# Neuromuscular Electrical Stimulation in Critically ill patients

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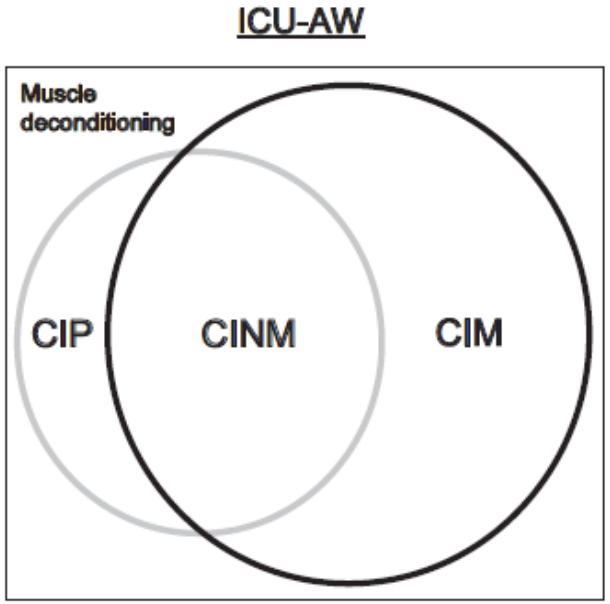
2022.04.02, 14:40~15:10

# Introduction

# Post-intensive care syndrome (PICS)

- **PICS** describes the disability that remains in surviving the critical illness.
  - impairment in ***cognition***, ***psychological health***, and ***physical function*** of the ICU survivors



