Electrical Stimulation for Muscle Recovery Post CVA

Allison Larson PT, DPT

Objectives

- Be able to discuss the indications, contraindications/ precautions related to using electrical stimulation post cerebral vascular accident (CVA)
- Differentiate between normal muscle activation and functional electrical stimulation (FES)/ neuromuscular electrical stimulation (NMES) evoked activation
- Design an electrical stimulation (ES) treatment session for post CVA muscle recovery and be able to adjust parameters for optimal contraction.

Allison Larson PT, DPT

Education: 2010 DPT from Des Moines University

Work Experience

- 2010 – 2018 Mercy Center for Rehabilitative Medicine (4 North)
- 2018 – Present MercyOne Clive Rehabilitation Hospital

Certifications

- 2015 - present CBIS – Certified Brain Injury Specialist
- 2018 SCCE – Site Coordinator of Clinical Education, Advanced APTA Clinical Instructor
- 2019 – Level 1 EKSO GT Exoskeleton

Financial disclosures: None

My electrical stimulation experience

- Handheld NMES units
- Table top units such as Chattanooga
- Bioness L300
- RT300 FES lower extremity ergometer

- Nov 2018 completed 20 hour FES Powered Systems and Xcite Clinical Station course at Restorative Therapies in Baltimore, MD.

How often do you utilize electrical stimulation?

1. rarely/ never
2. A few times per month
3. A few times per week
4. Daily to multiple times per day

How do you primarily use electrical stimulation?

1. For sensory stimulation/ pain relief/ muscle relaxation

2. For muscle contraction in a neurologically intact individual

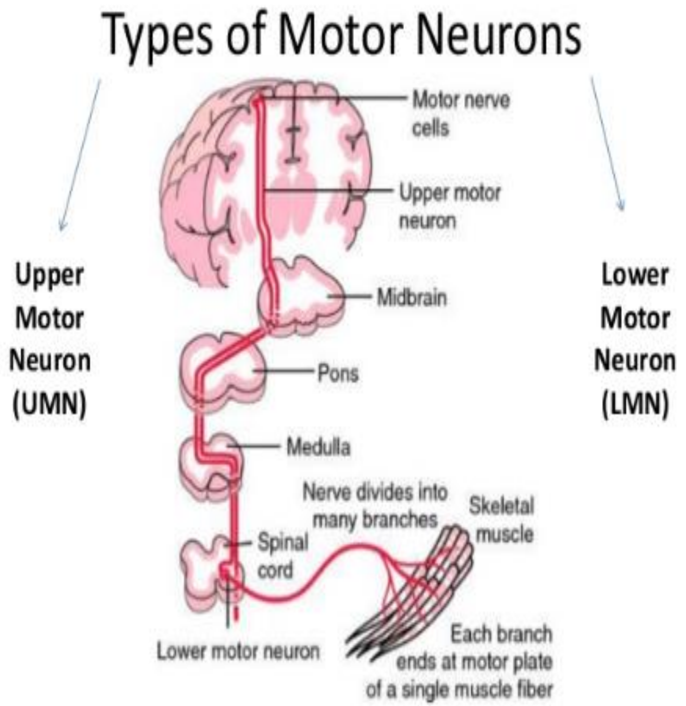
3. For muscle contraction in a neurologically compromised individual

4. For functional muscle contractions with multichannel system

Why is electrical stimulation needed post CVA?

- Upper Motor Neuron (UMN) injury
  - Results in denervation of muscle due to interruption of the neuronal pathways to the intact motor units
    - causing weakness/ paralysis/ disuse atrophy
      - leading to decreased functional mobility (Doucet, Lam, & Griffin, 2012) (Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018) (Takeda, Tanino, & Miyasaka, 2017)
  - 80% of patients with CVA experience motor impairments (Sabut, Sikdar, Kumar, & Mahadevappa, 2011)

Electrical stimulation (ES) is used throughout the medical field: pacemakers, cochlear implants, deep brain stimulation to reduce Parkinson's tremor, spinal cord stimulators to reduce pain (Takeda, Tanino, & Miyasaka, 2017)



