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INTRODUCTION

Our understanding of the nervous system dates back thousands of years. Sumerian records from around 4000 B.C. indicate knowledge of the euphoric sensations elicited by consumption of the poppy plant. One of the earliest documents about brain emergencies is found in an ancient Egyptian medical text from approximately 1700 B.C., which describes forty-eight examples of head and spine injuries of the time. Even in the 4th century B.C., the Greek philosopher Aristotle asserted that the heart was the center of the nervous system. However, it has only been relatively recently that humans understood the significance of the brain for our higher functioning and personality.

The human nervous system can voluntarily and involuntarily operate and regulate bodily functions. It can also sense, perceive, think and feel. Information is constantly being received, processed, and acted upon by the brain and nervous system throughout the body.

The brain and nervous system are responsible for memory, feelings, senses, intuition, intellect, movement, and organ function. Visual, tactile, olfactory, auditory, and gustatory senses all go to the brain. Personality, memory, intellect, and the essence of one’s being all stem from the inner-workings of this mass of neural tissue.

The human nervous system is made up of a network of sensory input and muscle output pathways which are connected by miles of nerves interconnected to not only each other, but also to the spinal cord and, ultimately, to the brain. These pathways send messages through nerves using chemical neurotransmitters. The nervous system’s input is typically sensory and its output is typically neuromuscular (movement). It is the brain’s job to handle and interpret all of these sensory inputs and to coordinate outputs through the nervous system – telling your legs to move away from danger, tasting and enjoying a sugary dessert, or seeing something sad and eliciting an emotional response.

Many bodily functions are regulated by the brain. The body’s hormones are produced, regulated, and monitored by the brain. Vital cardiac, circulatory, and respiratory functions are also monitored and regulated by the brain.

With such a complex system (and with no in-house IT Department to trouble-shoot issues), there is much that can go wrong with this complex system. Incredibly sophisticated and not fully understood, the human brain and nervous system will be examined in this course, with a focus on some of the most common anomalies that can occur with this system.

ANATOMY OF THE NEUROLOGICAL SYSTEM

The brain is the most highly specialized organ in the body. It is richly supplied with blood and demands a constant supply of oxygen. The brain is typically divided into three regions:

- cerebrum
- cerebellum
- brain stem
Cerebrum

The cerebrum is the largest region of the brain. It is here that most of the brain’s higher intellectual functions reside. This region of the brain creates and controls conscious thought, memory, personality, speech, motor function, visual perception and tactile impulses.

The cerebrum is split into two hemispheres. The left hemisphere has historically been identified as containing the language centers of the brain:

- Wernicke’s area (*responsible for speech understanding*)
- Broca’s area (*responsible for speech production*)

However, research has shown that language has assets in both hemispheres – some parts of intonation, accentuation, and other nuances of language are thought to occur in the right hemisphere.

Cerebellum

Coordination of body movement is controlled by the cerebellum (Latin: Little Brain). The cerebellum is located below and behind the cerebrum in the base of the skull. Its primary function is to coordinate muscle activity and balance through impulses it receives from the eyes, ears and balance inputs from the body.
Brain Stem

Moving lower down toward the bottom of the brain, the brainstem controls the most primitive functions vital to survival. These include respiratory and cardiac functions, digestion, glandular secretions and the autonomic nervous system. It connects the brain to the spinal cord, passing through a hole in the base of the skull called the foramen magnum. Increased intracranial pressure can force the lower brain structures through the foramen magnum and produce herniation syndrome with evidence of brain stem dysfunction.
Nervous System

The nervous system is comprised of billions of nerve cells, called neurons. Neurons sense stimuli, relay impulses, and send impulses to muscles to help the body react. Glial cells support and nourish neurons.

The nervous system is composed of the Central Nervous System (CNS) and Peripheral Nervous System (PNS). The CNS is comprised of the brain and the spinal cord. The PNS is comprised of the rest of the nerve cells throughout the body. The PNS is literally “the eyes and ears” of the central nervous system.

The peripheral nervous system is broken down into two parts: a voluntary system and an involuntary system.

Voluntary system - Also called the Somatic Nervous System, the voluntary portion of the PNS controls muscular movement.

