The Normal Neurological Examination

Introduction

One of the most daunting aspects of the medical examination for the Emergency Physician and the primary care provider is the normal neurological exam. Most of us feel inclined to do an abbreviated survey because the complexity of the neurological exam is greater than that of any other organ system. Many chapters, books and articles have been devoted to the topic of the neurological exam, but this module is dedicated to those physicians who not only need to perform a screening neurological examination but also those who have to teach other medical providers the basics of completing such an exam.

The underlying focus of this module is to help physicians identify, diagnose and participate in the management of the patient with an acute stroke. In this review, basic neuroanatomy will be covered as well as the required history and physical skills required make a diagnosis in a time sensitive manner.

There are four basic questions to the neurological examination.
   A) Is there a lesion?
   B) Where is the lesion?
   C) What caused the lesion?
   D) What are the key management interventions?

This module will focus only on the first three questions.

Neuroanatomy

The central nervous system can be divided very simply into several discrete compartments. One can be criticized for oversimplification when it comes to the nervous system, but an operational compartmentalization is often helpful when it comes to managing patients with a neurological complaint.

The nervous system can be divided into the peripheral and central nervous systems. The peripheral nervous system contains the peripheral nerves. The central nervous system can be thought of as a neuroaxis consisting of the 1) brain (cortex and subcortex) 2) brainstem and 3) cerebellum and 4) spinal cord.

In gross anatomical terms, the brain (cortex and subcortex) region can be considered the supratentorial region. (Not to be confused with the common medical term often associated with patients who exaggerate or embellish symptoms that have no organic basis.) The infratentorial region consists of the cerebellum and brainstem. See Figure 1.
The cortex functionally is responsible for several activities. Among its most famous activities are consciousness, speech, motor and sensory functions – in essence, the cortex is the higher functioning command center.

The subcortex contains the **internal capsule, basal ganglia and the thalamus.** The subcortex can be considered a relay station for the higher command station and the lower distribution pathway of the spinal cord. The **internal capsule** directly relays motor and sensory function, the **basal ganglia** is responsible for the fine adjustment of movements, the **thalamus** is the sensory relay point.

The **cerebellum**, in conjunction with the basal ganglia helps to refine motor activity.

The **brainstem** contains the origin of the cranial nerves and contains the primitive functions of living – the breathing center, vasomotor center, and modulates the interaction between the cerebellum and the rest of the neuroaxis.

The **spinal cord** is divided into three basic columns – anterior, posterior and lateral. The anterior columns is primarily responsible for motor function, the posterior column is primarily responsible for sensory (proprioception) function and the lateral column has an ascending sensory tract (pain and temperature) and a descending motor tract.
The General Approach

Any patient who requires a neurological evaluation should have a complete history and physical examination performed. After a careful general history and physical exam, a neurological review of systems should be performed. This includes a review of basic neurological functions. The importance of the general physical examination cannot be emphasized enough. Diseases of virtually every organ system will eventually have neurological sequelae. Similarly, the history and review of systems need to be reviewed as well. The subsequent neurological exam is used more to rule in or out the possibilities of a neurological problem.

Table 1 includes a brief summary of the neurological functions and includes the minimum question for each function.

Once the review of systems is complete, a focused neurological examination should ensue, followed by localization and key interventions. The neuro exam has five components – 1) mental status 2) cranial nerves 3) motor and reflexes 4) sensory 5) coordination and gait. Several neurological scales can be very helpful in completing a focused, yet effective neurological evaluation. These include the Glasgow Coma Scale, the MiniMental Status Examination and the NIH stroke scale, as well as the prehospital LA stroke scale and the Cincinnati Stroke scale.

The nice thing about neurologic exam is that the examiner can rapidly localize the lesion once an abnormality is detected by history and confirmed by the physical examination. Please refer to table 1.

Table 1

<table>
<thead>
<tr>
<th>Exam</th>
<th>Localization</th>
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<tbody>
<tr>
<td>Mental status</td>
<td>Cortex</td>
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<tr>
<td>Cranial nerves</td>
<td>Brainstem</td>
</tr>
<tr>
<td>Motor and reflexes</td>
<td>Upper motor and lower motor neurons</td>
</tr>
<tr>
<td>Sensory</td>
<td>Subcortical (thalamus), spinal cord</td>
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<tr>
<td>Coordination</td>
<td>Cerebellum</td>
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To properly assess mental status four basic areas need to be addressed. The first is consciousness and orientation. This can be quickly accomplished by determining the patient’s Glasgow Coma Scale. See table 3 for the Glasgow Coma Scale. The patient’s orientation to person, place and time should also be determined. When questioning a patient to determine orientation, one should start with the more general questions and work towards the specifics. When it comes to person, most people know who they are, what is more helpful is for the patient to identify who has accompanied them.
The second area to assess is **concentration and attention**. Patients should be asked to perform **serial seven subtraction**, that is count backwards from 100 decreasing by seven each time. **Drawing a clock face**, a higher cognitive function, is a combination of visual-spatial capability and concentration. Alternatively, the patient can be asked to spell words forwards and backwards, such as WORLD and TABLE. For patients with limited education, making change is an effective diagnostic task, such as “how many quarters in $1.75.”

