, or unable to provide self-care.

**Treatment Options**

There are a variety of psychotherapy treatment options for traumatized individuals, including individual psychotherapy, group therapy, and support groups. It is important to recognize that treatment may also be required by significant others of a trauma victim, because they may experience secondary victimization. Different types of evidence-based treatment options are listed in Table 3.1. The goal of treatment is for the traumatized individuals to return to their previous or higher level of functioning.
### TABLE 3.1 EVIDENCE-BASED TREATMENT OPTIONS

<table>
<thead>
<tr>
<th>Type of Therapy</th>
<th>Brief Description of Therapy</th>
<th>Where to Find More Information</th>
</tr>
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<tbody>
<tr>
<td><strong>Trauma</strong></td>
<td>Focus on altering trauma-related beliefs and behaviors. Teaches relaxation and breathing skills. Recommended for ASD treatment (Roberts, Kitchiner, Kenardy, &amp; Bisson, 2009).</td>
<td>A web-based training course for TF-CBT: <a href="http://tfcbt.musc.edu/">http://tfcbt.musc.edu/</a> and the TF-CBT Therapist Certification Program: <a href="https://tfcbt.org/">https://tfcbt.org/</a></td>
</tr>
</tbody>
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Psychotropic medications may be prescribed to help reduce patients’ feelings of anxiety and depression. Although various medications, including hydrocortisone, have been trialed to attempt to ward off the development of PTSD, Amos, Stein, and Ipsen (2014) found insufficient evidence to recommend pharmacological intervention immediately following acute trauma.

### INTERDISCIPLINARY RESOURCES AND REFERRALS

Because high levels of distress and anxiety make it difficult for victims to retain information, the nurse should provide a printed list of available community resources: legal aid advocacy center, local mental health center (Medicaid and...
Medicare), local rape recovery center if a sexual assault occurred, and victim advocacy groups or contacts. If the victim has insurance, a referral to a mental health therapist certified in evidence-based trauma treatment should be provided. Therapists and advocacy groups can provide information on local resources such as group therapy or support groups. State laws vary regarding victims’ compensation funds, which offer state financial assistance to victims, including healthcare and therapy programs. In addition to local resources, there are a number of additional resources for victims of trauma:

- National Sexual Assault Hotline sponsored by Rape, Abuse & Incest National Network (RAINN) (24/7): 1-800-656-HOPE
- National Sexual Assault Online Hotline sponsored by Rape, Abuse & Incest National Network (RAINN): https://ohl.rainn.org/online/
- Pandora’s Project—Support and resources for survivors of rape and sexual assault and their friends and family: http://www.pandys.org/index.html
- Resources from the National Sexual Violence Resource Center: http://www.nsvrc.org/resources
- The National Domestic Violence Hotline (24/7): 1-800-799-SAFE (7233)
- Disaster Distress Helpline (24/7): 1-800-985-5990

Case Study: Trauma

Pam, a 24-year-old woman, reports to her local emergency department (ED) to receive care following a rape. Pam is placed in an ED examination room, and a sexual assault nurse examiner (SANE) and rape recovery advocate are paged to respond. You are the ED nurse caring for Pam. You ask Pam what happened to...
her and if she was hurt. She makes little eye contact, speaks softly, and is curled up on her side on the hospital gurney. She tells you, “He raped me. I hurt all over, but mainly my arms and legs cause I think he held me down.” After asking Pam’s permission, you quickly examine Pam’s arms and legs and notice scattered bruises on her upper arms and legs, but do not find any serious bodily injury. You tell Pam, “I’m so sorry this happened to you. A forensic nurse and a rape recovery advocate have been called in to see you. They should be here in a few minutes. When did this happen to you?” Pam responds, “Last night, around midnight.” You inform Pam that it is best for evidence collection if she doesn’t eat or drink anything, but you will get her food as soon as possible. You ask Pam if there is anything you can do to make her more comfortable. She shakes her head “no” and begins to cry softly. You give Pam a box of tissues and ask if she would like you to just sit with her until the SANE arrives. Pam shakes her head “yes.” You ask if she would like a warm blanket. She indicates “yes” and you place a warm blanket on her.