NMES compared to FES

NMES	FES
Typically single channel application (Yan, Hui-Chan, & Li, 2005)	Typically applied multichannel (Yan, Hui-Chan, & Li, 2005)
Cyclical (repetitive) stimulation aimed at strengthening the muscle (Nascimento, Michaelsen, Ada, Polese, & Teixeira-Salmela, 2014)	Produces or compensates for functional movement (Yan, Hui-Chan, & Li, 2005) (Takeda, Tanino, & Miyasaka, 2017)
Goal is muscle contraction for muscle strengthening and paralysis recovery (Nascimento, Michaelsen, Ada, Polese, & Teixeira-Salmela, 2014) (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005) (Takeda, Tanino, & Miyasaka, 2017)	Goal to improve the performed movement (Nascimento, Michaelsen, Ada, Polese, & Teixeira-Salmela, 2014)
Frequency sufficient to produce muscle tetany and contraction (Doucet, Lam, & Griffin, 2012)	Pairing NMES simultaneously or intermittently with a functional task, adjusting NMES to the timing of functional motion (Doucet, Lam, & Griffin, 2012) (Takeda, Tanino, & Miyasaka, 2017)

Indications for use of NMES and FES

- Decreased muscle spasticity/ hypertonia
- Prevent or slow disuse atrophy
- Increase local blood circulation and improves cardiopulmonary function
- Maintain or increase ROM
- Muscle re-education/ improved motor control (increased ability to perform voluntary movements)
- Increased muscle strength
- Increases aerobic capacity

(Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018) (Doucet, Lam, & Griffin, 2012) (Sabut, Sikdar, Kumar, & Mahadevappa, 2011) (Bauer, Krewer, Golaszewski, Koenig, & Müller, 2015)

Indications for use of NMES and FES - continued

- Minimizes complications from immobilization
- Reduces pain
- Improvement in sensation and tactile awareness
- Accelerate recovery of over ground locomotion (Ambrosini, Ferrante, Ferrigno, Molteni, & Pedrocchi, 2011)
- Provide repetition for motor learning (Yan, Hui-Chan, & Li, 2005)
- In stroke recovery NMES is used for muscle strengthening, motor recovery, reducing spasticity, improving swallowing function (Takeda, Tanino, & Miyasaka, 2017)

(Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018) (Doucet, Lam, & Griffin, 2012) (Sabut, Sikdar, Kumar, & Mahadevappa, 2011) (Bauer, Krewer, Golaszewski, Koenig, & Müller, 2015)

Contraindications/ Precautions for use of Electrical Stimulation

- Patients with a demand-type cardiac pacemaker or defibrillator
- Use near where a cancerous lesion is present or suspected
- Use on a body part with fracture or dislocation (precaution)
- Pregnancy (limited research)
- Impaired sensation (precaution)
- Impaired cognition (precaution)
- Superficial metallic implant (precaution)

- Limitations of ES: less efficient than human movement, induces neuromuscular fatigue, uncoordinated movement (Doucet, Lam, & Griffin, 2012)

Which examples represents normal muscle activation?

- A. type IIa/IIb fibers are recruited before type I fibers
- B. smaller motor units are recruited before larger motor units
- C. muscle units are recruited in synchrony

- 1. A and B
- 2. B and C
- 3. B
- 4. A, B and C
- 5. A and C

Which examples represent ES evoked activation?

- A. type IIa/IIb fibers are recruited before type I fibers
- B. smaller motor units are recruited before larger motor units
- C. muscle units are recruited in synchrony

- 1. A and B
- 2. B and C
- 3. B
- 4. A, B and C
- 5. A and C

Comparison of muscle activation

Normal activation

- Type I (slow twitch) recruited before Type II (fast twitch)
- Size principle applies: smaller motor units are recruited before larger
- Asynchronous Recruitment allows for a smooth contraction
- Caused by cortical command and sensory input
- Fatigue resistant

(Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018)(Doucet, Lam, & Griffin, 2012)

ES induced activation

- Type II (fast twitch) fibers are activated first
- Reverse recruitment: Larger type II motor units are recruited first
- Synchronous recruitment of motor neurons
- Caused by neurotransmitter release
- Causes excess fatigue

(Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018)(Doucet, Lam, & Griffin, 2012)

Devices used for CVA rehabilitation

- Hand held/ portable devices and table top devices: Empi, Chattanoga
- Foot drop systems: Ness L300, L300 Go, WalkAide, Odstock O2CHS
- Hand/ UE: Ness H200, Xcite, RT300, RT200
- Ergometers: RT300, RT200, MyoCycle, RehaMove (MotoMed upgrade), RT600, Therapeutic Alliances
- Gait devices: Parastep I

(Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018) (Doucet, Lam, & Griffin, 2012) (Takeda, Tanino, & Miyasaka, 2017)

"It was more of a '*triple-blind*' test. The patients didn't know which ones were getting the real drug, the doctors didn't know, and, I'm afraid nobody knew."