The third area to assess is **language** and can be performed quickly. Listen to the fluency of the patient’s speech, testing for comprehension of simple commands such as repetition of words, **naming** of objects, writing a **sentence** and **reading a phrase**.

**Memory** should be tested in the **immediate, recent and remote events**. A traditional method of doing so is asking the patient to repeat three separate items, then ask them to recall them one minute then in five minutes. A remote event would be asking the patient their date of birth, or birth of their children or some other personal event.

Testing for mental status reveals a great deal about how the cortex is functioning. The cortex can be thought of as having several different areas, the frontal, parietal, temporal and the occipital. The mental status exam attempts to assess the function each of these areas. See table 2 for a description of what each area does in **terms of mental status**. Finally the Mini Mental Status examination is a convenient way to assess cortical function. Though originally designed to test patients with Alzheimer’s disease and other dementia’s, is does help the examiner get a quick assessment of cortical function.

<table>
<thead>
<tr>
<th>Frontal Cortex</th>
<th>Intellectual function, production of speech (i.e. non-fluent ‘expressive’ aphasia’s), Motor control</th>
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</thead>
<tbody>
<tr>
<td>Parietal Cortex</td>
<td>Analysis of sensory information, also serves a role in intellectual function (e.g. visual-spatial neglect)</td>
</tr>
<tr>
<td>Temporal Cortex</td>
<td>Comprehension of speech (i.e. fluent ‘receptive’ aphasia)</td>
</tr>
<tr>
<td>Occipital Cortex</td>
<td>Vision</td>
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</table>

The **cranial nerve examination** is an excellent way to localize a brainstem lesion. Most cranial nerves originate in the brainstem, because their nucleus resides there. It should be noted that their supranuclear tract descends from the cortex, once again demonstrating that the cortex has the highest command center. The supranuclear tract comes from the cortex and crosses before it gets to the nucleus of the cranial nerve. So a lesion in the cortex will cause a contralateral deficit of the cranial nerve while an infranuclear will cause an ipsilateral deficit.
Most of the cranial nerves are lumped into three areas of the brainstem, all except CN I and CNII, who have escaped the infratentorium and reside in the supratentorium. Although this is not entirely anatomically correct, CN III and IV are located in the midbrain, CN V-VII is in the pons and CN VIII- XII are in the medulla.

**Motor function** is controlled by the cortex. It begins in the **upper motor neurons** (the Betz cells of the precentral gyrus). The axons project via the posterior limb of the internal capsule (part of the subcortex), travel through the brainstem (the pyramidal tract), cross in the lower medulla, then descend in the spinal cord (corticalspinal tract within the lateral column) to the lower motor neurons in the spinal cord. See figure 4

The lower motor neuron originates from the anterior column of the spinal cord and ends in the motor end plate. (Somehow the anterior column of the spinal cord communicates with the lateral column.) The distinction between an upper motor and lower motor neuron is important because a lesion in either of the pathways gives markedly different clinical presentation.

The standard motor examination should include five areas, **strength, tone, posture, involuntary movements and reflexes**. Rating scale for motor examination is important for two reasons. Knowing where the motor deficits allows for localization (ie which side of the brain is involved). With the **rating of the motor deficits** one can follow progression or improvement which has important prognostic implications.

Muscular bulk and tone will help in differentiating between **upper and lower motor neuron deficits**. There are two major postures that are important to note – **decorticate and decerebrate**. Both are upper motor neuron problems, decorticate suggests a supratentorial pathology verses the decerebrate posturing which indicates an infratentorial pathology. Because the lesion goes deeper in the brainstem, decerebrate posturing has a worse prognosis. Decorticate posturing is extension of the lower extremities and flexion of the upper extremities whereas decerebrate rigidity is extension and internal rotation of all extremities.

Involuntary movements indicate involvement of the extra-pyramidal system, which includes complicated neuronal tracts between the basal ganglia, and cerebellum. (pyramidal tract =cortex and internal capsule tracts ).

