Description

A stroke happens when blood flow to the brain is interrupted which causes brain cells to die and brain damage to occur.

Anatomy review

The brain communicates with muscles via upper motor neurons and lower motor neurons. The upper motor neurons (UMN) communicate signals from the brain to the lower motor neurons (LMN) which are the final neurons connecting to muscle fibers. Cranial nerves, whose axons leave from the brain stem, are the lower motor neurons for the vast majority of muscles involved in swallowing, coughing, and respiration. There are 12 pairs of cranial nerves, each with a left and ride side.

Swallowing is controlled by both cortical and brainstem regions. Multiple cortical areas of control for swallowing have been identified and include the primary motor cortex, supplementary motor area, and the anterior cingulated cortex. (Ludlow 2005) The cortex is primarily responsible for volitional swallowing. Studies have shown that swallowing is likely represented in both cortical hemispheres with most people having a dominant swallowing hemisphere (which is not necessarily the same as handedness).(Hamdy 2003; Hamdy and Rothwell 1998)

Almost all the cranial nerves receive bilateral innervation from the brain via the UMNs. This means that both the left and right side of a pair of cranial nerves are innervated by the cortex of both the left and right hemispheres. (Ertekin and Aydogdu 2003) This redundancy is a safety mechanism. If there is a unilateral lesion in the brain, signals will continue to the nerves from the undamaged area. The remaining unilateral message will not be as strong as an intact system but will not result in total paralysis.

Two of the cranial nerves receive innervation from only one side of the brain (the contralateral side): CN XII (hypoglossal which innervates the tongue) and CN VII (facial which innervates the muscles of the face). Since there is not bilateral innervation to these nerves, a unilateral UMN lesion (stroke) can cause paralysis of the muscles innervated by these nerves on the opposite side of the body.

The brainstem is primarily responsible for the involuntary phases of swallowing. Swallowing is represented on both sides of the brainstem, but these sides are interconnected and normal functioning depends on intact function of both sides. Since both sides of the brainstem work together, a unilateral brainstem stroke could result in bilateral pharyngeal dysfunction. A bilateral brainstem stroke would result in more severe deficits than a unilateral brainstem stroke alone.

There is evidence of a central pattern generator (CPG) for swallowing located in the medulla oblongata of the brainstem (Ertekin et al 2003). A CPG is a network of neurons that is hardwired so as to produce a sequence of activities that is always the same. Thus, when an individual triggers a swallow, the same set of movements will occur in the same sequence every time. The fact that an individual can swallow volitionally demonstrates that this network can be activated by input from the cerebral cortex. (Hamdy et al. 2000) If a patient has a stroke in the medulla oblongata that impacts the CPG, it will not be possible to initiate a volitional or automatic swallow.

Both motor (efferent) information and sensory (afferent) information are communicated between the cortex, brainstem, and the periphery. It has been found that sensory feedback communicated to the brain impacts and alters the motor aspects of swallowing (Robbins et al, 2008). Therefore, the information flowing in both directions to and from the brain is vitally important for normal swallowing function (Fig. 1).