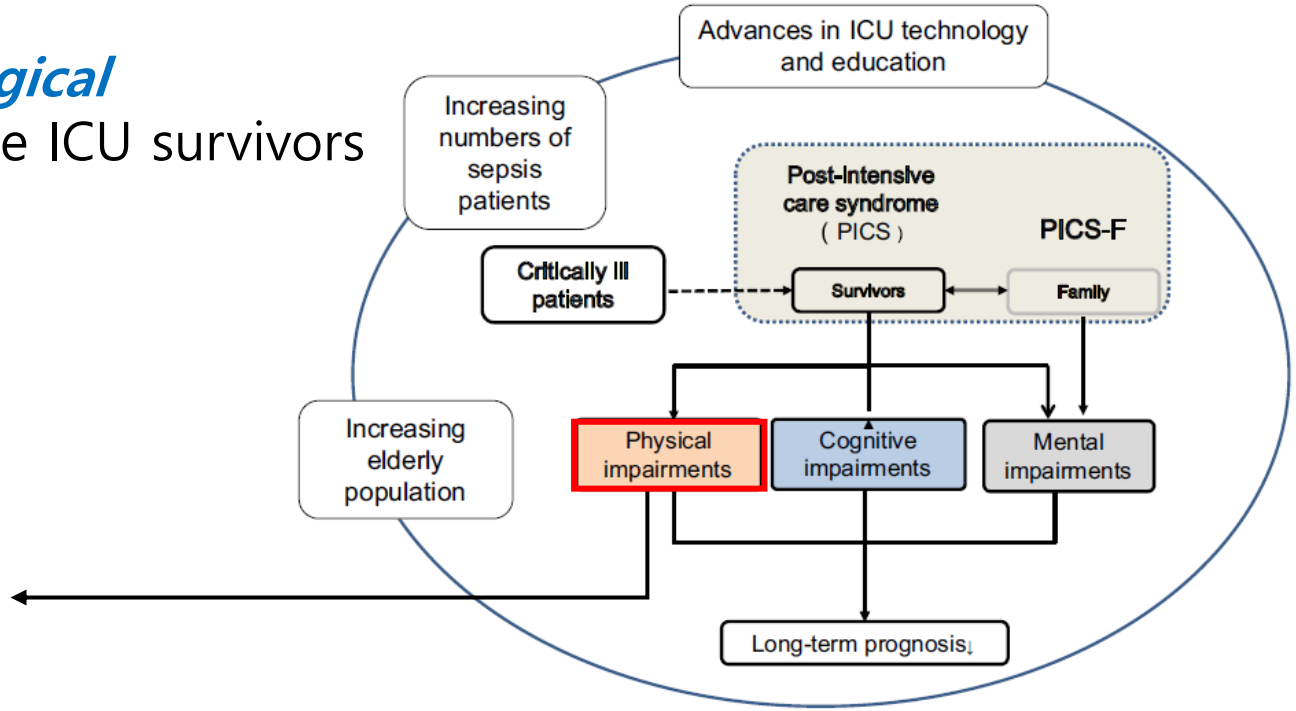



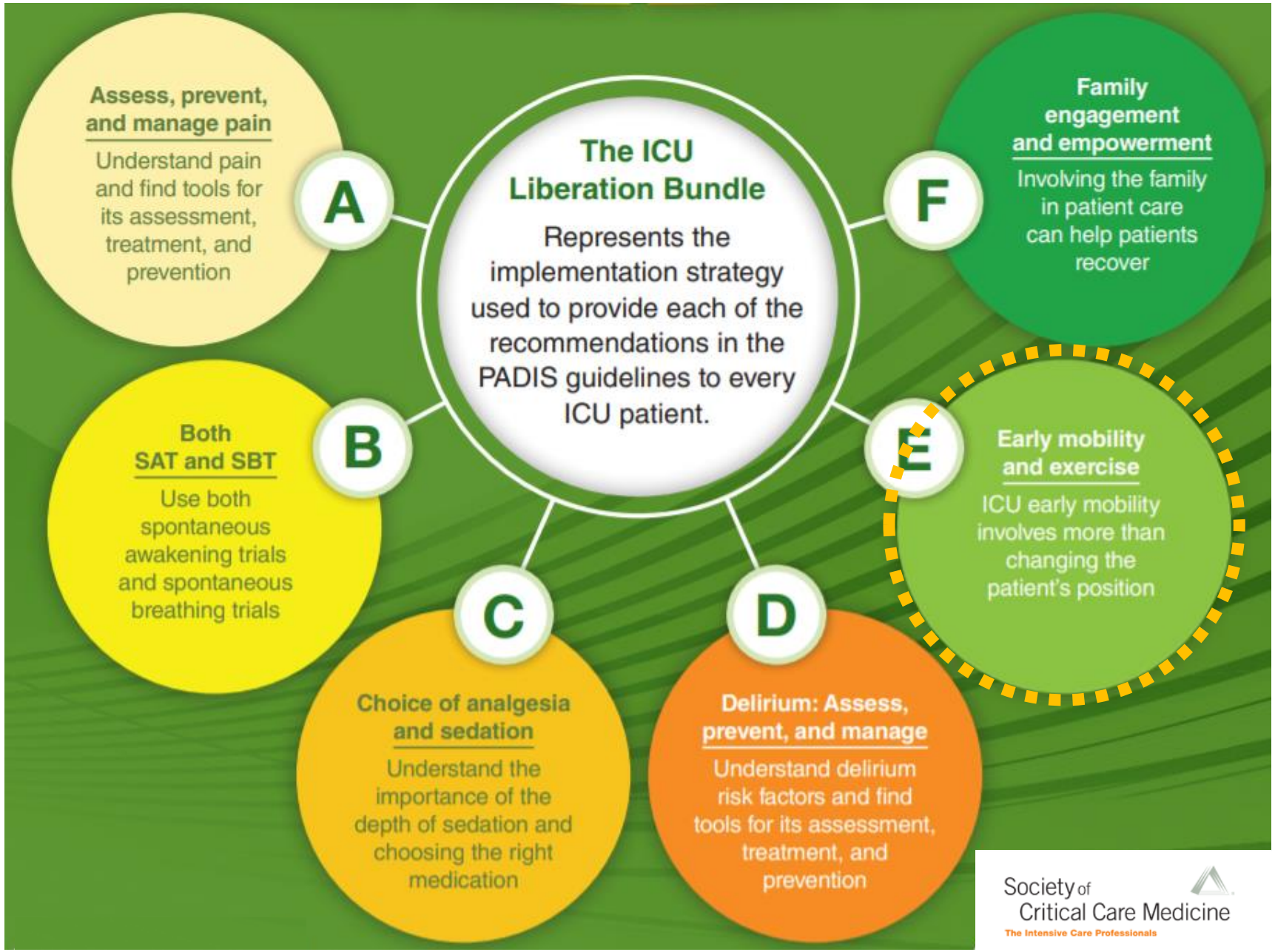

**Fig. 1.** Conceptual framework of post-intensive care syndrome (PICS). ICU, intensive care unit; PICS-F, PICS – family.



Inoue S, et al. **Post-intensive care syndrome: its pathophysiology, prevention, and future directions.** Acute Med Surg 2019;6:233-46.

# Prevention of PICS

- **ABCDEF** bundle




https://www.sccm.org/Clinical-Resources/ICULiberation-Home/ABCDEF-Bundles

Ely EW. **The ABCDEF Bundle: Science and Philosophy of How ICU Liberation Serves Patients and Families**. Crit Care Med 2017;45:321-30.

# Early mobilization in Critically ill patients

- Medical or Medical-surgical ICU ★☆☆
- Neuro ICU ★★☆
- Neuro-trauma ICU ★★★

# Rehabilitation Role's in PNUH Trauma

퇴원
or
전과

재활
치료

입
원

재활
평가

## TICU

ICU rounding
48시간 screening
환자 평가 및 재활 처방
재활치료 모니터링 (TRC)
Missed injury

## GW

GW rounding
전실 후 재평가
Bed side or 치료실 재활
환자 및 보호자 교육

## Pulmonary

PFT, MIP(NIP), MEP,
PCF(PEF), US
(diaphragm, lung)