Research

- FES cycling with "visibly good muscle contraction" reduced both impairments and activity limitations in hemiparetic patients. (Ambrosini, Ferrante, Ferrigno, Molteni, & Pedrocchi, 2011)
- Walking ability improved significantly more in cycling with ES vs without ES. Gait rehab combined with FES shows enhanced gait recovery. (Bauer, Krewer, Golaszewski, Koenig, & Müller, 2015)
- ES can be customized to control fatigue and to optimize force output by adjusting parameters. During ES muscle contraction sensory fibers are also activated and has shown improvements in sensation and tactile awareness following motor ES program. (Doucet, Lam, & Griffin, 2012)
- ES for muscle strengthening must elicit a muscle contraction. Electrical stimulation combined with progressive resistance training is recommended for patients with neurologically induced weakness. (Glinsky, Harvey, & Es, 2007)
- An optimal response to ES is muscle contraction, motion/ full joint motion was achieved by a variety of parameters. Muscle contraction is the crucial effect of ES to obtain benefits. Motor ES produces cutaneous, muscle, and joint proprioceptive afferent feedback. (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005)

Research - continued

- Systematic review shows ES can increase strength and improve activity after stroke. ES can be effectively applied to the weak (3-4/5) and very weak (1-2/5). Useful for the very weak patient with cognitive impairment. (Nascimento, Michaelsen, Ada, Polese, & Teixeira-Salmela, 2014)
- ES with conventional rehab should be the standard therapeutic protocol to correct spastic foot drop. (Sabut, Sikdar, Kumar, & Mahadevappa, 2011)
- NMES can be used post CVA for muscle strengthening, motor recovery, reducing spasticity, and improving swallowing function. (Takeda, Tanino, & Miyasaka, 2017)
- To create work and fatigue muscle contraction must be achieved (Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018)
- A study comparing FES to sham stimulation resulted in the FES group demonstrating improved functional mobility and improved motor recovery in acute stroke patients (Yan, Hui-Chan, & Li, 2005)

The goal is muscle contraction!
- How do we get it?

- Waveforms
- Frequency
- Pulse width/ duration
- Amplitude/ Intensity
- Ramp time and duty cycle
- Electrode size/placement

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Waveforms

- Stimulation may be monophasic, biphasic, and burst (polyphasic) waves
- Rectangular waves, Sine waves, biphasic waves can be symmetrical/asymmetrical or balanced/ unbalanced
- Studies have found Sine wave produce greater strength with less pain (Doucet, Lam, & Griffin, 2012)
- Studies have found monophasic or biphasic waves produce less fatigue than burst
- RT300 uses alternating monophasic waveform
- RehaStim uses rectangular biphasic waveform
- Bioness uses balanced biphasic in symmetrical or asymmetrical waveform
- Bottom line: the marketed devices have been FDA approved and have chosen the parameters that work best for the device.

(Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018) (Takeda, Tanino, & Miyasaka, 2017)

Frequency (Hz)

- Number of pulses per second
- For muscle tetany 20-50 Hz
- Higher Hz are reported to produces a more comfortable and smoother contraction
- Higher frequency can increase fatigue, the parameter most greatly tied to fatigue when studied
- A literature review of trials studying ES for motor control found most researchers use a fixed frequency of 20 to 50Hz
- Frequency and amplitude together determine the quality of contraction

(Doucet, Lam, & Griffin, 2012)(Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005) (Takeda, Tanino, & Miyasaka, 2017)
(Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018)

