How do Addicted Brains Differ from Nonaddicted Brains?

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It gives me a great deal of pleasure to introduce this critical review of the neuroimaging science of addictive disorders written by E. Laura Wright, CRNA, PhD, MNA. Wright has recently joined the Health and Wellness Committee’s Peer Assistance Advisors Committee. Her doctoral research focused on those resilience factors that were part of the shared experience of CRNAs in long-term recovery from chemical dependency.

The evolving neuroscience that is beginning to define the persistent morphological and physiological alterations that are mediated by the processes involved in neuroplasticity are essential to our understanding of how the alterations in brain functioning parallel the alterations in physiology of other chronic diseases such as coronary artery disease. These diffuse alterations in brain physiology and downstream motivation, learning, and behaviors underpin the chronic, progressive nature of addictive disorders.

I thank Dr. Wright for her significant contributions to our understanding of the neuroscience, particularly as it applies to our recovering colleagues.

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It is rare that someone has never been affected on some level by addiction. Often, it is easy to see the outward signs of chemical dependency as addicted coworkers or loved ones appear to make incomprehensible choices, especially when they relapse. Understanding some of the neurobiological underpinnings of the disease of addiction helps raise awareness about the challenges faced by those in recovery and can help explain why recovery is so difficult. Imaging studies of the brain provide a unique perspective of its neural activity and illustrate some of the alterations noted in people with chemical dependency.

Modern imaging techniques reveal that the brains of addicts are different. While there are several areas of the brain involved in the process of chemical dependency, certain areas involving dopaminergic neurons in the areas responsible for reward, memory, and inhibitory control, play significant roles in the desire, as well as the motivation, for acquiring the substance of abuse. This motivational reinforcement manifests as a craving and stimulates that overwhelming compulsion to seek and use. In fact, it is thought that the craving of an addictive substance is more an attribute of desire than it is the actual feeling of pleasure. In other words, the anticipation of pleasure is greater than the actual sensation of pleasure, and it is craving that motivates drug-seeking behavior. The brain learns to get pleasure from preceding events or cues that stimulate the desire. The pleasure associated with anticipation becomes over-inflated and in a sense, the reward system is “hijacked.” The normal pleasure pathways are wired differently. As chemical disease progresses, this sense of anticipation plays a larger role, feeding the addiction by inflating the reward and pleasure associated with anticipation of the substance. The anticipation of the substance through associated activities becomes almost as rewarding as the getting substance itself. This inflated reward associated with anticipation plays a large role in relapse. While in recovery, inadvertent exposure to these substance-associated preceding activities stimulates a sudden craving, and if impulse control is not present or strong, these experiences can be overwhelming. A nurse anesthetist in recovery from fentanyl might experience this craving while in recovery when he or she holds a fentanyl vial or walks into an operating suite restroom. If mechanisms are not in place to deal with these intense anticipatory feelings, the sensations can greatly challenge the impulse control of that nurse anesthetist.

The nucleus accumbens is an area of the brain associated with a sense of pleasure. The ventral tegmental area is a mid-brain structure that has dopamine projections into the nucleus accumbens. Stimulation of the ventral tegmental area with subsequent stimulation of the nucleus accumbens appears to play a large role in substance abuse and dependency as essentially all substances of abuse directly or indirectly stimulate one of them. While normal responses of pleasure to natural rewards such as food and sex result from dopamine release, drugs produce a more intense, but shorter acting dopamine response. Another important area for reinforcement of addictive behavior is the orbitofrontal cortex, which has projections to the ventral tegmental area.

Neural activity can be detected with tracers attached to synthetic radioactive receptor agonists (positive emission tomography [PET]) scanning or tracers of glucose metabolism through functional magnetic resonance imaging (fMRI). Both techniques display a visual image of neural activity in response to particular stimuli. These types of imaging techniques reveal some very interesting differences between the chemically dependent and non-chemically-dependent brains.

In the area of addiction, dopamine activity has been widely studied. When cocaine addicts look at drug-related videos, they are likely to experience a craving. At the same time, PET scans reveal increased dopamine activity in certain areas of the brain that are not noted when non-drug-related videos are watched. Similar results have been seen with exposure to verbal cues. Mood altering drugs are not the only substances that result in altered brain activity. When high-calorie foods were shown to obese and non-obese women, greater dopamine activation was noted in particular areas of obese women’s brains, but not in those of the non-obese women.

Another feature of addiction is a person’s loss of control of sub-
stance intake. In chemically dependent brains, blunted dopamine activity has been noted in the areas of the brain responsible for inhibition of behavior. When medications that stimulate dopamine release and mimic dopamine activity were given to detoxified alcoholics, a reduced dopamine activity was noted when compared to non-alcoholics. Impulsivity scores have been negatively associated with reduced activity in some of the inhibitory areas of the brains such as the ventral striatum among detoxified alcoholics.

Even at rest, brains of addicted individuals are different. When heroin abusers and their matched controls were asked to remain quiet with eyes closed, there was more spontaneous activity between the areas of reward such as the nucleus accumbens, ventral tegmental area, and orbitofrontal cortex. These areas were primed for activity.

Imaging genetically different brains is an emerging field. Investigators have researched genes that modulate dopamine in the reward system and have shown that dopamine receptor polymorphism affects reward system processing configuration. In some variants, fewer receptors are expressed. Dopamine binding to these receptors is reduced as well. In an addicted, this reduced sensitivity could result in desire and motivation to increase dopamine levels via his or her substance of abuse. Another area of genetic imaging research involves the catabolism and re-uptake of dopamine. Synaptic dopamine levels are maintained by catechol-O-methyltransferase, which catabolizes synaptic dopamine, and the dopamine transporter enzyme, which transports synaptic dopamine back into the presynaptic vesicle. Specific variants of either of these genes cause reduced expression and activity of these enzymes, ultimately resulting in increased synaptic dopamine and increased activity in the prefrontal cortex and ventral striatum. In certain areas of the brain these variants have shown, via imaging studies, to have an altered reward processing response. This knowledge provides a foundation for understanding how genetic predisposition plays a role in reward and risk-taking behaviors associated with addiction.

Summary
Imaging studies clearly show differences between the addicted brain and the nonaddicted brain. Most of these differences are in the areas that deal with reward processing. This processing, not only behavior, is dysfunctional in addiction. Functional neuroimaging techniques provide a deeper understanding about the intricacies of how the brain functions and may play a future role in predicting those at risk, as well as evaluating treatment and recovery programs.

References

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