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Sensory Training:

translating research to clinical practice & home program

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Course Objectives

- Discuss the prevalence of sensory impairment following a stroke
- Describe the stroke survivors' experiences of sensory impairment in the upper limb and impact with daily life
- Review sensory assessments and outcome measures
- Review the adaptive / compensatory strategies for sensory impairment
- Discuss the passive and active sensory training
  - Discuss the recommended parameters, electrodes placements and dosage for passive sensory training using TENS
  - Discuss Thermal Stimulation to improve thermal awareness
  - Identify sample objects for active sensory training
- Describe sensory training home program
- Present case studies

Stroke Statistics

- Stroke kills about **140,000** Americans each year—that's **1 out of every 20 deaths**.[1]
- Someone in the United States has a stroke every **40 seconds**. Every **4 minutes**, someone dies of stroke.[2]
- Every year, more than **795,000 people** in the United States have a stroke. About 610,000 of these are first or new strokes.[2]
- About 185,00 strokes—**nearly 1 of 4**—are in people who have had a previous stroke.[2]
- About **87%** of all strokes are ischemic strokes, in which blood flow to the brain is blocked.[2]
- Economic impact was estimated at **$34 billion** each year.[2] This total includes the cost of health care services, medicines to treat stroke, and missed days of work.

Post stroke dysfunction

- Stroke is a **leading cause of serious long-term disability**.[2]

- Sensation is commonly impaired after stroke

- Sensory impairments are associated with stroke severity, decreased motor function, and are prognostic factor for treatment outcomes [6,7,8]

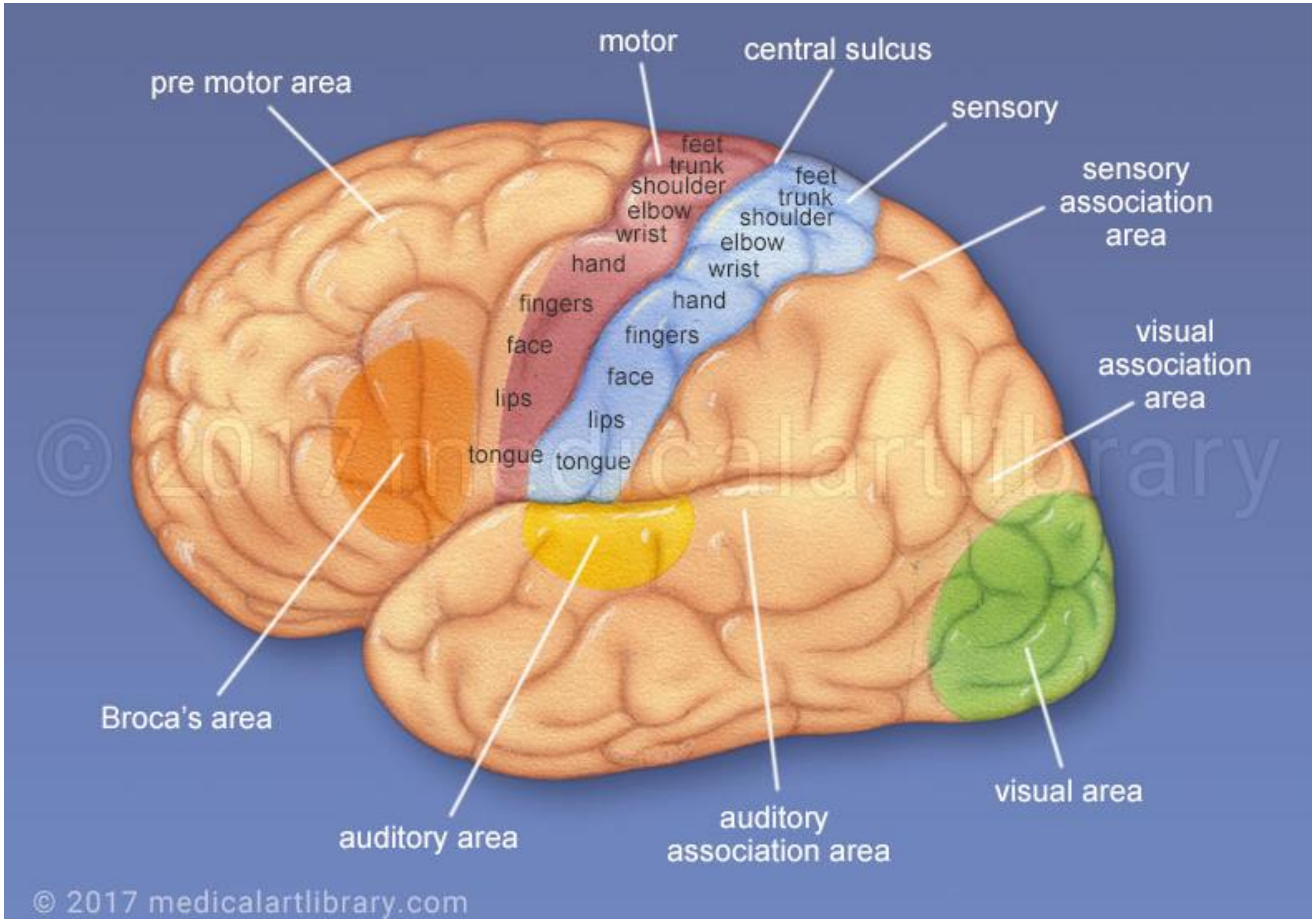
- Sensory deficits can prolong the duration of hospital stay and negatively affect a person’s ability to use the upper limb