**Reflexes** are important to note because they give information about the upper motor neuron verses lower motor neuron lesions and lateralization. (Symmetric verses asymmetric indicating systemic or metabolic verses isolated neurological pathology.)

The presence of an abnormal reflex such as **Babinski reflex** (toe fanning and upward big toe upon stimulation of the lateral aspect of the sole from heel to big toe) is important to note. Either a patient has an abnormal reflex, the Babinski reflex, or there is a normal plantar response, downgoing toe. The presence of a Babinski indicates an upper motor lesion.
Sensory examination is often difficult because it is a very subjective examination. With an uncooperative patient the sensory exam may be impossible to perform accurately. But when it can be done, the sensory exam will reveal information about where lesions are located.

Sensations are transmitted from the peripheral nerves to the spinal cord. Once in the spinal cord the nerve transmissions ascend through several tracts or columns. Pain and temperature are located in the lateral column and decussate (cross to the other side) at the level of entry. Proprioception and vibration travels through the posterior columns and decussate at the level of the brainstem. Touch travels through both the lateral and posterior columns, proving that the body has redundant systems for important functions.

Once the nerve impulses leave the spinal cord, they enter the brainstem via the posterior horn of the internal capsule through the thalamus on the way to the post central gyrus of the cortex. Along the way they send information, via collaterals, to the cerebellum and the thalamus.

Dermatomes are the peripheral distribution of the specific spinal cord roots.

Coordination and gait require the integration of parts of the nervous system. It essentially assess all of the areas mentioned, and can be thought of as the “final exam of the nervous system”. Many patients deemed “non-focal and intact” have an exam limited to the gurney. When asked to walk, these patients reveal significant dysfunction. The classic neurologic abnormality indicating cerebellar dysfunction is the presence of ataxia, which can be in the upper extremities, the lower extremities or in the trunk. Ataxia is manifested by a lack of smooth movements and loss of coordinated movement. Gait must be checked and any gait ataxia must be differentiated from motor weakness.

Coordination and gait is an integration of multiple tracts including the pyramidal, extrapyramidal, posterior columns and cerebellar tracts. The most important finding for cerebellar function is the presence of ataxia, which can be in the upper extremities, the lower extremities or in the trunk. Ataxia is manifested by a lack of smooth movements. Gait must be checked and any gait ataxia must be differentiated from motor weakness.

A useful tool in the rapid evaluation of a patient with a suspected neurologic problem is the NIH Stroke Scale. It incorporates many of the elements of the neurologic exam discussed, yet condenses them into a quick assessment scale.
Localization

Knowing where the lesion is not just an intellectual exercise to be completed by the examiner to prove that they know their neuroanatomy. Where a lesion resides has important implications in terms of diagnostic and therapeutic interventions. It is helpful to consider the four major areas of the neuroaxis.

Cortex

Subcortex

Thalamus

Basal Ganglia

Internal Capsule

Brainstem

Spinal Cord.

Cortex Lesions

There are five major findings associated with lesions in the cortex.

1) **Dysphasia** – any disorder of language, which includes expressive, receptive, global aphasia, naming and reading.

   Geographic area: Frontal or Temporal Cortex (see diagram 4.1)

2) **Cortical Sensory loss** - which includes an inability to identify objects in your hand (stereognosis), loss of two point discrimination and the inability to discern writing on one’s palm. (graphesthesi

   Geographic area: Post central gyrus

3) **Face and extremity weakness with possible paresthesia.** It is important to note whether the arm is involved more than the leg. If the arm is more involved, the lesion is in the middle cerebral artery territory. If the leg is more involved, then it is anterior cerebral artery territory. Note: Both the face and extremity involvement will be on the same side because the upper motor neuron fibers have crossed together at the level of the brainstem. The lesion is higher than the brainstem.

4) **Conjugate Gaze Palsy** – There are three gaze centers, two reside in the cortex and one in the brainstem. The major one is the frontal cortex gaze center. So if the eyes deviate together at all, the most likely lesion is in the frontal cortex.

   The eyes will deviate toward the cortical lesion, because the right frontal gaze center is responsible for looking to the left and vice versa. So when the right frontal cortex gaze center is knocked out, the conjugate gaze will be toward the right.
5. **Seizures** – Seizures associated with hemiplegia are most likely due to a cortical lesion. Seizures generally originate in the cortex.

**Subcortical Lesions** – internal capsule, basal ganglia and thalamus

1. **Visual Field Defect** – When a patient has difficulty with detecting simultaneous movements in certain visual fields, the lesion is likely to be in the cortex or the subcortical area. For example, presence of the left homonymous hemianopsia indicates a subcortical lesion in the visual pathway.