Pulse width/duration

- Duration of each pulse in microseconds (μs)
- Wider pulse width produce stronger contractions (Doucet, Lam, & Griffin, 2012)
- Wider pulse width will penetrate more deeply into subcutaneous tissue (Doucet, Lam, & Griffin, 2012)
- Pulse width can be increased to recruit more fibers in an area as fatigue ensues (Doucet, Lam, & Griffin, 2012)
- Higher pulse width will lead to greater overflow into surrounding muscles
- Studies report comfort greatest at 200-300μs (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005)
- A literature review of trials studying ES for motor control found most researchers use a fixed pulse duration of 200 to 300μs (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005)
- Can be adjusted for optimal contraction and comfort (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005)

Amplitude/ Intensity

- Determines the pulse height
- Multiple studies place intensity at maximum tolerated for visibly good muscle contraction (Yan, Hui-Chan, & Li, 2005) (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005) (Ambrosini, Ferrante, Ferrigno, Molteni, & Pedrocchi, 2011) (Nascimento, Michaelsen, Ada, Polese, & Teixeira-Salmela, 2014) (Doucet, Lam, & Griffin, 2012) (Glinsky, Harvey, & Es, 2007) (Sabut, Sikdar, Kumar, & Mahadevappa, 2011)
- Higher intensity leads to stronger depolarizing effect underlying the electrode (Doucet, Lam, & Griffin, 2012)
- Higher intensities foster increased strength (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005) (Doucet, Lam, & Griffin, 2012)
- Higher intensities can activate a large number of muscle fibers but have been shown to result in less CNS stimulation (Doucet, Lam, & Griffin, 2012)
- Higher amplitude/ intensity is typically less tolerated/ more painful/ higher likelihood of skin irritation(Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005) (Doucet, Lam, & Griffin, 2012)
- Frequency and amplitude together determine the quality of contraction (Doucet, Lam, & Griffin, 2012)
- Low intensity will evoke a sensory reaction without a motor reaction, can be use to reduce spasticity (Kroon, Ijzerman, Chae, Lankhorst, & Zilvold, 2005)

Dosage - Ramp time - Duty cycle

- 15 min of FES training x 20 sessions = significant improvement over control in motor power, over ground walking speed, trunk control test, motor control test, and pedaling test (Ambrosini, Ferrante, Ferrigno, Molteni, & Pedrocchi, 2011)
- FES 20 min x 3 times per week x 3 weeks = FES group showed significantly more improvement in walking ability and postural control than control (Bauer, Krewer, Golaszewski, Koenig, & Müller, 2015)
- Ramp time: 1 to 3 seconds in common. Longer ramp times can improve comfort. Longer ramp times can help when a patient has increased tone. Ramp times can be adjusted to mimic function and to smooth contraction. (Doucet, Lam, & Griffin, 2012)
- Duty cycle: cyclical on/off times, typically a ratio. Helps to preserve force development and to increase comfort. 1:3 is common but can be adjusted to fit your goals. (Doucet, Lam, & Griffin, 2012)
  - My recommendation is to gauge the patients current level of function and strength and the risk involved if a patient becomes over fatigued

Electrode size and placement

- Success of stimulation reaching the muscle tissue is highly related to electrode size and placement
- Larger electrode = reaches more muscle tissue, decreased current density due to current being spread over a larger area
- Smaller electrode = concentrates current, more focal, less overflow, increased chances of pain and skin irritation
- Placement: will increase the muscle response. Debate in the research between using muscle belly or motor point. Muscle belly is easier, more reproducible, and quicker… but motor point (located through stimulation) produces higher torque, more blood flow, and greater oxygen usage.

(Doucet, Lam, & Griffin, 2012)

Fatigue

- What is required of the muscle/ limb the remainder of the day and next day?
- Signs of fatigue during stimulation: decreased ROM, decreased power, decreased speed, muscle twitching/ trembling, soreness/ deep muscle pain
- Frequency is the parameter found to impact fatigue the most. A constant of frequency of 30 Hz closely aligns with physiological rates and preserves force better than higher or lower frequency (Doucet, Lam, & Griffin, 2012)
- In normal physiology internal frequency is low 10-20 Hz until 50% of max tension then increases to build wave summation and increased tension (Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018)
- Charge is determined by pulse width and amplitude, maximizing charge recruits more muscle fibers resulting in slower onset of fatigue. Increased charge recruits more type I fibers which are more fatigue resistant (Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018)
- Fatigue is NOT bad. Fatigue is often the goal! As fatigue is reached over multiple sessions recovery time will decrease (Warfield, McElroy, Baker, Magerfleisch, & Huber, 2018)