Incidence of Sensory dysfunction

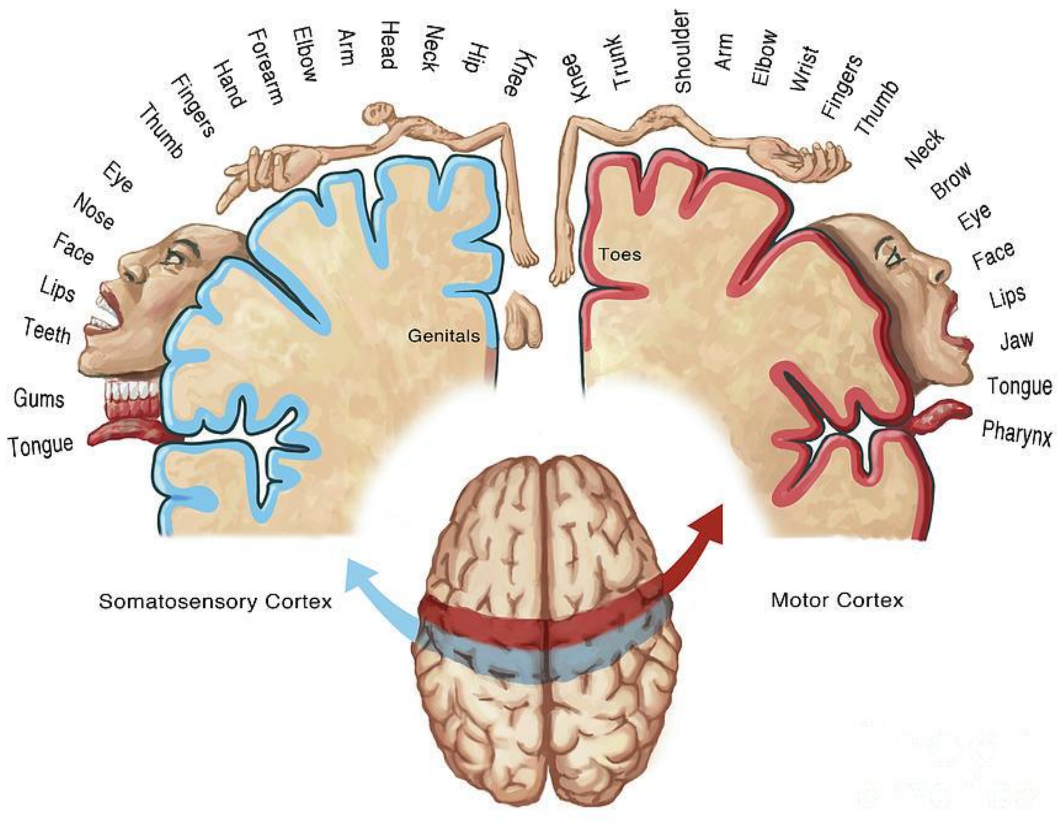
- Individuals with right hemisphere brain lesions have been reported to have a higher incidence of post stroke sensory dysfunction (37%) compared with those with left hemisphere lesions (25%)[8]

- Damage to the parietal lobe (where the somatosensory cortex is located) and damage to the thalamus and brainstem (which relay sensory information to the cortex) can cause sensation issues. Sensory problems post stroke differ from one person to another.

Sensory Cortex



Sensory Homunculus



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Parietal Lobe

- located near the center of the brain (upper middle lobe of each cerebral hemisphere), behind the frontal lobe, in front of the occipital lobe, and above the temporal lobe
- interprets sensory information, such as letting us know the location of parts of our body and aiding in physical navigation
- integrates sensory information among various modalities, including spatial sense and navigation (proprioception), the main sensory receptive area for the sense of touch (mechanoreception) in the somatosensory cortex
- helps determine your own orientation in space, as well as the orientation of other objects. It also receives significant input from the hand, suggesting that it helps coordinate fine motor skills and sensory input from the hands.
- functions in processing sensory information from the various parts of the body. It is heavily related to the sense of touch and involved in the manipulation of objects, as well as in detecting the orientation and numbers of objects encountered. It is also an essential element of spatial information, which gives us the ability to judge size, distance, and shapes.

Thalamus

- functions as an important relay and integrative station for **sensory** signals and motor information passing to all areas of the **cerebral cortex**, the basal ganglia, the hypothalamus, and the brainstem. It also regulates consciousness, sleep and alertness.

Somatosensory system[14]

- Handles sensory input from superficial sources such as the skin and deep sources such as musculoskeletal system
- Sensation is stimulated by receptors in the periphery of the body and the sensory information travels to the brain by way of the spinal cord
- Somatosensory receptors:
  - Mechanoreceptors – respond to touch, pressure, stretch, & vibration
  - Chemoreceptors – respond to cell injury or damage
  - Thermoreceptors – respond to heat or cold
- Each of these receptors has a subset called nociceptors which sense pain when stimulated[15]

Sensory Pathways

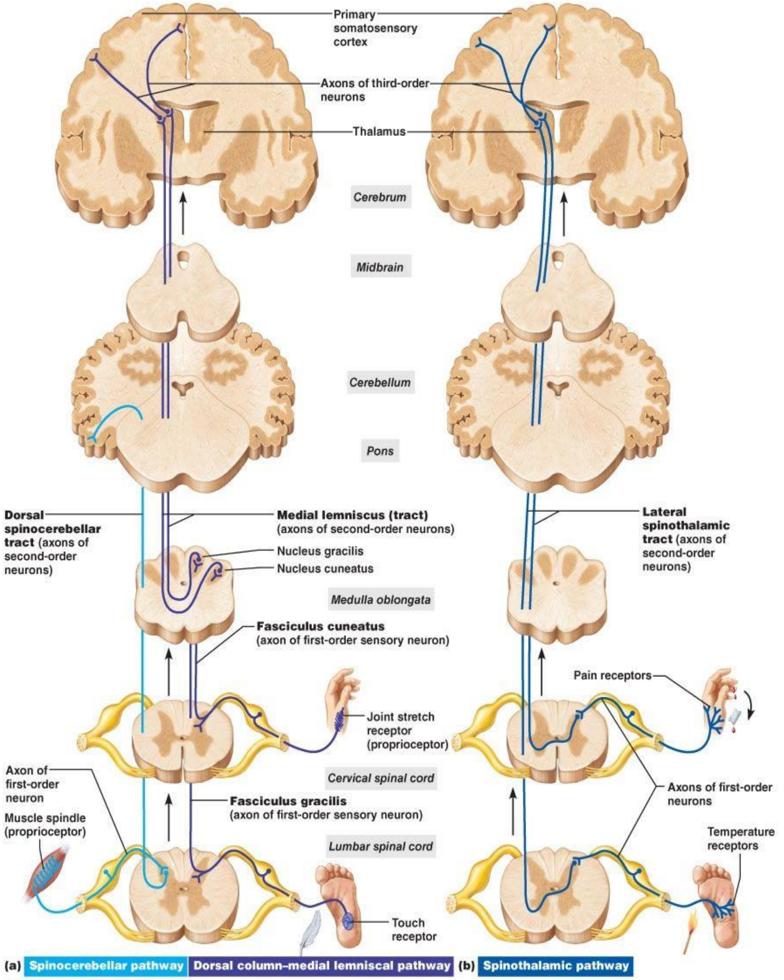
- Spinothalamic pathway
  - Anterior spinothalamic – crude touch & pressure
  - Lateral spinothalamic – pain & temperature
- Posterior/Dorsal column pathway – “fine” touch, pressure, vibration, proprioception
- Spinocerebellar pathway – proprioceptive information