2. **Dystonic postures** – When there are unusual, uncoordinated movements such as choreoathetosis (involuntary jerky movements) hemibalismus (slow bizarre movements of half the body) or simply loss of harmony of refined movements. Such bizarre movements are indicative of basal ganglia lesions. Remember that the basal ganglia helps modulate movement, and refines the motor activity the pyramidal system.

3. **Face and extremity weakness** – When the face, arm and leg are equally involved then the lesion must reside in the internal capsule.

4. **Dense Sensory Loss** – Loss of pain and touch in face and extremities signifies a lesion in the thalamic area. The thalamus is a sensory relay point, as well as a primary receptive center, so a lesion there will affect the sensation in the face and extremities.

**Brainstem Lesions** – midbrain, pons and medulla, cerebellum

Lesions in the brainstem result in a crossed finding.

1. **Crossed Hemiplegia** - The cranial nerves will be affected on one side, while the extremity motor deficits are on the other side. This brainstem lesion will affect the infranuclear cranial nerves ipsilaterally, and the motor tract contralaterally, because the motor tract decussates just above the spinal cord.

2. **Cerebellar findings** - Ipsilateral ataxia, dysmetria (finger to nose)

3. **Nystagmus** - The medial longitudinal fasciculus helps to coordinate eye movement and resides in the brainstem axis. It connects the two nuclei of the CNIII and of the CNVI so that conjugate gaze. A problem in the brainstem could result in MLF malfunction which would yield nystagmus. The nystagmus could be horizontal, vertical or rotary.

4. **Lower Cranial Nerve findings** - Cranial Nerves 8 – 12 project from the lower brainstem. Thus lesions in this area will cause hearing loss and vertigo (CN VIII), dysarthria (difficulty with articulation), dysphagia (CN IX – X) (difficulty with swallowing), and tongue deviation (XII).
Spinal Cord Lesions
Lesions in the spinal cord cause predictable deficits. Assuming normal cortical, subcortical and brainstem functions the findings are listed below.
1. Intact cranial nerves
2. Motor deficits can be monoplegic (one extremity), paraplegic (both lower extremities), hemiplegia (one side of the body) or quadriplegic (four extremities). In case of monoplegia or hemiplegia the lesion will be ipsilateral.
3. Sensory finding will be contralateral because pain and temperature fibers cross immediately after entering the cord.
4. A sensory level may be present.

Dominance
The controlling hemisphere in most human beings is the left side of the brain. The dominant hemisphere really controls most things in the body. Neurologists like to whether a patient is right handed or left handed. Right-handed people are left hemisphere dominant. Most left handed people are also left hemisphere dominant except for about 10% which will be right hemisphere dominant.

The reason dominance is so important is that a stroke in a dominant hemisphere for the same sized lesion can be more devastating. The complexity of function in the dominant hemisphere should not be underestimated. The speech centers are located in the cortex of the dominant hemisphere. Aphasia just does not occur when the nondominant hemisphere.

When the nondominant hemisphere is involved the following symptomatology results.
1. **Inattention and Denial** – These patients neglect the left side of the body despite having significant deficits. These patients will not see you if you stand on his or her left. They may not shave the left side of their face. They remain unconcerned about their deficits, because they do not believe they have any.
2. **Constructional Apraxia** – Patients are unable to do a motor task without having a motor deficit. They just won’t be able to do it. They may not be able to open the door, but they just can’t do it, even though they have the motor capability.
3. **Spatial Disorientation** – Patients are able to get lost in their own home.
4. **Confusional State** – This occurs infrequently.
Cerebral ischemia is caused by a reduction of blood flow, which may be transient or lead to infarction. Strokes are clinical syndromes with different etiologies and different symptom complexes.

1. **Ischemic Stroke**
   A. Thrombotic
   B. Embolic
   C. Hypoperfusion

2. **Hemorrhagic Stroke**
   A. Intracranial hemorrhage
   B. Subarachnoid hemorrhage

Lacunar infarcts are small areas of thrombotic infarct in the brain usually the result of hypertension and diabetes mellitus complication. They are often found in the basal ganglia and the pons.

The questions that should be asked in patient with a suspected stroke are
- Where is the stroke? (cortex, subcortical area, brainstem, or spinal cord)
- What is the vascular anatomy? (carotid or vertebro-basilar territory)
- How did the stroke develop? (ischemic or hemorrhagic)

**Summary**

This module has attempted to provide the reader with a brief but comprehensive review of the neurological examination. An understanding of neuroanatomy is necessary to appreciate the fine points of the neurological examination. In many cases, neuroanatomy has to be reviewed several times before a complete understanding is obtained.

Good Luck!
The Neurological Emergency Group