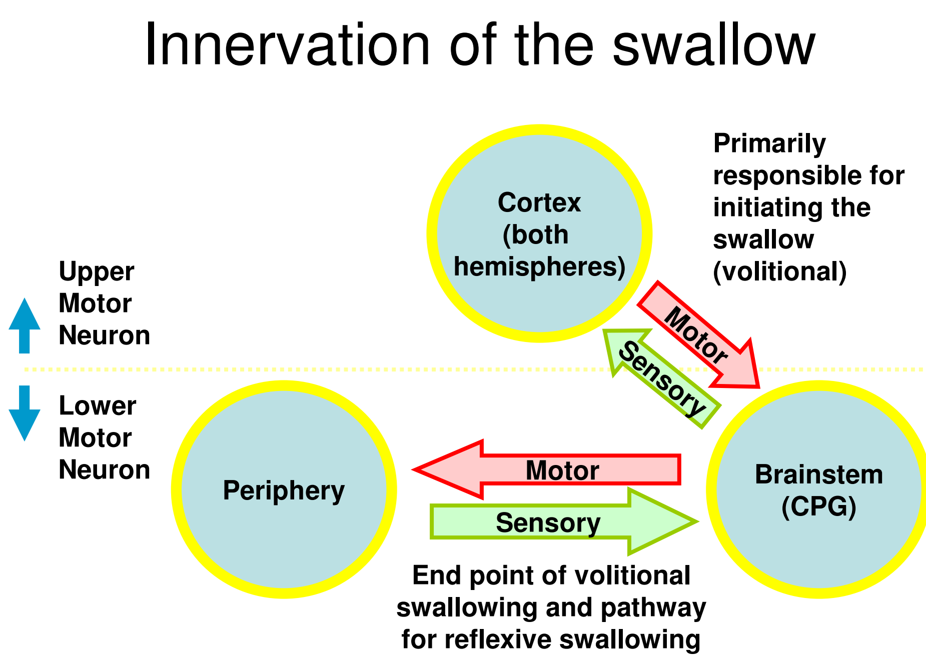

Fig. 1. Diagrammatic representation of the innervation of the swallow.

Cortical Stroke:
Two million brain cells, upper motor neurons (UMN), die every minute during a stroke. (NSA 2009) After a stroke, the UMNs damaged by the stroke can no longer send signals to the lower motor neurons in the brainstem which in turn will not “power” the muscles involved in swallowing properly.

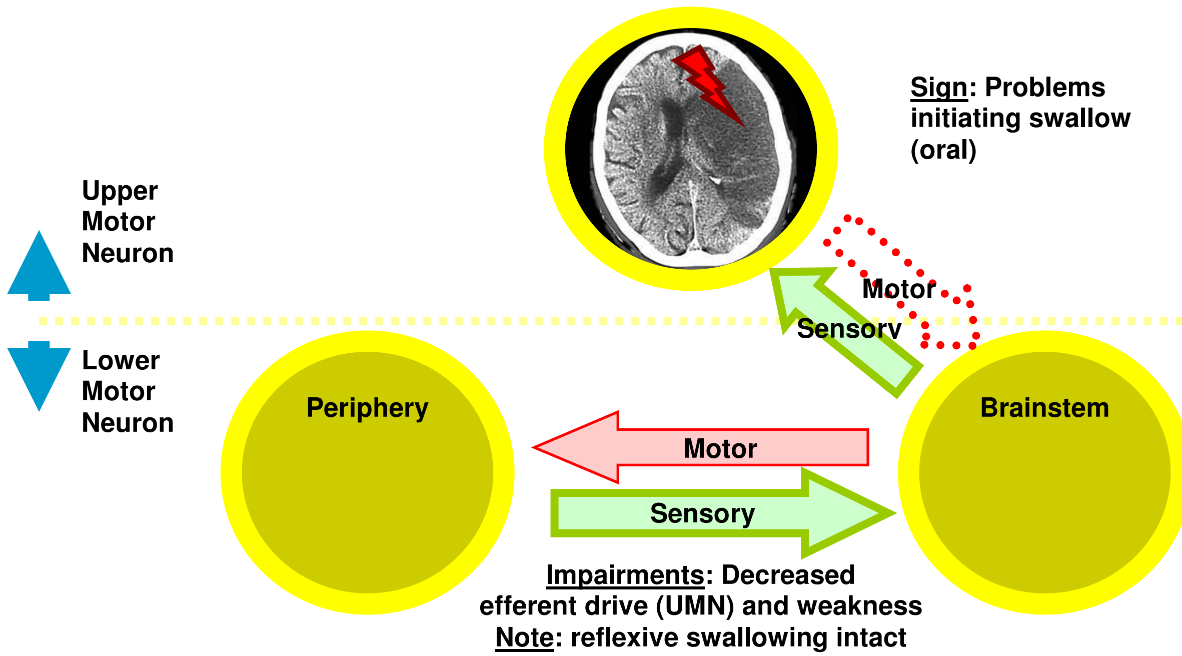

Fig. 2. Diagrammatic representation of the results of a cortical stroke.