General Starting Parameters

Large muscle

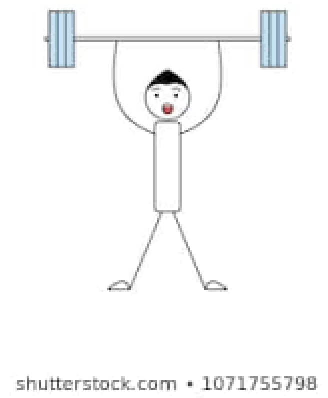
- Frequency: 40 to 60 Hz
- Pulse width: 200 to 350μs
- Amplitude: maximum necessary and tolerated for muscle contraction

Small muscle

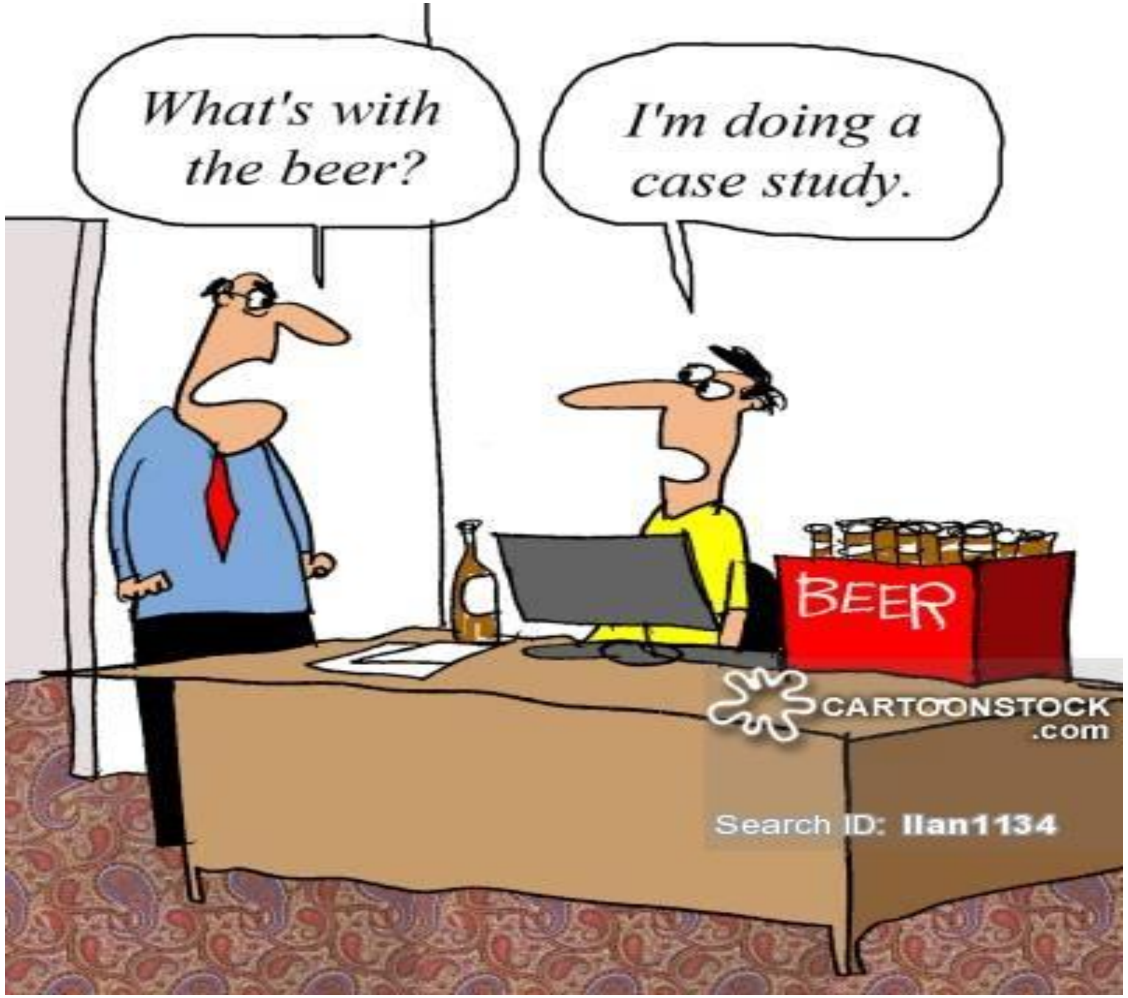
- Frequency: 20 to 40 Hz
- Pulse width: 100 to 250μs
- Amplitude: maximum necessary and tolerated for muscle contraction