Major Ascending Pathways for the Somatic Senses

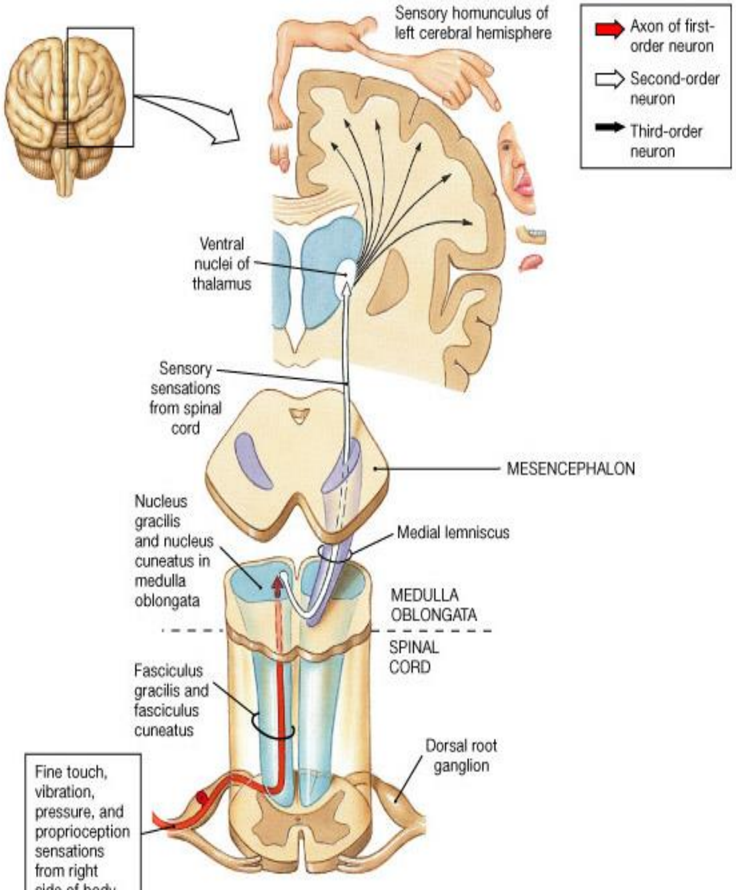
- **Spinocerebellar**: proprioception from skeletal muscles to cerebellum of same side (don't cross); large fibers

- **Posterior (Dorsal) column:** discriminative touch sensation through thalamus to somatosensory cortex (cross in medulla); large fibers

- **Spinothalamic (Anterolateral):** carries non-discriminate sensations through the thalamus to the primary somatosensory cortex (cross on spinal cord before ascending); small fibers



Posterior column pathway



(a) Posterior column pathway

Motor pathways

- Lateral pathway – voluntary control over skeletal muscles
  - Lateral corticospinal tract – controls distal muscles
  - Anterior corticospinal tract – controls proximal muscles
  - Rubrospinal tract – control of muscle tone in flexor muscle group

- Anterior Medial pathway – muscle tone and gross movement of the trunk (posture & balance) and proximal limb
  - Vestibulospinal tract – maintain head and eye coordination, upright posture and balance, and conscious realization of spatial orientation and motion
  - Reticulopsinal tract
  - Tectospinal tract – coordinates head & eye movements
  - Anterior corticospinal tract – controls proximal muscles

Frequency of sensory / somatosensory impairment after stroke

- Connell, LA (2008)[9]
  - 7–53% had impaired tactile sensations
  - 31–89% impaired stereognosis
  - 34–64% impaired proprioception
  - Proprioception & stereognosis were more frequently impaired than tactile sensations
- Carey, L & Matyas, T (2011)[10]
  - 47% had touch discrimination impairment on affected hand contralateral to the lesion & 16% experienced impairment on ipsilesional "unaffected" hand
  - 49% showed impaired limb position sense (proprioception) in the affected limb & 20% on unaffected limb
- Concern has been expressed by authors about the validity of using the uninvolved limb as the "normal reference" in testing because of evidence of bilateral sensory impairment [8]

Stroke Survivors' self-reported experiences of upper limb sensory impairments

Carlsson H, et.al. (2018) – qualitative study, 15 participants

- Changed & varied perception of sensation
- Affected movement control
- Problems using the upper limb (UL) in daily life
- Various strategies to cope with the upper limb disability
- Lack of sensory training

Stroke Survivors' self-reported experiences of upper limb sensory impairments

Carlsson H, et.al. (2018) – qualitative study, 15 participants

- **Changed & varied perception of sensation**
  - Numbness (fingertips were asleep similar to dental anesthesia), tingling, burning sensation – some c/o UL was not alive, others reported feeling of heaviness
  - Changes in temperature sensitivity – sensitive to cold even if they wore gloves, delay in perception of heat
  - Increased sensitivity to touch & pain
- **Affected movement control**
  - Difficulty adjusting the grip force – used too much pressure when holding or manipulating objects because they were afraid of dropping; some reported they had lost their automatic movements & had to increase their concentration when holding or carrying task object resulting in increased mental fatigue
  - Proprioceptive & perceptual difficulties – difficulty performing smooth movements w/precision, difficulty recognizing small objects with their hand w/o vision or identifying an object in their pocket by touch alone

Stroke Survivors' self-reported experiences of upper limb sensory impairments

Carlsson H, et.al. (2018) – qualitative study, 15 participants

- **Problems using the upper limb in daily life**
  - Personal care & dressing difficulties – such as washing hair, combing or styling hair, cutting nails, brushing teeth, applying make up, putting earrings, tying shoelaces, managing fasteners (buttons, zippers)
  - Difficulty with cooking & eating – difficulty cracking an egg, cutting/chopping, whipping food
  - Difficulty performing leisure activities – gardening, playing piano / tennis, applying brakes on a bicycle, finding the safety belt

- **Various strategies to cope with the upper limb disability**
  - Often use non-affected hand – lead to learned non-use of affected hand
  - Compensate w/ vision

- **Lack of sensory training**
  - Participants reported little attention was paid to their sensory impairment in IP & OP rehabilitation
  - Focus was on motor recovery
  - No training program after discharge

Consequences of sensory loss

- At the risk of skin damage and burning due to loss or reduced temperature sensation.
- With hypersensitivity to sensation, they may become over sensitive to pain just by light touch or when moving. This may result in the clothing being uncomfortable or even painful next to the skin.
- The loss of sensation from the bladder or bowel may lead to incontinence problems.
- Paresthesia, an altered sensation such as numbness, tingling, aching, burning or ‘pins and needles’ may cause great discomfort and confusion.
- Proprioception (the loss or reduced ability to know where a body part is) may make walking more difficult even if the muscle movements are intact. They may not know when the foot is flat on the floor or turned at the ankle joint.
- Movement lack precision and control.

