Disorders of Consciousness: Brain Death, Coma, and the Vegetative and Minimally Conscious States

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Approximately five minutes after a terrible car accident that ejected Matt Trenton from his car, first responders found him face down and not breathing. They placed an endotracheal (breathing) tube in his trachea (windpipe) and transported him to the hospital, where he was admitted to the ICU. He received treatments, such as medications to elevate blood pressure, ventilator support of breathing, and IV fluids for hydration, all of which are necessary to support the brain and the body so that the brain can recover from injury.

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Although Matt's vital organs were not seriously injured, a CT scan showed widespread swelling of the brain. Dr. Roberts, a neurologist, evaluated him. Matt was still in the bed and didn't move spontaneously. When blood was drawn from his arm, he did not move it or even wince. When Dr. Roberts shouted Matt's name and applied painful stimuli to assess his level of consciousness, his eyes did not open. When she held his eyes open, no spontaneous eye movements were evident, nor did he look at her face. A review of Matt's medications and the lab and toxicology tests showed the presence of no substances that might worsen Matt's neurologic exam. Therefore, it was clear that Matt had sustained severe brain damage that was causing severely impaired consciousness—i.e., coma. Matt's parents asked Dr. Roberts if Matt was conscious or unconscious and whether he was likely to recover.

(Note: Matt is not a real patient, but a realistic composite of many patients for whom we have cared.)

In the following report, we present two possible scenarios, discuss how doctors answer these questions, and define the terms: wakefulness, awareness, consciousness, coma, vegetative state, minimally conscious state, and brain death.

A Working Definition of Consciousness: Simultaneous Wakefulness and Awareness

In assessing Matt's consciousness, Dr. Roberts was not concerned with the notoriously thorny philosophical problems of defining consciousness. She was concerned with assessing the function of the parts of the brain that are responsible for consciousness so that she could determine if Matt was aware of anything and if he was capable of suffering.

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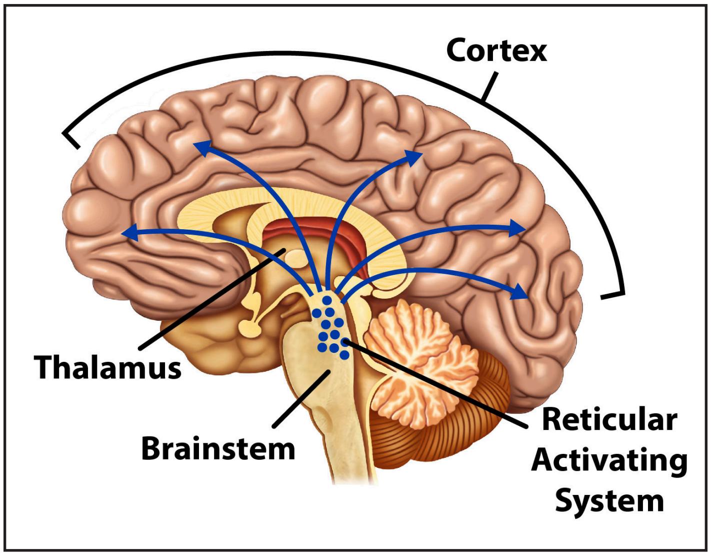
Neurologists divide consciousness into two components: *wakefulness* and *awareness*. Both must be present for consciousness to be present. The neurons and their circuits (connections) that support wakefulness are in one region of the brain, and the neurons and circuits that provide awareness are in other regions of the brain. Dr. Roberts first had to determine whether Matt's brain was capable of wakefulness, and then she would look for signs of awareness.

Wakefulness

The part of the brain responsible for wakefulness is the *reticular activating system* (RAS), a collection of neurons in the upper brainstem that send widespread stimulatory projections to the areas of the brain responsible for awareness. (See figure1.) When the RAS stimulates the brain, a person's eyes open. Therefore, spontaneous eye opening or eye opening in response to stimuli is a reliable sign that the RAS is functioning and that wakefulness is present. However, although wakefulness is *necessary* for consciousness, wakefulness alone is *insufficient* for consciousness. In other words, eye opening alone is not sufficient to indicate that a person is conscious. Clinically, if the RAS is not functioning normally, then the patient is incapable of becoming conscious and the eyes will

Figure 1.



not open—even in response to painful stimuli (such as pinching the clavicle or pressing a knuckle into the sternum). As a result, the brain is not "turned on" and cannot support awareness. This is much like a computer—if the power supply does not provide electricity to the computer, the computer will not function.