Success can be a mindset

- Words/ preparation
- Positioning
- Encouragement/ Share the research
- Motivation
- Don’t say “Tell me when it hurts” that leads the patient to expect and anticipate pain



Parameter Adjustments – Case Studies



Case 1

Electrical Stimulation to the anterior tibialis for treatment of weakness/ foot drop. Wears an AFO for gait and mobility.

Parameters: patient in supine with bolster under posterior ankle, frequency 30 Hz, Pulse width 250, electrodes 2 x 3.5 applied to anterior tibialis, 15 sec on/ 30 sec off with 2 sec ramp

Result: as amplitude increases ant tib contraction noted, but ROM is in the direction of PF instead of DF. No c/o discomfort.

Case 1 – what adjustments would you chose?

Electrical Stimulation to the anterior tibialis for treatment of weakness/ foot drop. Wears an AFO for gait and mobility.

Parameters: patient in supine with bolster under posterior ankle, frequency 30 Hz, Pulse width 250, electrodes 2 x 3.5 applied to anterior tibialis, 15 sec on/ 30 sec off with 2 sec ramp

Result: as amplitude increases ant tib contraction noted, but ROM is in the direction of PF instead of DF. No c/o discomfort.

- Increase frequency to 60 Hz?

Case 1 – What adjustments would you chose?

Electrical Stimulation to the anterior tibialis for treatment of weakness/ foot drop. Wears an AFO for gait and mobility.

Parameters: patient in supine with bolster under posterior ankle, frequency 30 Hz, Pulse width 250, electrodes 2 x 3.5 applied to anterior tibialis, 15 sec on/ 30 sec off with 2 sec ramp

Result: as amplitude increases ant tib contraction noted, but ROM is in the direction of PF instead of DF. No c/o discomfort.

- Decrease pulse width to 150?

Case 1 – What adjustments would you chose?

Electrical Stimulation to the anterior tibialis for treatment of weakness/ foot drop. Wears an AFO for gait and mobility.

Parameters: patient in supine with bolster under posterior ankle, frequency 30 Hz, Pulse width 250, electrodes 2 x 3.5 applied to anterior tibialis, 15 sec on/ 30 sec off with 2 sec ramp

Result: as amplitude increases ant tib contraction noted, but ROM is in the direction of PF instead of DF. No c/o discomfort.

- Move electrodes?

Case 1 – What adjustments would you chose?

Electrical Stimulation to the anterior tibialis for treatment of weakness/ foot drop. Wears an AFO for gait and mobility.

Parameters: patient in supine with bolster under posterior ankle, frequency 30 Hz, Pulse width 250, electrodes 2 x 3.5 applied to anterior tibialis, 15 sec on/ 30 sec off with 2 sec ramp

Result: as amplitude increases ant tib contraction noted, but ROM is in the direction of PF instead of DF. No c/o discomfort.

- Switch to 2 x 2 electrodes?

Case 1 – What adjustments would you chose?

Electrical Stimulation to the anterior tibialis for treatment of weakness/ foot drop. Wears an AFO for gait and mobility.

Parameters: patient in supine with bolster under posterior ankle, frequency 30 Hz, Pulse width 250, electrodes 2 x 3.5 applied to anterior tibialis, 15 sec on/ 30 sec off with 2 sec ramp

Result: as amplitude increases ant tib contraction noted, but ROM is in the direction of PF instead of DF. No c/o discomfort.

- Lower ramp time?

Case 1 – Summary

Electrical Stimulation to the anterior tibialis for treatment of weakness/ foot drop. Wears an AFO for gait and mobility.