Critical window for recovery

- Timeframe [3,4]
  - **Acute**: 1st month (offers the highest rate of recovery)[5]
  - **Sub-acute**: 1 month to 6 months
  - **Chronic**: > 6 months
- Initial days & weeks represent a critical window for therapeutic interventions to maximize neurologic recovery of body functions & activities
- Recovery occurs through spontaneous neurologic process such as reperfusion (return of blood supply) to tissue and reduction of swelling to minimize cortical damage
- There is no clear picture of expected time period for recovery of sensory impairments after stroke, one study suggested most recovery seems to occur in the first 3 months, but some modalities (e.g. warm detection threshold, vibratory detection threshold and two-point discrimination), recovery may continue between 3 and 12 months [19,20]
- Two other studies demonstrated recovery of sensation from time of stroke to 6 months [19,21]

Lack of knowledge & training on evidence-based interventions to effectively address sensory loss / dysfunction

- Despite high incidence of sensory impairments post-stroke, studies of somatosensory retraining programs are limited
- Clinicians pay little attention to sensory retraining in stroke rehabilitation
- **Puppa LU, et.al. (2015)** – have shown therapists reported barriers
  - Lack of time and resources
  - Limited knowledge of evidence-based interventions
  - Focus was on motor recovery training
  - Focus on compensatory strategies instead of remediation of sensory impairments
- Education for therapists should focus on assessment of the sensory impairment, meaningful goal-setting related to upper limb sensory impairment, as well as providing specific sensory training [9,18]

Evaluation of Sensation

- There is no widely accepted or standardized test of sensory impairments after stroke [16]
- Clinical descriptors such as "*present*", "*impaired*", or "*absent*" are utilized
- Touch Sensation (Light Touch, Deep Pressure) - Semmes-Weinstein Monofilaments
- Pain (protective sensation)
- Thermal / Temperature Awareness (protective sensation)
- Proprioception – Fugl Meyer [12,13]
- Localization Touch
- Stereognosis

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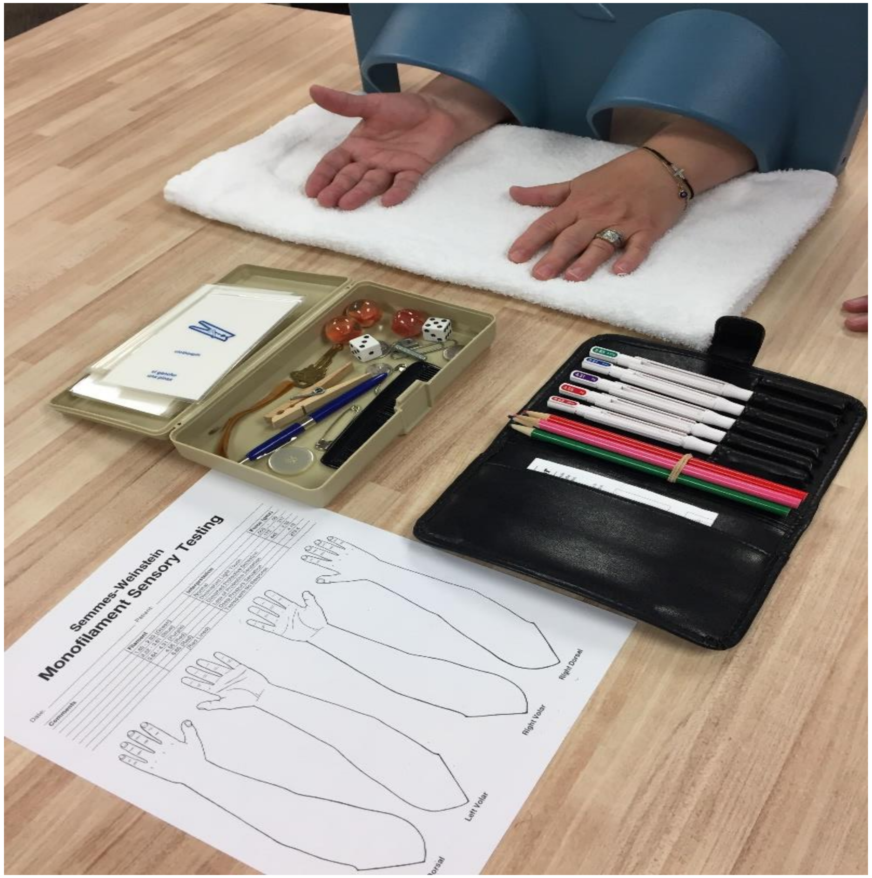
Touch Sensation & Stereognosis



Touch Sensation - Monofilaments

Thermal / Temperature Awareness

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Proprioception

Secondary Outcome Measures

- Coordination
  - Nine Hole Peg Test (NHPT)
  - Box & Blocks Test (BBT)
- Pinch Strength
- Grip Strength
- ADLs/IADLs – tying shoelaces; managing fasteners (buttons/zippers); putting on: belt, seat belt, earrings; grasping task objects; cutting food, etc.
- Patient Specific Functional Scale (PSFS)

Sensory Re-education

- Sensory re-education is a technique therapists use in attempt to retrain sensory pathways or stimulate unused pathways.

- Therapists also teach adaptive techniques to help compensate for sensory loss.