Involuntary system – Also called the Autonomic Nervous System, the involuntary portion of the PNS controls everything which we cannot consciously control ourselves – heart rate, respiratory rate, digestion, pupil dilation, and many others. The Autonomic Nervous System is further broken down into the Sympathetic and Parasympathetic Nervous Systems.

PHYSIOLOGY OF THE NEUROLOGICAL SYSTEM

Neurons pass impulses up the chain of the nervous system to the spinal cord and brain via electrical impulses created by electrolyte release (i.e., sodium, potassium, and calcium). This electrochemical signaling event is called an action potential. This concept explains why patients with high or low sodium or potassium levels can find themselves in serious medical emergencies without prompt treatment. The normal-functioning human body has microscopic intracellular pumps that actively and passively control the electrolyte levels inside and outside of our cells. Disturbances of these systems by disease or poisoning can have catastrophic consequences.
COMMON NEUROLOGIC EMERGENCIES

When you respond to a call and start to make your SICK / NOT SICK determination, you are rapidly assessing a multitude of different nervous system functions in that patient.

- Skin signs are mediated by the peripheral nervous system
- Level of conscious is controlled by the central nervous system
- Pupil dilation and heart rate are controlled by the peripheral nervous system
- Gait and posture are controlled by the cerebellum in the CNS and neurons of the PNS

Any number of the complex inner-workings of the Neurologic System can go wrong. This section outlines some of the more common conditions which your patients may be experiencing.

**Stroke**

A stroke is a condition in which loss of brain function occurs due to a disturbance in the normal blood flow to an area of the brain. The two major types of stroke are ischemic (caused by a blockage in the arteries feeding the brain) and hemorrhagic (caused by a rupture of the arteries feeding the brain).

**Ischemic Stroke**

Ischemic strokes account for the vast majority of strokes. An ischemic stroke results from a clot that causes a sudden blockage of a blood vessel, preventing oxygenated blood from reaching brain tissue downstream. Ischemia can cause temporary or mild neurologic symptoms and may ultimately lead to tissue death. The clot can develop in an artery at the site of the blockage (a thrombus) or the clot can form elsewhere in the body and circulate in the bloodstream (an embolus) until it gets stuck in a smaller downstream artery.

Stroke is a time dependent medical emergency, and the sooner the patients can receive care the better the outcome. A critical decision in the management of stroke patients is determining whether the patient is eligible for thrombolytic therapy. Some hospitals have instituted stroke protocols where the patient is taken directly to the CT bypassing the emergency department.

To help the hospital make this determination, it is crucial that the prehospital healthcare provider call the hospital ahead with key patient information such as the patient’s last known well (LKW), FAST exam results, and medication history so that the hospital can determine if the patient might be eligible for thrombolytic therapy. Because of this time critical element, the goal for on scene EMS time with stroke patients is 15 minutes.

If the initial onset of symptoms is not severe, the majority of ischemic stroke patients survive. There are limited prospects of regaining neurologic function unless the person is given clot-dissolving drug therapy within several hours of when he or she was last known to be normal. This time frame starts at the onset of symptoms and must be reliably determined.

Most emboli originate in the legs from a deep vein thrombosis (DVT), but they can also originate in the heart. Emboli that form in the heart commonly do so due to abnormal heart contraction or blood flow in patients with atrial fibrillation or coronary valve problems. Other causes of emboli include: fat cells that enter the blood due to a major bone fracture, infected blood cells, small gas bubbles, or cancer cells that enter the blood stream.
Hemorrhagic Stroke

Hemorrhagic stroke (sometimes informally called a head bleed) results from either a ruptured blood vessel on the surface of the brain (subarachnoid hemorrhage) or within the brain (intracerebral hemorrhage). The effects of a burst blood vessel are a decrease in blood flow to parts of the brain and, potentially, increased pressure against the brain. Both eventualities decrease the amount of oxygenated and nutrient-rich blood that reaches the brain cells. The signs and symptoms of hemorrhagic stroke can appear rapidly. Many individuals experience a sudden, severe headache. Patients may also exhibit other neurological symptoms including motor, vision, and mental status changes.

The prognosis for hemorrhagic stroke is poor compared to that of ischemic stroke. The prognosis for those who do survive is variable, depending on the type of hemorrhage (subarachnoid vs. intracerebral), the size of the hemorrhage, the location of the hemorrhage or existing medical conditions.