To determine if Matt was capable of wakefulness, Dr. Roberts examined him for either spontaneous eye opening or eye opening in response to painful stimuli.

Awareness

The parts of the brain responsible for awareness—the ability to think and perceive—are the *neurons* (brain cells) in the cortex (grey matter) of the two hemispheres and the *axons* (communicating projections) in the white matter between those neurons. The brain's neurons are located in the *cerebral cortex*—the grey matter at the surface of the brain—and in the deep grey matter in nuclei such as the thalamus. These billions of neurons make trillions of connections via axons in the white matter, constituting functional neural networks that support all conscious effort of the brain, as well as many functions of the brain that do not require consciousness.

Awareness is not a function of solely a single area of the cortex or deep grey matter. Rather, it emerges from the coordinated activity of many parts of the brain. Although consciousness is possible with loss of limited areas of the cortex (as can be seen in some stroke victims), severe and widespread injury to the cortex, thalami, white matter, or any combination of these will result in unconsciousness, even if the RAS is functioning normally.

Awareness is tested by attempting to elicit a response to a command that requires some thinking ability, such as "look at me," "hold up two fingers," or "try to mouth words." Awareness can also be indicated by purposeful movements such as pushing away at a painful stimulus; this purposeful response contrasts to the automatic reflex movements that occur in response to painful stimuli when one is in a coma.

States of Disordered Consciousness

In the first scenario below, we consider Matt's condition in the days, weeks, and months after his accident and describe his states of consciousness, along with what was known about his prognosis. Patients with severe brain injury and coma who recover may, depending on the severity of the brain injury, progress through several levels of consciousness, from coma, to vegetative state, to minimally conscious state, to consciousness, with varying degrees of motor, cognitive, and affective impairment. The range of potential outcomes is wide.

Coma—Neither Awake nor Aware

Two days after the accident, Matt did not open his eyes, make any purposeful spontaneous movements, or respond to Dr. Robert's commands or to any other stimuli, including painful stimuli. Dr. Roberts concluded that the RAS was not working, and she described Matt as being in *coma*—he was neither awake nor aware. She had good reason to believe that Matt was not simply in the *locked-in state*, which is the state of being conscious but unable to move. This happens rarely after certain types of stroke (which would have been seen on his brain scan), or in the late stages of some neuromuscular diseases.

The presence of coma early after an injury does not predict a patient's outcome. Patients with widespread injury to the brain are more likely to have severe neurologic deficits and are at a higher risk of prolonged unconsciousness. Patients with more focal injuries (for example, only a brainstem injury) may have less severe neurologic impairment and are more likely to have temporary coma. The nature of the neurologic impairments depends on the areas of the brain that have been injured, and Matt's injuries were uncertain. Although his brain CT scan did not reveal major structural injuries, he may have suffered (1) widespread injury to the neurons of the cortex and thalamus because he was deprived of oxygen and (2) injury to the white matter because of the physical forces of the traumatic brain injury.

Although the RAS was not functioning normally, Dr. Roberts found that other important brainstem areas were still functioning. Matt's pupils responded to light, his eyes blinked when his eyelashes were touched, he gagged when a suction catheter was passed through the endotracheal tube to his lungs, and he was initiating breaths on his own, even though he required support from the ventilator. The presence of these brainstem functions was favorable but did not indicate whether he would eventually recover consciousness. Although he had spontaneous breathing, he could not swallow safely or protect his airway from aspiration (sucking liquids into the lung), which would cause pneumonia; therefore, he needed the endotracheal tube. He also required a nasogastric tube into the stomach to receive a feeding solution for adequate nutrition.