Adaptive or Compensatory Techniques[25]

- Use your vision to observe motion and location of body parts.
- Avoid exposure of the involved limb to heat, cold, and sharp objects (especially if the person is impulsive, inattentive, or lacks safety awareness)
  - Use your unaffected side to check temperature before bathing or washing objects.
  - Use your unaffected side to handle sharp objects &/or to perform household management tasks such as cooking, eating, and ironing
  - Use adaptive devices such as one-handed cutting board
  - Enlist the aid of caregivers to prepare hot meals

Adaptive or Compensatory Techniques cont.[25,26]

- Adapt task objects / use built up handles on the affected side to distribute pressure (the smaller the handle the less distribution of pressure over the gripping surfaces).
- Change positions frequently to prevent too much pressure on affected area.
- Observe the skin for signs of stress (redness, edema, warmth) from excessive force or repetitive pressure, and rest the hand if these signs occur
- When gripping an object, don't apply more force than is necessary.

Remediation of sensory loss / dysfunction post-stroke

- Sensory training post-stroke can be divided into two methods: [9,22]
  - **Active sensory training** - involves manual exploration of different textures, figures, and objects with the hand and fingers, and spatial detection of limb position
    - Commonly prescribed sensory re-education techniques / exercises can include touching different textured objects (finding objects w/o looking, sensing how different objects feel), massage, vibration, pressure, determining joint position, identifying different temperatures, and sensory locating.
  - **Passive sensory training** - involves the application of electrical stimulation to produce activation of cutaneous nerves in absence of muscle contraction.
    - Thermal stimulation is the application of heating/cooling stimulant

Active sensory training[25]

- Try to differentiate between textures (i.e. cotton, sandpaper, satin, velcro, rubber, velvet, wool, etc.)
- Hide objects such as marbles, coins, etc. in a bowl of rice/dry beans/sand. Without using vision, try to find the objects with your hand.
- Have another person touch you on one spot with your eyes open, then with your eyes closed. Try to associate where you saw the object touch your skin to know how it felt on your skin.
- Have another person keep pressure still on your skin then move it around. Watch and pay attention to how it feels. Close eyes and try to identify when the pressure is still versus when it is moving.
- Close your eyes and have a person apply vibration to your skin via a massager. See if you can identify when the vibration is applied to the skin. Have the person move the vibration around and see if you can tell when it is still versus moving around on your skin.

Active sensory training cont.[25]

- Have someone place different objects in your hand while you are looking (i.e. cotton ball, marble, key, paper clip). Close your eyes and then try to identify objects as they are placed in your hand again one at a time.
- Fill a flexible paper cup (i.e. Dixie cup) half full with water. Attempt to grasp cup without spilling the water or smashing the cup. Use your vision to determine how much pressure you are putting on the cup (i.e. if cup is slipping out of hand, apply more pressure; if cup is squeezed to hard, lessen grip)
- Repeat exercise with paper cup above but now move the cup from one spot to another maintaining a steady, even grasp (not too tight, not too loose)
- Have another person apply cold and or warmth to your skin and see if you can detect temperature differences.
- Feel an object then try to find a matching object inside a bowl of dry beans or rice.

Active sensory training cont.[25]

- Close eyes and have someone else position your affected arm. See if you can tell what position your arm is in (i.e. my elbow is bent) then open your eyes to see what position it is in.
- Close eyes and have someone else place a lighter object on your hand then a heavier object. Try to determine which object was heavier or lighter.
- Block your vision or close eyes. Have someone else move your hand while holding a pencil. Try to identify what letter, number or drawing is made.

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Active Sensory Training

Evidence-based studies to support use of TENS in passive sensory training

- **Schabrun SM & Hillier S (2009)** – meta-analyses shows moderate support for the effectiveness of passive sensory training in relation to sensory impairment and improving dexterity & hand function
- **Serrada I, Hordacre B & Hillier S (2019)** – meta-analyses (13 comparisons, 385 participants) demonstrated moderate effect in favor of passive sensory training on improving upper limb activity following stroke
- **Kita K, et.al. (2013)** – A pilot study of sensory feedback by TENS to improve manipulation deficit caused by severe sensory loss after stroke
- Passive sensory training using electrical stimulation (TENS)
  - has a high degree of clinical utility (readily available and cheap)
  - is relatively risk free
  - easy to implement when combined with active sensory training (noninvasive intervention)

Passive sensory training using TENS

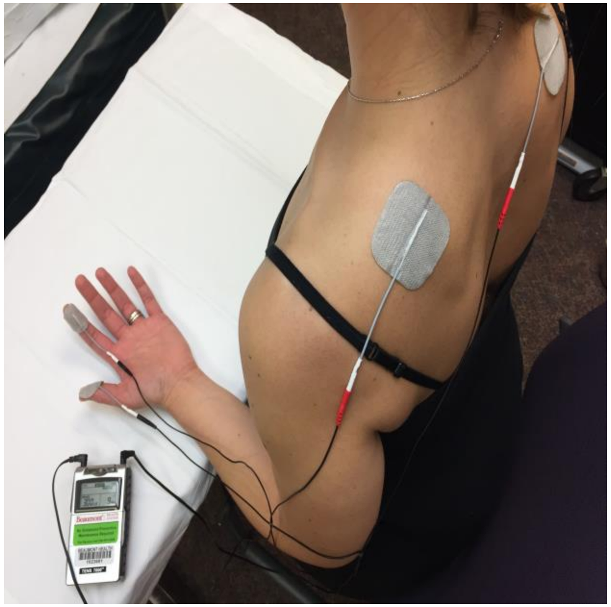
- Optimal stimulation parameters are yet to be determined [23]
  - Mode – normal or continuous
  - Monophasic rectangular pulse sequence
  - Pulse Width (PW): 250 - 300 us
  - Frequency (PR): 10 – 100 Hz
  - Intensity - adjusted __ mA
  - Treatment duration – 15 – 60 mins; 1-3x daily; 4-6 weeks

- **Chipchase LS, Schabrun SM, Hodges PW (2011)**[24] – PR 50 Hz and PW 300 us are appropriate for activating skin sensory sensation

Passive Sensory Training using TENS: Electrodes Placement

One Pair of Electrodes: Base of the Neck (Middle Trapezius) on same side – **Indifferent (Red)**

Pad of the Thumb / Index Finger - **Active (Black)**



Second Pair of Electrodes: Base of the Neck (Middle Trapezius) on R/L side – **Indifferent (Red)**

Tip of the MF/RF/SF – **Active (Black)**

Parameters: Mode _______; Pulse Width 250-300 us; Pulse Rate 50-100 Hz; Intensity ____ mA

Total treatment & frequency: **_15 - 60__**minutes; _1-3_ times per day; 4 to 6 weeks