Subarachnoid hemorrhage: occurs when a vessel bursts in the outer coverings of the brain within the subarachnoid space. The area rapidly fills with blood. There may be a sudden, intense headache, neck pain and nausea or vomiting. It is often described as "the worst headache of my life."

Intracerebral hemorrhage: is usually caused by bursting of small blood vessels weakened by years of high blood pressure. Less commonly, it is caused by abnormal tangles of blood vessels called vascular malformations. In this type of hemorrhagic stroke, blood accumulates in the brain tissues and can extend into the space between the brain and the membranes covering it.

Aneurysms

A common cause of a ruptured artery in the brain is an abnormality or weakness in the vascular wall called an aneurysm. This is more likely to occur in patients with existing aneurysms of cerebral vessels, hypertension, or with congenital malformations of the cerebral blood vessels.

Transient Ischemic Attack

A transient ischemic attack (TIA) is a condition in which brain cells temporarily stop working because of insufficient oxygen. This causes temporary stroke-like symptoms that resolve completely within 24 hours of onset – though most commonly, symptoms persist for less than an hour or two. The symptoms of a TIA, like those of a stroke, are rapid in onset. TIAs may precede a stroke. At the time of symptoms, it is impossible to distinguish a stroke from a TIA. If the symptoms resolve, the episode is considered a TIA. If the symptoms remain beyond 24 hours it is considered a stroke.

Altered Mental Status

Any number of medical emergencies or conditions can cause an alteration in a patient’s mental status or level of consciousness. Trauma, disturbances in oxygen flow to the brain, electrolyte imbalances in the body, the presence of intoxicants or poisons, too much or too little glucose in the blood, psychiatric disorders, and serious infections can all alter the mental status of a patient.

A patient with altered mental status might present with minor or major symptoms. It is very important to try to ascertain the root cause of this condition so you can determine what treatment they might need and whether ALS is required.
Seizures

A seizure can have many different presentations. Most often, it is a convulsion of the muscles of the body in a tonic-clonic fashion. The word “tonic” refers to a sudden and often very brief tensing of the body. It is often followed by the “clonic” phase of the seizure, which is a sequence of rapid contractions and relaxations of the body most often associated with the descriptions of seizures that bystanders might report. Seizures are typically caused by a sudden change in the normal activity of the brain. This might be excessive, atypical, or otherwise altered electrical brain activity. We do not know all of the reasons that people have seizures. Some people have the congenital condition called epilepsy, which causes seizures. Other factors like past brain trauma or surgeries, low blood sugar, drugs and alcohol (or withdrawals from such), and high body temperature can also cause seizures.

Partial seizures will present a little differently than the generalized seizures described above. Partial seizures typically affect just a portion of the body, not the whole body. This type of seizure might look like focal twitching of the hand or face. Symptoms may even move from one hand, up that same arm, and on to the lips, face or another part of the body.

Most seizures will usually resolve themselves without treatment and last less than 5 minutes. When a patient experiences a seizure lasting longer than 30 minutes, or when multiple shorter seizures are witnessed without a period of consciousness in between the seizures, we call this status epilepticus and it is a medical emergency.

After a seizure, a patient will be lethargic. He may be temporarily unconscious or slow and/or unable to respond verbally. This is called the postictal state. Postictal periods typically last 5 to 30 minutes and are marked by a gradual improvement of symptoms. A seizure is rough on the human body – muscles are fatigued, lactic acid has accumulated, and the brain is slow to come around. However once the seizure has subsided, the body slowly recovers.