- Evaluate yourself as the first nurse responder.

- You asked permission before touching Pam and asked only necessary questions as well as telling her what to expect. Was there anything else you could have done?

Within minutes the SANE (Mary) and the rape recovery advocate (Sue) arrive. They introduce themselves and you leave the room telling them to let you know if they want you to return to the room. Mary and Sue sit in chairs so that they are eye level with Pam, who remains curled up on her side. Mary says, “I’m so sorry this has happened to you. I don’t know your story yet, but I know you are not to blame. You were a victim.” Pam then tells Mary that she was to blame as she had gotten “really drunk on a first date.” They tell her, “Just because you were drunk doesn’t give anyone the right to hurt you.” Pam begins to cry softly. Mary then says, “When you are ready I am going to tell you about the examination. It is important that you understand that you are in control of this examination. I won’t do anything without telling you about it first and having your permission.”
After a few moments, Pam says that she is ready. Mary explains the examination and interview process following a rape. Mary tells Pam that she would need to ask her specific questions about what happened to her. Pam signs the consent forms. Mary asks Pam to tell her what happened, and Pam states, “We were drinking at the bar and then went to his apartment. He seemed like a nice guy. He fixed me a drink at his apartment, but I was already feeling really drunk so I didn’t want to drink it. After a few minutes, I asked him to take me home. He got mad and said that wasn’t the plan. I started to get scared and just wanted to get out of there, but I couldn’t find my purse. The next thing I remember, he grabbed my arms and pushed me down on the floor. At first I tried to get away, but then I froze. I couldn’t even yell. After that, I only remember bits and pieces. He was on top of me and raped me. I felt like I wasn’t connected to my body, like this was happening to someone else. I just wanted to get out of there.” Pam tells most of the story with her eyes closed and a flat affect. When she is done, she cries softly. Mary asks Pam if anything like this had ever happened to her before. Pam nods “yes” and says, “When I was about 11 years old, my step-uncle held me down and touched my genitals. I told my mom, but she didn’t do anything. She just told me not to be alone with him again.”

What do you see reflected in Pam’s story about the neurobiology of trauma?

- Tonic immobility: Pam reports feeling like she could not move or yell.
- Memory fragmentation: Pam reports remembering only portions of the rape.
- Dissociation: Pam reports feeling disconnected from her body. She also states that she was a victim of a prior sexual assault as a child. Disassociation is more common in victims of multiple traumas.

Following the forensic interview, examination, and evidence collection, Mary and Sue provide Pam with verbal and written information on the local rape recovery center, law enforcement victim advocate’s contact information, follow-up healthcare information, and the state agency for payment of her examination as a victim. They ask Pam about her social support. Pam states that she has some good friends whom she might tell about the rape to help her through it. After the supportive response Pam receives at the hospital, she makes eye contact while...
speaking and no longer blames herself for what happened to her. Pam expresses interest in the group therapy sessions offered at the rape recovery center.

This case study highlights key points found in the neurobiology of trauma. By receiving compassionate nursing care by informed nurses on the immediate consequences of trauma, Pam is placed in a position to begin healing by seeking out appropriate resources.

**Summary**

Nurses work with many individuals who have suffered trauma as well as those who have inflicted trauma on others. When they understand how the neurobiology of trauma can affect the functioning of the brain with lasting consequences, they can better help their patients. Patients may suffer immediate symptoms, such as tonic immobility and dissociation, which may lead to chronic symptoms of depression and anxiety, common aftermaths of sexual assault. They can develop Acute Stress Disorder or post-traumatic stress disorder, and may lose memory of the event. Patients can even experience physical health problems.

Nurses should adopt an evidence-based psychotherapy treatment to diagnose trauma and its effects. Providing compassionate, nonjudgmental care to victims of trauma helps in patients’ healing process.

**References**