Parameters: patient in supine with bolster under posterior ankle, frequency 30 Hz, Pulse width 250, electrodes 2 x 3.5 applied to anterior tibialis, 15 sec on/ 30 sec off with 2 sec ramp

Result: as amplitude increases ant tib contraction noted, but ROM is in the direction of PF instead of DF. No c/o discomfort.

Yes – in order of approach	No
Move electrodes	Increase Frequency to 60 Hz
Decrease pulse width to 150	Lower ramp time
Switch to 2 x 2 electrodes	

- How can we make this more active/functional?

Case 2

- Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.
- Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp
- Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

Case 2 – What adjustments would you choose?

Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.

Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

- Increase frequency to 70 Hz?

Case 2 – What adjustments would you chose?

Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.

Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

- Increase pulse width to 350?

Case 2 – What adjustments would you chose?

Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.

Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

- Move electrodes?

Case 2 – What adjustments would you chose?

Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.

Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

- Switch to 3 x 5 electrodes?

Case 2 – What adjustments would you chose?

Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.

Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

- Decrease ramp time to 1 sec?

Case 2 – What adjustments would you chose?

Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.

Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

- Coach patient?

Case 2 - Summary

Electrical stimulation to quadricep for strengthening due to patient lacking positive support in stance due to strength 1/5.

Parameters: patient in sitting, Frequency 40Hz, Pulse width 250, electrodes 2 x 3.5, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: as amplitude is increased patient c/o pain and will not allow amplitude to increase further just as muscle begins to fasciculate

Yes – in order of approach	No
Coach patient	Decrease ramp time to 1 sec
Switch to 3 x 5 electrodes	Move electrodes
Increased pulse width to 350	
Increase frequency to 70 Hz	

- How can we make this more active/functional?

Case 3

- ES to anterior tibialis for ankle DF due to weakness
- Parameters: Patient in sitting with foot suspended, frequency 40 Hz, pulse width 120, 2 x 3.5 electrodes, 10 sec on/ 20 sec off with 2 sec ramp
- Results: Able to achieve contraction with ROM into DF but with excess inversion or eversion

Case 3 – What parameters would you adjust?

ES to anterior tibialis for ankle DF due to weakness

Parameters: Patient in sitting with foot suspended, frequency 40 Hz, pulse width 120, 2 x 3.5 electrodes, 10 sec on/ 20 sec off with 2 sec ramp

Results: Able to achieve contraction with ROM into DF but with excess inversion or eversion

- Increase frequency to 80Hz?

Case 3 – What parameters would you adjust?

ES to anterior tibialis for ankle DF due to weakness

Parameters: Patient in sitting with foot suspended, frequency 40 Hz, pulse width 120, 2 x 3.5 electrodes, 10 sec on/ 20 sec off with 2 sec ramp

Results: Able to achieve contraction with ROM into DF but with excess inversion or eversion

- Increase pulse width to 200?

Case 3 – What parameters would you adjust?

ES to anterior tibialis for ankle DF due to weakness

Parameters: Patient in sitting with foot suspended, frequency 40 Hz, pulse width 120, 2 x 3.5 electrodes, 10 sec on/ 20 sec off with 2 sec ramp

Results: Able to achieve contraction with ROM into DF but with excess inversion or eversion

- Move electrodes?

Case 3 – What parameters would you adjust?

ES to anterior tibialis for ankle DF due to weakness

Parameters: Patient in sitting with foot suspended, frequency 40 Hz, pulse width 120, 2 x 3.5 electrodes, 10 sec on/ 20 sec off with 2 sec ramp

Results: Able to achieve contraction with ROM into DF but with excess inversion or eversion

- Switch to 2 x 2 electrodes?

Case 3 – What parameters would you adjust?

ES to anterior tibialis for ankle DF due to weakness

Parameters: Patient in sitting with foot suspended, frequency 40 Hz, pulse width 120, 2 x 3.5 electrodes, 10 sec on/ 20 sec off with 2 sec ramp

Results: Able to achieve contraction with ROM into DF but with excess inversion or eversion

- Increase ramp time to 4 sec?