Headaches

Headaches are a very common ailment. They range in magnitude from a mild irritant of short duration and minimal frequency, to nearly debilitating long-lasting and frequent occurrences. Most people have had some sort of headache in their life and, in most cases there is no medical emergency at play. Headaches of sudden onset, which might be described as the worst headache of the patient’s life might be a medical emergency like a hemorrhagic stroke (head bleed). In such cases, look for other signs of neurological impair – blurred or double vision, new onset of poor memory or cognition, or alterations in the patient’s mental status. You would also expect these patients to have abnormal vital signs. Although we do not encounter meningitis frequently, this is another medical emergency which might cause a headache. Patients with meningitis may also present with other symptoms such as: high fever, neck stiffness, and sensitivity to light. This is a communicable disease and it poses an exposure risk to EMS workers. Populations at heightened risk for contracting meningitis are the very young and those living in close quarters like college students and military personnel living on base.
PATIENT ASSESSMENT AND IDENTIFICATION OF NEUROLOGICAL EMERGENCIES

Initial Assessment

The first step in evaluating a patient is to conduct an initial assessment to determine immediate life threats – SICK or NOT SICK. This is a quick survey of the patient to determine immediate disturbances of the ABC’s, critical bleeding, signs of hypo-perfusion or hypoxia. This part of the assessment starts from across the room, as you approach the patient. A SICK patient is physiologically unstable based on key clinical indicators such as vital signs, level of consciousness, and work of breathing. A NOT SICK patient is physiologically stable. He or she still may require BLS treatment or ALS evaluation.

You should be able to decide within the first minute of contact whether or not the patient is critically ill. You do this by forming a clinical picture. Once the decision is made, your actions should proceed in a manner appropriate to the patient's condition and your initial assessment should be reevaluated as you obtain more information.

Patient History

Another key part of the BLS assessment is a thorough medical history. This includes signs and symptoms, allergies, past and current medical conditions, medicines, a history of the present illness, the patient’s social history, and how the patient has been feeling leading up to the 911 call. It also includes the patient’s description of his or her symptoms – onset, provocation, quality, radiation, and severity.

In a patient exhibiting an altered mental status, certain medical conditions like atrial fibrillation or chronic pain might give you a hint as to the cause of the patient’s altered state. As we learned earlier, atrial fibrillation can cause small clots to form in the heart and travel to the brain – causing an ischemic stroke. A patient with chronic pain may have accidentally overdosed on their pain medicines. The patient’s medicines may also provide hints: Plavix, Xarelto, Coumadin (aka, Warfarin), and Pradaxa are common anticoagulants taken by patients with atrial fibrillation. Hydrocodone, Hydromorphone (Dilaudid), Methadone, Demerol, Oxycodone and Oxycontin are common pain medicines which, in high doses, could lead to somnolence or even unconsciousness.

Your patient assessment ends with a repeat set of vital signs and reevaluating the patient’s ABC’s, Level of Consciousness, and your Sick / Not Sick impression. At this point, you can reconsider whether ALS is necessary.

Focused Physical Exam

Performing a basic physical exam is critical in all patient management, but especially so in patients with neurologic symptoms, as these symptoms can sometimes change and worsen over time.

A good physical exam of a neuro patient can start with a determination of the patient’s level of consciousness and comparison of this to the patient’s baseline. It is also important to obtain a set of vital signs to establish a baseline. If the patient’s level of consciousness is altered, look for clues such as slurred speech or stroke signs, trauma, medic alert tags, signs of hypoxia, drug use or diabetes. Blood glucometry and pulse oximetry are tools to help assess the cause of altered mental status.
Signs and Symptoms of Ischemic Stroke

Early detection of the warning signs of a stroke is crucial. The signs and symptoms can vary greatly depending on which part of the brain is affected. In general, these can include the sudden onset of (or sudden awakening) with:

- paralysis (hemiplegia) or weakness (hemiparesis) on one side of the body
- facial droop on one side
- altered level of consciousness (from confusion to unconsciousness)
- change in personality or mood
- headache or dizziness
- impaired speech
- blurred vision
- poor coordination

A decreased level of consciousness or coma is more common with hemorrhagic stroke compared to ischemic stroke. Often this is due to an increase in intracranial pressure.

FAST Exam

An important part of the physical exam for a stroke patient is testing neurological function with the FAST Exam. FAST is based on the Cincinnati Prehospital Stroke Scale and focuses on three symptoms with the addition of time: facial droop (F), arm drift (A), speech problems (S) and (T) time when the patient was last known well (LKW). It is accurate in identifying patients with stroke. The results of this test will be used in further diagnosis and treatment at a hospital. An abnormal finding in any of the three tests strongly suggests a stroke.
FAST Exam

- **F (Face drooping)** – Does one side of the face droop or is it numb? Ask the person to smile. Is the person’s smile uneven?

