**Title and Focus of Activity**: Differentiating Upper From Lower Motor Neuron Lesions *Linking foundational and clinical sciences*

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**Course Information:** Human Neurobiology; 3 semester credits; First year, either 2nd or 3rd semester.

**Learning Experience Description:** One of the most difficult concepts for PT students learning about the organization of the human nervous system for the first time is the difference between upper motor neuron lesions versus lower motor neuron lesions. Part of the difficulty in learning this foundational knowledge is the terminology that is used to describe these lesions. The confusion can arise from the fact that while most upper motor neurons are located in the cerebral cortex, some are located in the brainstem. Lower motor neurons are located in the ventral horn of the spinal cord, but there are also lower motor neurons located in the brainstem where their axons are part of the cranial nerves (CN) that have a motor function (specifically CNs: III, IV, V, VI, VII, IX, X, XI and XII). Thus there is an anatomical region of overlap that contains both upper and lower motor neurons.

This activity is usually done in lab, but could be done in a lecture setting. The students are in small groups (5-8 per group; but this can also be done individually) and are asked to draw the location of upper motor neuron cell bodies and lower motor neuron cell bodies in a simplified schematic of the CNS (see Haines DE. Neuroanatomy, An Atlas of Structures, Sections, and Systems, 7th Edition, Lippincott, Williams and Wilkins, page 213, as an example). They are instructed to draw just one neuron in each area. To help them get started they are reminded to recall the definition of a lower motor neuron and an upper motor neuron, which they have been introduced. They are given 10-15 minutes to accomplish this task. There is usually a lot of discussion and disagreement as the students work on this task.

The students are asked if a complete T-6 spinal cord injury is an example of an upper or lower motor neuron disorder. Then they are asked to draw a full transection of the spinal cord at T-6 on their handout and see if their answer changes. Next the students are asked to add axons to the cell bodies of these populations of neurons and told to draw the axons from the cell bodies to the normal termination/target of these axons. If they seem lost or confused, they are asked “What do the populations of neurons innervate; what is their target?” This part of the activity sometimes causes the students to change their answers. The students are asked if this patient would exhibit normal, hypo- or hyper- reflexes in their upper extremities and lower extremities and what sort of functional deficits this individual would have.

These questions normally result in a rich discussion of spinal cord injury consequences and pathology. It also demonstrates the complexity of the CNS, and the fact that few CNS conditions are explained in absolute terms. For example a SCI can injure ventral motor neurons (LMNs), but the predominant injury that leads to the significant functional deficits that are seen in individuals with a SCI is the damage to the descending motor axons (UMNs) that control the output of the ventral motor neurons that are located inferior to the injury. So an individual would have UMN symptoms in their lower extremities as a result of cutting the axons of all descending UMNs that innervate the LMNs below the level of the injury. The LMNs below the level of the injury are not directly damaged by this injury and still innervate their target skeletal muscle cells. Some students will ask about the LMNs located at the level of the transection/injury and wouldn’t their involvement result in LMN signs. This is true, yes there can be involvement of LMNs at the level of the SCI. For this injury, a transection located between the cervical and lumbosacral enlargements, the signs and functional deficits secondary to LMN involvement are less of a concern than the severance of all descending axons to the LMNs that innervate the lower extremities. This is a good time to ask the students to recall material from gross anatomy, such as what muscles would be innervated by LMNs at T-6, and what functional deficits would be observed if these muscles were not under voluntary control. During this discussion it becomes apparent that the UMN signs present in the lower extremities would be more obvious and of much more concern functionally. If you have time you can continue the discussion and talk about the nature of the SCI injury and how much tissue is damaged and how this will relate to greater or lesser involvement of LMNs, which could result in some SCIs resulting in noticeable LMN signs along with UMN signs.

Next the students are asked if someone with a lesion in the anterior part of their caudal medulla restricted to the right or left side would have upper or lower motor neuron lesion symptoms. They are then told to put this lesion on their drawing and see if that changes their answer. They are asked about what type of reflex response they would expect to see in the patient’s upper and lower extremities, both ipsi- and contralateral to the lesion. Since lesions here can cause a combination of UMN and LMN symptoms due to involvement of descending motor tracts (UMNs) and cranial nerve motor neurons (LMNs) the students learn that these conditions are not mutually exclusive.

These questions normally result in a good review of cranial nerve anatomy and function, descending motor tract anatomy and function, and the significance of understanding where motor tracts decussate. This conversation can also lead to a discussion of somatosensory consequences following these injuries.

If there is time and if the class seems to be grasping the concepts presented here, then we discuss how lumbar spinal cord injuries can have a more significant lower motor neuron lesion appearance than what is seen with cervical or thoracic spinal cord injuries.

Importantly, this exercise requires critical thinking skills, and the integration of information from multiple learning experiences. It also causes students to review what has been covered in the course to this point, as they clearly see the applicability of this knowledge.

Time for student to complete the activity: 1. preparation for activity outside of/before class: - 2. class time completion of the activity: 30 minutes

Readings/other preparatory materials: This exercise should come after the students have covered spinal cord anatomy, spinal nerves, brainstem anatomy including cranial nerves and the descending motor tracts. It should either immediately follow, or coincide, with an introduction to the difference between upper and lower motor neuron location, signs and symptoms.

Learning Objectives: 1. Contrast the location of upper motor neuron cell bodies and lower motor neuron cell bodies and compare the targets that are innervated by each type of neuron. 2. Differentiate the symptoms of a lower motor neuron deficit from an upper motor neuron deficit. 3. Contrast the prognosis for recovery from a lower motor neuron deficit and contrast this to recovery from an upper motor neuron lesion. 4. Give 2-3 examples of injuries or disorders that can result in each type of lesion.

Methods of evaluation of student learning: There are questions that test their knowledge of these concepts on both the 2nd and final exams in this neuroscience course. Here are examples:

1. Differentiate UMN lesions from LMN lesions in terms of signs, functional deficits and prognosis.

2. Describe the location of upper motor neuron cell bodies and lower motor neuron cell bodies and list the axonal target for each type of neuron.