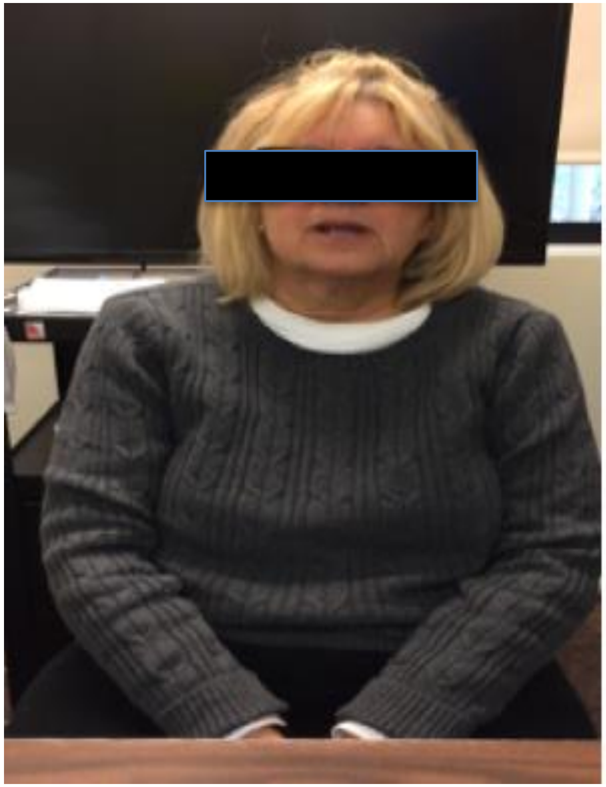
Precaution when using TENS

- Patients with implanted electronic device such as a cardiac pacemaker, implanted defribrillator, or any other metallic or electronic device should not undergo TENS treatment without first consulting a doctor
- Patients with heart disease, epilepsy, cancer or any other health condition should not undergo TENS treatment without first consulting a physician
- Electrical current of this magnitude must not flow through the thorax or across the chest because it may cause a cardiac arrythmia
- Do not place electrodes on the front of the throat as spasm of the laryngeal & pharyngeal muscle may occur.
- Stimulation over the carotid sinus (neck region) may close the airways, make breathing difficult, and may have adverse effect on the heart rhythm or blood pressure.
- Do not place electrodes on your head or any sites that may cause the electrical current to flow transcerebrally (through the head)

Precaution when using TENS cont.

- The device should not be used while driving or operating a machinery, close to water, or during any activity in which involuntary muscle contractions may put the user at undue risk or injury.
- Turn the TENS off before applying or removing the electrodes.
- Isolated cases of skin irritation may occur at the site of electrode placement following long term application.
- If TENS treatment becomes ineffective or unpleasant, stimulation should be discontinued until its use is re-evaluated by the therapist.
- Keep the device out of reach of children.

Case studies baseline (video)

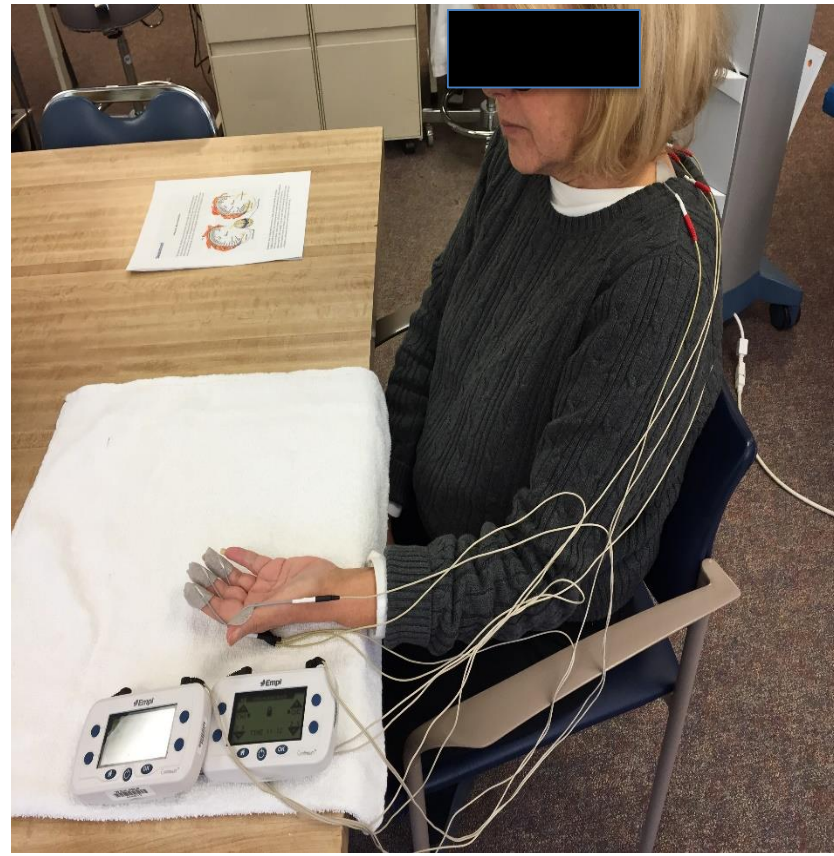


- Janet M, 66 y.o.
- Dx: CVA w/ mild L hemiparesis
- CT: subtle hyperacute ischemic changes in upper R frontal-parietal junction w/ subtle edema in the cortex & loss of gray-white matter interface junction
- Total visits: 15, seen 2x/wk

Case studies baseline (video)

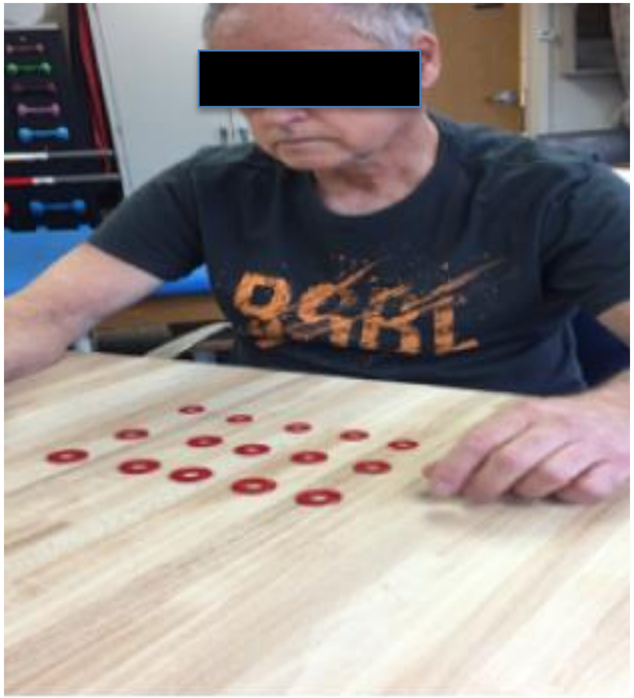
- David K, 63 y.o.
- Dx: CVA w/ mild left hemiparesis; s/p CAE
- CT: subacute ischemic infarct R frontal lobe & R temporal parietal junction
- Total visits: 24, seen 3x/wk