- **A (Arm weakness)** - Is one arm weak or numb? Ask the person to raise both arms. Does one arm drift downward?

- **S (Speech difficulty)** – Is speech slurred? Is the person unable to speak or hard to understand? Ask the person to repeat a simple sentence, like “The sky is blue.” Is the sentence repeated correctly?

- **T (Time last known well)** – Document the time that the patient was last known to be normal.

Additionally, you may check both hands for equal grip strength and check if the individual can push with both feet equally.

Identify a contact person (family member, spouse, care giver, etc.) who has the best information about the onset of the stroke, as well as knowledge of the medical history or any medications the patient may be taking. If possible have this person accompany the patient to the hospital. If this person does not accompany the patient you must write their name and phone number on the incident report so hospital staff can contact this person. Key information the hospital will need, in addition to the last known well, includes medications (particularly anticoagulants) and a history of recent surgery, trauma, brain cancer, or bleeding disorder.
Signs and Symptoms of Hemorrhagic Stroke

In the field it is impossible to know for sure whether a patient is having a hemorrhagic stroke. You may have a high index of suspicion for a hemorrhagic stroke when you see certain indicators. These patients may have subtle or acute signs & symptoms. Only a CT scan in the hospital will be able to verify this.

**Signs & Symptoms**

Signs and symptoms of hemorrhagic stroke may include:

**Acute Signs and Symptoms:**
- Rapid onset of symptoms
- obtunded
- exhibiting abnormal vital signs
- vomiting profusely
- they may describe the worst headache of their lives

**Subtle Signs and Symptoms:**
- temporary loss of consciousness
- poor memory of the event
- dizziness
- blurred or double vision
Signs and Symptoms of Aneurysm

Brain aneurysms range from being very small and having no symptoms so as to be totally unnoticeable by the patient to a sudden large rupture that can cause immediate death. In the field, we typically are called for aneurysms when they have burst and have created a medical emergency. Many people have stable or previously undiagnosed aneurysms. Aneurysms are diagnosed by CT Angiography (injecting dye into a vein while the patient is undergoing a CAT scan). Just like outcomes vary for patients with aneurysms, so too do the signs and symptoms vary.

Signs & Symptoms

Signs and symptoms of aneurysm may include:

**Acute Signs and Symptoms:**
- sudden onset of acute headache
- exhibiting abnormal vital signs
- vomiting
- altered mental status or loss of consciousness
- seizure

**Subtle Signs and Symptoms:**
- generalized headache or pain in a specific part of the head – usually sudden
- visual disturbances - blurred or double vision, light sensitivity
- disruption of the facial muscles – weakness or facial droop
- numbness of face
- numbness or weakness in other parts of the body
- neck stiffness
- difficulty articulating

Signs and Symptoms of TIA

The signs and symptoms of a TIA are usually identical to those of an ischemic stroke. The main difference is the duration of symptoms. TIA signs and symptoms usually last a matter of minutes or hours, and (by definition) resolve on their own and last no longer than 24 hours.

Signs and Symptoms of Altered Mental Status

A patient exhibiting altered mental status can have a wide variety of presentations. The patient’s ability to articulate may be altered – from confused or garbled speech to unintelligible words or no speech whatsoever. The patient’s level of consciousness could range from alert to unconscious. Their gaze might be normal, favoring a particular direction, or their eyes may not open spontaneously whatsoever.
Signs and Symptoms of Seizures

Tonic–clonic seizures are easy to spot, but partial seizures may be much more subtle. The partial seizure patient may have an odd gaze (e.g., upward and leftward). The partial seizure patient may also have facial or extremity twitching, sometimes very subtly such that only the eyelids are affected.

Signs and Symptoms of Headache

Headaches can be more than just pain in the head. Sometimes patients with headaches have a syndrome of associated symptoms, including: visual disturbances, sensitivity to light, sensitivity to sound, and nausea or vomiting. Patients with chronic headaches can be asked how this headache differs from their usual headaches.

Vital Signs

We know that obtaining a baseline set of vital signs is important in all patient contacts. But it can be particularly important in aiding in the determination that a patient may be having a hemorrhagic stroke. Cushing’s Response (also known as “Cushing’s Triad”) is a phenomenon in which an increase in intracranial pressure results in an increased blood pressure, a decreased heart rate, and irregular breathing pattern. You are likely to see this in only the most dire of head bleed cases. Often, these patients are herniating and need a neurosurgeon emergently.