Figure 2 shows how after a cortical stroke the UMNs of the cortex are no longer able to communicate with the swallowing system. While the unaffected hemisphere of the brain may continue to provide innervation to the muscles, the signal to the muscles will not be as strong and weakness will result. After a patient has a stroke, the reduced use of the muscles for swallowing will also result in disuse atrophy within a relatively short time span. Since the brainstem, where the central pattern generator for swallowing is located, continues to provide signals to the muscles for swallowing, patients may still be able to trigger swallows.

Cortical Stroke Recovery

Rehabilitation of the swallow function after a cortical stroke depends on cortical reorganization and the use of compensations to overcome residual deficits. There is substantial evidence that the recovery of the swallow function after a cortical stroke is primarily due to reorganization of the undamaged cortex to assume functions of the injured cortex. (Hamdy et al. 1997; Hamdy et al. 1998; Hamdy and Rothwell 1998)

Rehabilitation efforts should contain several characteristics to facilitate cortical reorganization:

"Use it or lose it": The patient must practice the swallow function. If the neural substrate that innervates swallowing is not active, its function may not recover.

"Use it and improve it": With increased activation of the neural substrate for swallowing, the function is improved.

Experience specific: Improvements in the neural substrate for swallowing are dependent on training using those particular functions.

Repetition: The quantity of exercise/intervention has a direct correlation with the therapeutic benefit.

Intensity: The more intense the intervention, the greater the stimulation to the neural substrate.
Salience: Repeated success engages the positive feedback loop and functional movement is facilitated. Movement specific feedback about the quantity and quality of the attempted movement stimulates motor return. (Robbins et al. 2008)

Application to swallowing rehabilitation:
Given the "use it or lose it" and "use it and improve it" concepts, rehabilitation of swallowing should encourage frequent swallowing and discourage disuse. While some patients may require non-oral feeding to sustain nutrition and hydration, patients should be encouraged to swallow as soon as possible. In the early stages of recovery, this might be only during swallowing therapy.

Given the experience specific principle of cortical reorganization, exercises and activities implemented during therapy should mirror how the muscles are actually used during swallowing. PO trials are an excellent treatment technique as the best exercise for swallowing is swallowing. Isolated exercises should also use the muscles in a way that is as close in function to the long term goal as possible. For example, if a patient has difficulty with bolus manipulation, a more effective exercise than moving the tongue from side to side would be to have the patient try moving and manipulating a bolus. This may be a non-nutritive bolus such as a piece of gauze tied to dental floss or a toothette if there are concerns about patient safety with an actual food bolus.

Given the repetition and intensity principles, as many swallows as possible should be facilitated during a treatment session. And the swallow trials should be challenging in order to produce a change in function.

Given the salience principle of cortical reorganization, during treatment swallows should emulate as "normal" a swallow as possible. This may mean minimizing the use of compensatory strategies during the treatment session. While the patient may still need to use the strategies outside of therapy for safe PO intake, therapy should focus on trying to facilitate normal swallowing dynamics as much as possible.

Role of neuromuscular electrical stimulation (NMES): Patients who have sustained a cortical stroke are generally excellent candidates for the use of NMES during treatment. The LMNs (peripheral nerves) which are stimulated during NMES remain intact.

There is emerging evidence that the sensory stimulation provided during NMES has a positive influence on swallowing recovery (Ludlow, 2007) (Park 2009).

Given that the use NMES enhances the ability to facilitate functional swallowing activities, patients who have sustained a cortical stroke are likely excellent candidates for treatment using NMES.

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