Case studies (video/photo)



Case studies post treatment (videos)

Case studies (videos)



Thermal Stimulation (TS)

Chen J-C, Liang C-C, Shaw F-Z (2005). Facilitation of Sensory and Motor Recovery by Thermal Intervention for the Hemiplegic Upper Limb in Acute Strokes Patients: A Single-Blind Randomized Clinical Trial. Stroke

Materials needed:

- Heating pad or Water pad (heating agent / stimulus) – set at ~ 160° F (75° C)
- Frozen Gel pack (cooling agent / stimulus) - set at < 32° F (< 0° C)
- Towels & a pillow case
- Timer

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Thermal Stimulation[27]

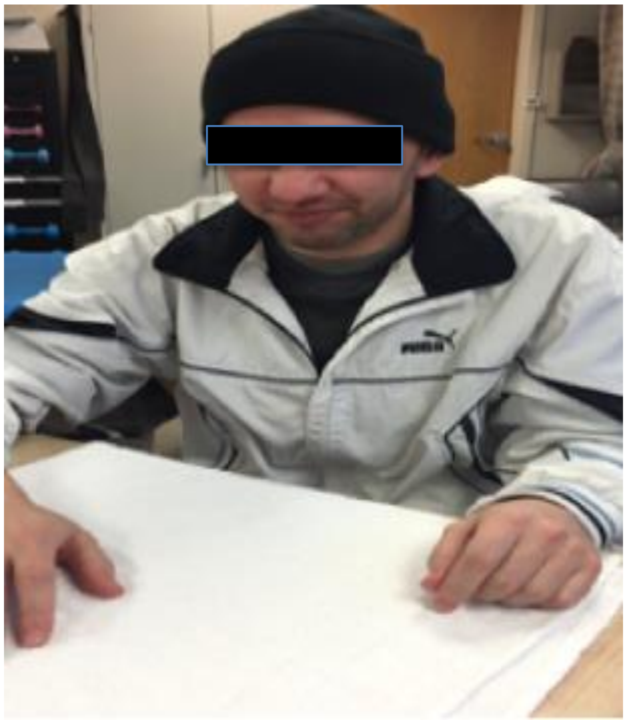
Instructions:

- **Heating Agent Stimulation**
  - wrap the heating / water pad with 2 layers of towels
  - place the involved/paretic _____ hand on the **heating agent/stimuli for 10-15 seconds** as shown by your therapist (also place _____ hand as sensor to avoid tissue damage on involved hand), when unpleasantness develops, reflexively pull hands off the heating agent/stimulus.
  - **Repeat 10x allowing 30 seconds pause in between** repetition.
  - **After 10-time heating stimulation, allow the involved/paretic _____ hand to cool to body temperature (~20 – 30 minutes) before starting the cooling agent/stimulus.**

- **Cooling Agent Stimulation**
  - wrap the frozen gel pack / cooling agent with 1 towel or a pillow case
  - place the involved/paretic _____ hand on the **cooling agent/stimuli for 30 seconds** as shown by your therapist, when unpleasantness develops, reflexively pull the hand off the heating agent/stimulus
  - **Repeat 10x allowing 30 seconds pause in between repetitions**

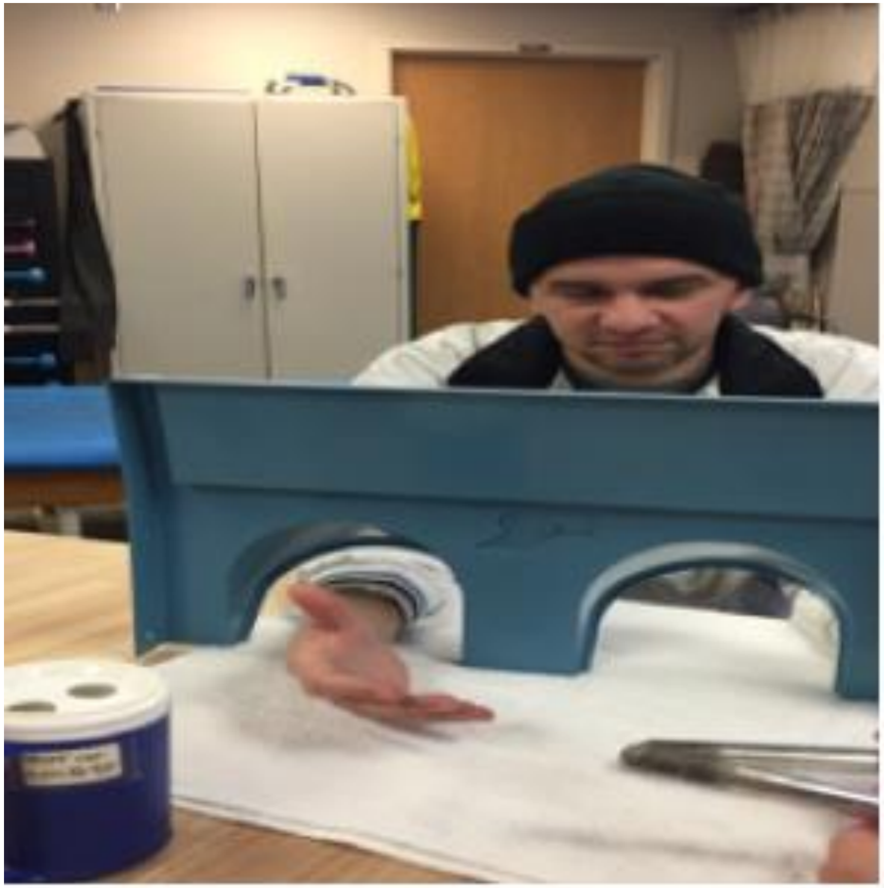
- **Perform two (2) cycles of heating and cooling stimulation once daily, 5x/week, for at least 6 weeks.**