Coma usually lasts for no more than two to three weeks. In most instances, coma evolves to the next level of consciousness, known as the *vegetative state*.

Vegetative State—Awake but Unaware

Unless the RAS is severely injured, its function returns in two to three weeks. Ten days after Matt's accident, his eyes began to open in response to painful stimuli, which implied the presence of wakefulness *and* that spontaneous eye opening would eventually occur. However, despite the fact that his eyes were open, when Dr. Roberts called his name or placed her face close to his, Matt did not look at her, which indicated that even though he was awake, he was not aware of her or of his surroundings—i.e., he was still unconscious. Similarly, his motor responses to pain consisted only of reflexes and not purposeful movements. Note that although patients in *vegetative state* have reflex responses to pain, because they are not conscious, they cannot experience either pain or suffering. Therefore, Matt's condition was defined as the vegetative state, a condition that may either be a temporary stage in recovery from coma or may be more longstanding if the brain injuries are severe and irreversible.

Endotracheal and nasogastric tubes that are placed when patients emergently enter the hospital can remain in the body for only a limited period of time because they may cause injury to the larynx or stomach over an extended period of time. However, patients in vegetative state, like Matt, are incapable of protecting their airways or of taking oral nutrition and hydration. Therefore, a more permanent breathing tube, called a *tracheostomy*, is surgically inserted through the front of the neck directly into the trachea, and a semi-permanent tube, known as *gastrostomy tube*, is inserted directly through the abdominal wall into the stomach so that the patient can receive nutrition and hydration.

Two weeks after his brain injury, Matt's prognosis was still uncertain. Dr. Roberts told Matt's parents that in the best case, he would regain consciousness but would likely have severe, permanent physical and cognitive limitations. In the worst case, he would never regain consciousness. Matt's parents, not wanting to give up prematurely and hoping that he would eventually "wake up," elected to have the tracheostomy and gastrostomy tubes placed.

Persistent Vegetative State

Six weeks after Matt's accident, he was breathing through the tracheostomy without the support of a ventilator; however, he still required the gastrostomy tube for nutrition and hydration. He was transferred to a rehabilitation hospital, where Dr. Roberts examined him again and found that he was still vegetative—awake but unaware. By convention, after one month, the vegetative state is described as the *persistent* vegetative state (PVS). Dr. Roberts explained to Matt's parents that the term "PVS" does not stand for "*permanent* vegetative state" and that Matt's long-term prognosis was still uncertain. Because patients may emerge from PVS, usually within 3–12 months, clarifying the distinction between *persistent* vegetative state and *permanent* vegetative state was important.

Matt's parents asked Dr. Roberts about Matt's odds of recovering consciousness. The most important factor influencing the likelihood of recovery is the type of brain injury a patient has suffered. Patients in the PVS after a traumatic brain injury can regain awareness as late as 12 months after the injury; however, after that, the likelihood of recovery is very slim. The prognosis with brain injury caused by hypoxic-ischemic injury (lack of blood flow and oxygen) is worse than that with injury caused by trauma. Common causes of hypoxic-ischemic injury are cardiac arrest and drowning. Patients with hypoxic-ischemic brain damage are very unlikely to recover any awareness after only three months in the vegetative state; and among those who do, a good neurologic recovery is very rare. Age is also an important factor. Younger patients have a higher probability of recovering consciousness early on; but after 3–12 months (depending on type of injury), even children are extremely likely to remain in a vegetative state.

Matt's brain injury was a combination of traumatic and hypoxic-ischemic injury because he was not breathing immediately after the accident. As a result, at six weeks after injury, the odds of Matt recovering some consciousness were small but not impossible. However, if Matt remained in the PVS at three months, his odds of recovering consciousness would be extremely poor, and Dr. Roberts would be able to say with a high degree of certainty that Matt would not have a good cognitive or functional recovery.