Patients with a hemorrhagic stroke who are experiencing increased intracranial pressure (ICP) may exhibit unequal pupil sizes (anisocoria). This is often a late and dire sign of a head bleed, so do not confuse it with the surprisingly large number of people in the world (as many as 20%) who have normal variations in pupil size with no associated pathology. The patient with a head bleed and unequal pupils will often be obtunded and/or have other SICK presentations (e.g., irregular breathing, abnormal vital signs). If your patient is conscious, ask them if they have ever been told that they have unequal pupils – this may help you avoid going down a misleading treatment path.

There is also a subset of patients with very minor symptoms who we need to be acutely aware of. These are patients who are elderly and/or who are on anticoagulants. These patients sometimes present with very minor complaints – maybe they fell and hit their head but feel fine now and do not want help. On closer evaluation, you notice:

- They are on an anticoagulant
- You observe an obvious outward sign of injury (e.g., hematoma, ecchymosis or laceration)
- There is a report of loss of consciousness
- You observe an altered mental status

These patients are not necessarily having a head bleed, but these factors put them at higher risk for head bleeds and they should not stay home. These patients will probably not require advanced care in the field, but in most cases they require a physician’s evaluation due to their risk factors for head bleed. Typically these are not ALS patients unless they have deficits to the ABC’s or abnormal vital signs.
TREATMENTS FOR NEUROLOGIC EMERGENCIES

In general, an EMT’s best treatment for the neurologically impaired patient is assessing and managing the ABCs, assessing and treating hypoperfusion or signs of shock, determining whether the patient requires an ALS or BLS level of care, and (if ALS is not needed) providing rapid transport.

The treatment of a neurologically impaired patient is very much patient-centered. We learned earlier that neurologic emergencies can stem from blood sugar issues, stroke, oxygenation, blood pressure, seizure, and many other causes. Your treatment will depend on what you think is causing the patient’s symptoms.

Hypoxic patients and patients who show signs of hypoperfusion may need high flow oxygen. But gone are the days of giving all patients high flow oxygen. In fact, studies show that patients experiencing ischemic strokes who have a pulse oximetry reading of >95% not only do not benefit from high-flow oxygen, but they may actually suffer from it.

Hypoglycemic patients will require glucose – ideally orally, or intravenous if they are unable to swallow.

EMTs evaluating patients whose neurologic emergencies are due to drugs or alcohol should make sure to closely monitor the patient’s ABC’s. The brainstems of these patients have impaired ability to sense and react to states of hypoventilation. These patients are also prone to vomiting and aspiration.

Treatment of suspected ischemic stroke patients is a little different than that of the other neurologic emergencies. Thrombolytic drug administration is time-sensitive and must be given as early as possible. Once it is determined that a patient is suffering an ischemic stroke and their ABC’s and vital signs are normal, they should be transported immediately. You must quickly gather information regarding onset of symptoms from the patient, family members or caregivers. Once at the hospital, it takes time for the stroke team to make an assessment and administer the thrombolytic therapy. Therefore, you will have little time to waste. The science on stroke intervention is ever-changing, but typically ischemic strokes can be treated if the time of last known well was ideally less than three hours (though for some patients it may be up to 4.5 hours) prior to intervention.

Acute hemorrhagic stroke patients require a different transport plan. Typically, these patients will be very sick. Your rapid assessment will likely reveal more than one ALS indicator right off the bat. These patients will have an altered mental status; they may even be combative or unconscious.

Special Transport Considerations

Not all emergency rooms are appropriate destinations for suspected stroke patients. Stroke patients (hemorrhagic as well as ischemic) will generally require a CT scan, so it is important to know if your local ER has CT available 24 hours per day. Some hospitals have also been identified as “Stroke Centers.” Others have many of those capabilities without the designation of being a Stroke Center. You may want to become familiar with the stroke transport protocols for your region. Most importantly, because time is of the essence with these patients, it is important to call ahead to make sure that the CT scanner is up and running and that the hospital is equipped to handle this type of patient.