Case 3 - Summary

ES to anterior tibialis for ankle DF due to weakness

Parameters: Patient in sitting with foot suspended, frequency 40 Hz, pulse width 120, 2 x 3.5 electrodes, 10 sec on/ 20 sec off with 2 sec ramp

Results: Able to achieve contraction with ROM into DF but with excess inversion or eversion

Yes – In order of approach	**No**
Move electrodes	Increase frequency to 80 Hz
Switch to 2 x 2 electrodes	Increased pulse width to 200
	Increase ramp time to 4 sec

Case 4

- ES to quadricep for strengthening due to 0/5 strength
- Parameters: patient in sitting, frequency 40Hz, pulse width 250, electrodes 3 x 4, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp
- Result: increasing amplitude to maximum but unable to elicit contraction

Case 4 – What parameters would you adjust?

ES to quadricep for strengthening due to 0/5 strength

Parameters: patient in sitting, frequency 40Hz, pulse width 250, electrodes 3 x 4, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: increasing amplitude to maximum but unable to elicit contraction

- Lower Frequency to 10 Hz?

Case 4 – What parameters would you adjust?

ES to quadricep for strengthening due to 0/5 strength

Parameters: patient in sitting, frequency 40Hz, pulse width 250, electrodes 3 x 4, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: increasing amplitude to maximum but unable to elicit contraction

- Increase pulse width to 350?

Case 4 – What parameters would you adjust?

ES to quadricep for strengthening due to 0/5 strength

Parameters: patient in sitting, frequency 40Hz, pulse width 250, electrodes 3 x 4, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: increasing amplitude to maximum but unable to elicit contraction

- Move electrodes closer together?

Case 4 – What parameters would you adjust?

ES to quadricep for strengthening due to 0/5 strength

Parameters: patient in sitting, frequency 40Hz, pulse width 250, electrodes 3 x 4, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: increasing amplitude to maximum but unable to elicit contraction

- Switch electrodes to 2 x 3.5?

Case 4 – What parameters would you adjust?

ES to quadricep for strengthening due to 0/5 strength

Parameters: patient in sitting, frequency 40Hz, pulse width 250, electrodes 3 x 4, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: increasing amplitude to maximum but unable to elicit contraction

- Change position of the leg?

Case 4 - Summary

ES to quadricep for strengthening due to 0/5 strength

Parameters: patient in sitting, frequency 40Hz, pulse width 250, electrodes 3 x 4, applied to quadricep, 10 sec on/ 20 sec off with 3 sec ramp

Result: increasing amplitude to maximum but unable to elicit contraction

Yes – in order of approach	No
Increase pulse width to 350	Switch to 2 x 3.5 electrodes
Change the position of the leg	
Move electrodes closer together	
Lower frequency to 10 Hz	

Tips for the hypersensitive/ painful patient

- Coach – stress the benefit, encourage
- Increase frequency
- Increase ramp time
- Step wise increase in amplitude until reaching contraction
- Larger electrodes to spread the intensity over a larger area
- Distraction: music, family, story telling
- Add movement/ activity

Tips for the patient with impaired sensation, neglect, and poor cognition

- Frequency at default in tetany range 20-50 Hz
- Pulse width as large as appropriate for muscle size
- Electrode size as large as appropriate
- Position the patient so that contraction will result in ROM and so that patient can see the muscle, use mirror if needed
- Monitor patient closely throughout
- Perform skin check after
- This population can benefit greatly!

Tips for the high level patient who already has strength greater than 3/5

- Add resistance
- Add movement
- Multiple channels
- Change position to pair to patients impaired mobility – stance support/ sit to stand/ stepping
- Explore functional devices or adding ES to reps on standard strengthening equipment
- Explore home device/ using ES as a home exercise program
- Beware of fatigue and increased recovery time

Take Home Message

- Electrical stimulation can be an effective tool to advance your standard rehabilitation program
- If you don't have success with electrical stimulation on the first trial there are multiple adjustments that can be made to the parameters to improve contraction or comfort
- There are a wide variety of devices to choose from - It does not have to be fancy to be effective

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Feedback – Will you change your use of ES?

1. No change – It doesn't fit well with my patient population/ practice
2. No change – I'm not convinced it is worth the time or equipment cost
3. Increase use – The evidence leads me to believe this can benefit my patient population
4. Increase use – I feel more confident using and adjusting ES parameters so I can use it with more of my patients
5. Decrease use – You talked me out of ever doing ES again!