The Minimally Conscious State

Nine weeks after the accident, Matt started responding—just a tiny bit—to examiners and his environment. His caregivers noticed that if his eyes were open and someone called to him, his eyes would often, but not consistently, look in the direction of the voice. Sometimes, if his blood was being drawn, he would moan or grimace or weakly pull away from the pain, in a purposeful nonreflexive way. His parents had also seen him attempt to mouth words, but he did not do so on a consistent basis.

Matt was showing possible signs of consciousness, but his degree of neurologic functioning was not sufficient for him to communicate his needs or to care for himself. His condition had progressed to the *minimally conscious state* (MCS), which is characterized by either minimal or fleeting and inconsistent responses that nonetheless are consciously driven and represent more than the reflex responses seen in coma and the PVS. Some patients in the MCS progress to have consistent awareness, whereas others continue to fluctuate between the PVS and the MCS. In some sense, the MCS is better than PVS because it suggests that some parts of the cortex, thalami, and white matter are working in a coordinated fashion. However, in the MCS, Matt was able to perceive his pain and his circumstances but was unable to communicate to others about his experience or his own perception of his condition. Because his MCS was the result of such a severe and widespread brain injury, Matt still needed the feeding tube for nutrition and hydration, and meticulous nursing care for all of his physical needs.

After Matt emerged into the MCS, his parents were hopeful that he would continue to improve. Sadly, after three more months, he had not. He continued to fluctuate between the PVS and the MCS. Dr. Roberts informed Matt's parents that the likelihood of a good recovery—meaning that Matt could communicate his needs and make useful movements with his hands and arms—was exceedingly low. Although she could not rule out the possibility of minimal improvement over months or years, she could say that he would never be able to care for himself or engage in complex social interactions.

Matt's parents considered whether Matt would want them to continue tube feedings in his current condition without a reasonable chance of a recovery that he would think was meaningful. After many discussions with their family, friends, social workers, and clinicians, Matt's parents concluded that he would not have wanted to continue treatment, and they asked that the tube feedings be stopped. This request was honored, and nine days later, Matt passed away without evidence of pain or discomfort.

Brain Death

In the previous scenario, Matt progressed from coma to the vegetative state to the MCS. However, rather than improve, some patients in coma worsen. In the following alternate scenario, Matt's brain injuries were much worse than described above, and the clinical course differed significantly.

Two days after his accident, Matt was comatose and had no brainstem reflexes. His pupils did not respond to light, his eyelids did not blink when his eye was touched with sterile cotton, he did not have a gag or cough reflex in response to tracheal suction, and he did not initiate any breaths on his own—all breathing was provided by the ventilator. Dr. Roberts concluded that Matt had suffered severe and potentially irreversible injury to all of the neurons in his brainstem, cortex, and thalami and that his condition was probably worsening toward *brain death*, a term that refers to irreversible loss of all clinical brain functions, including all brainstem reflexes and the drive to breathe.

To confirm brain death, Dr. Roberts performed a series of formal tests known as the *brain death examination*, which is recommended by the American Academy of Neurology to look for any brain function. This examination confirmed that Matt was comatose and that he lacked all brainstem reflexes, including respiratory drive. When the ventilator was temporarily disconnected from the endotracheal tube while his vital signs were being carefully monitored, Matt made no effort to breathe--even when the carbon dioxide level in the bloodstream reached levels that normally elicit gasping and breathing. Following her hospital's protocol, six hours later, Dr. Roberts performed a second brain death examination, which elicited the same findings.

As is the practice in the U.S. and many other nations, Dr. Roberts pronounced Matt dead on the basis of brain-death criteria. She explained how she made this determination to Matt's parents and told them that the ventilator and any fluids or medications would soon be stopped, once they had had a chance to say goodbye.

In accordance with hospital protocol and national standards of practice, Matt's parents were told about the possibility of organ donation. Patients pronounced dead by brain-death criteria have the opportunity to donate all of their major organs (kidneys, liver, pancreas, intestines, heart, and lungs) and tissues (cornea, skin, bone) because the organs and tissues can remain viable for transplantation until the ventilator is stopped. Matt's parents believed Matt would want to donate his organs, and after discussion with the regional Organ Procurement Organization, they agreed to the donation.

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