Case studies (videos)



- Riman S, 36 y.o.
- Dx: CVA w/mild right hemiparesis
- CT: large encephalomalacia (loss of brain tissue) w/in L MCA distribution consistent w/ h/o prior infarct
- Total visits: 15, seen 2x/wk

Case studies (videos)



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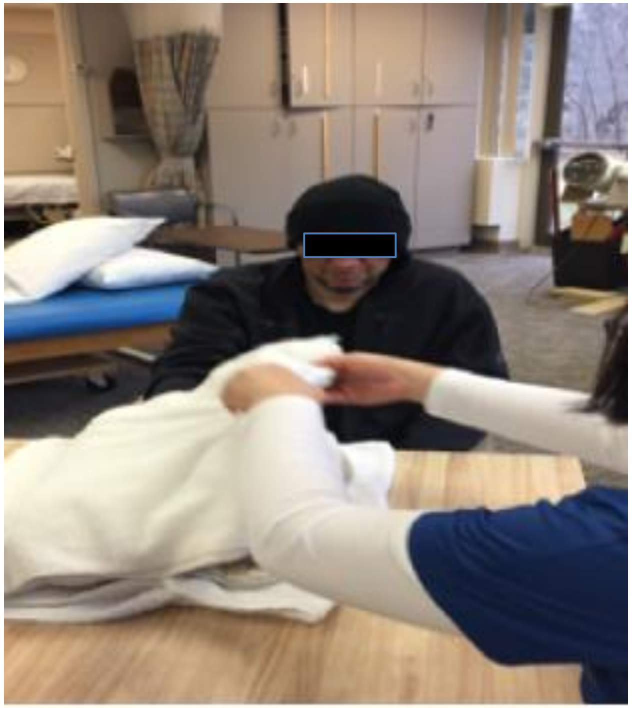
Case studies (videos)



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Sensory training using TENS

- Application to other diagnosis
  - Guillain Barre’ Syndrome (GBS)
  - Diabetic Peripheral Neuropathy (DPN)
  - CIPN – Chemotherapy-Induced Peripheral Neuropathy
  - MS

- Outcome Measure:
  - Neuropathic Pain Questionnaire (NPQ)
  - EORTC-CIPN20*

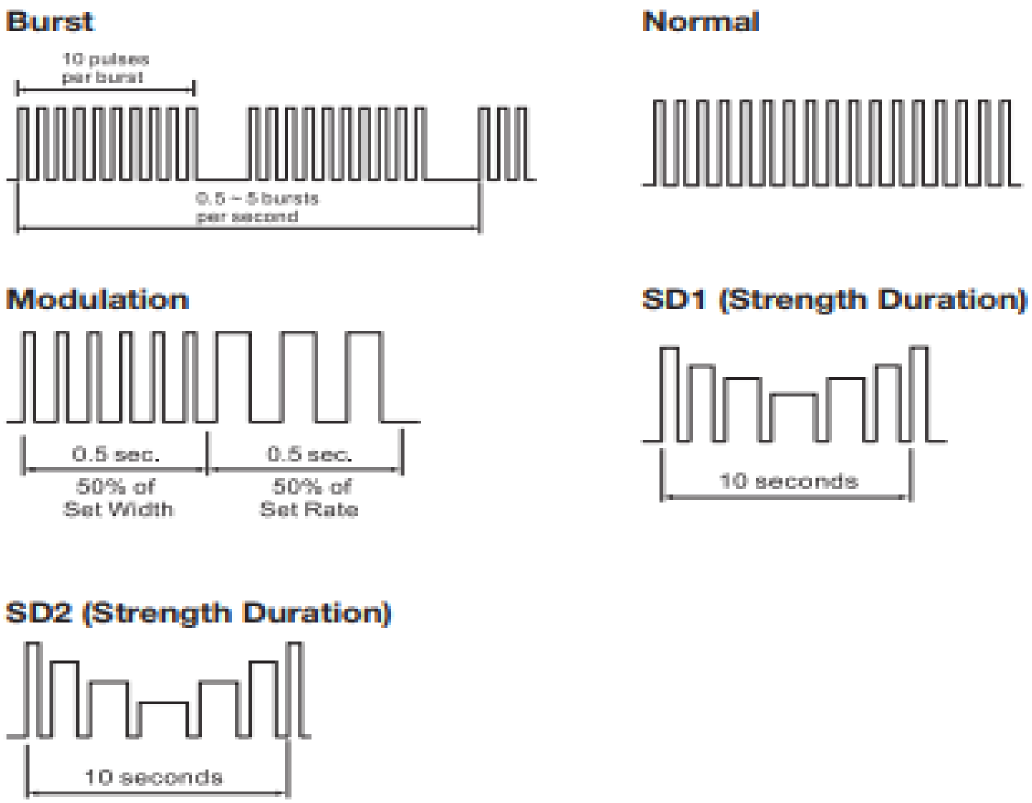
(* being evaluated)

Documentation

- Improve pinch strength & sensation on R hand to increase ease & independence in tying shoelaces, managing fasteners (zipper, buttons) as rated by (Patient-Specific Functional Scale) PSFS from 8-9/10 to 1-2/10
- Improve L pinch strength & proprioceptive sensation to increase ease in putting on the seat belt w/o having to look at the hand as rated by PSFS from 10/10 to 1-2/10 or better
- Increase thermal awareness on R hand (from absent to diminished) so patient can safely check water temperature when washing dishes, hands or bathing as rated by PSFS from 10/10 to 0/10
- Improve touch sensation & calibration of grasp on L hand so patient can effectively grasp a paper/styrofoam cup w/o spilling and/or maintain hold on a water bottle w/o slipping off his/her fingers as rated by PSFS from 9/10 to 1-2/10 or better
- Increase R pinch strength by 2-3# or > so patient can effectively use a nail clipper
- Improve sensation & coordination on R hand as evidenced by decreased time to complete NHPT from 121 secs to 60 secs or <
- Decrease neuropathic pain as evidenced by diminished NPQ score from 3.184 to zero or below

Recommended TENS 7000 2nd ed

TENS 7000 2nd ed. Mode



Summary / Clinical message

- With high incidence of sensory dysfunction post-stroke, OTs should evaluate & address the sensory impairments
- There is a growing evidence to support sensory-focused interventions worldwide
- Moderate evidence exists to support passive sensory training using TENS to improve hand function and dexterity following stroke

Any Questions?

- Thank you

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