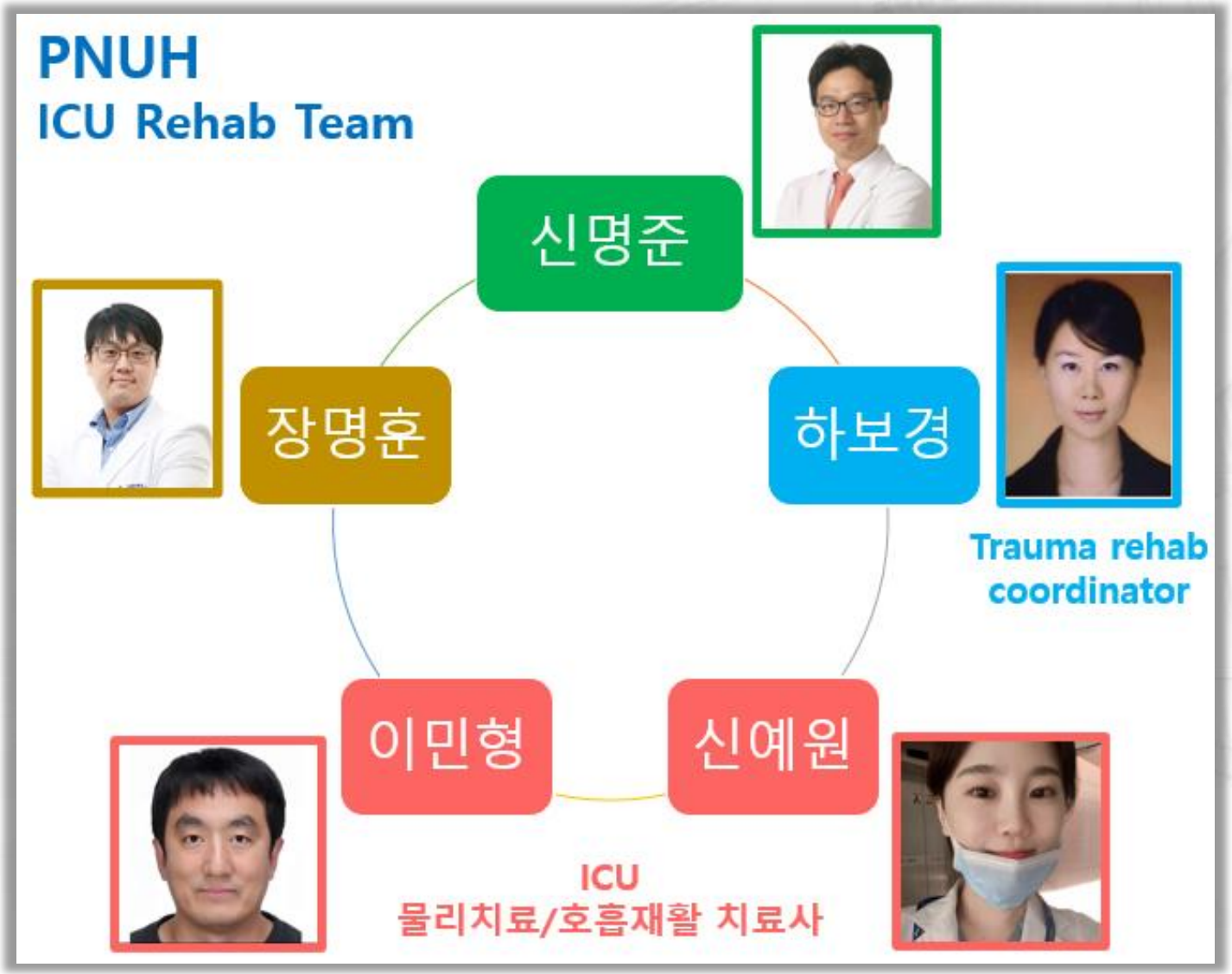
## Neurologic/ Musculoskeletal

Neurological and
Physical exam.,
EMG-NCS, US(MS)

## Dysphagia

FEES, VFSS, GUSS

# Multidisciplinary Team Approach




- **Roles of Rehab. Coordinator**

**1) 의료진 - 팀원 사이 의사소통**

: 치료 내용, 목표, 과정 등에 대해서 정보 공유

**2) 안전사고에 대비한 조치**

: 재활 중 모니터링 및 발관 등 안전사고에 대비

# Safety Criteria

- 조기재활을 안전하게 시작할 수 있는 환자의 심혈관계, 호흡기계, 신경계 등 임상적 지표
- 시작 뿐 아니라 재활치료의 중단이 필요한 임상적 지표
- 기준 지표들은 **환자의 임상적인 증상, 현재 상태, 목표 활동량에 따라서 조절 될 수 있음**

| System | Screening Item | |
|---|---|---|
| Cardiovascular | ☐ SBP < 90mmHg or SBP > 180mmHg<br>☐ MBP < 60mmHg or MBP > 110mmHg<br>☐ HR < 50bpm or HR > 130bpm<br>☐ New or symptomatic arrhythmia, MI<br>☐ PTE(discuss with MD to determine suitability)<br>☐ DVT(may mobilize as tolerated immediately after LMWH is given)<br>☐ Platelet count < 20,000/uL | < Vasoactive agent ><br>: new vasoactive agent, use of three or more agents or frequent increases<br>☐ Dopamine ☐ Norepinephrine<br>☐ Vasopressin ☐ Epinephrine<br>☐ Other : |
| Respiratory | ☐ RR ≤ 5 or RR ≥ 40breaths/min ☐ $SpO_2$ ≤ 88% ☐ $FiO_2$ ≥ 0.6 ☐ PEEP > 10mmHg<br>☐ Airway is not adequately secured | |
| Neurologic | ☐ Severe agitation, stress state ☐ Attention required for increased intraocular pressure<br>☐ ICP ≥ 20mmHg ☐ Unstable spinal injury or lesion ☐ CSF leakage or lumbar drain | |
| Other | ☐ BT ≥ 38°C ☐ Active or uncontrolled bleeding ☐ Unstable fracture ☐ Open abdomen | |
| *the cited values are not absolute criteria for withholding mobilization or chest physiotherapy. It may be modified according to the medical condition of the critically ill patient. | | |

| Stop Criteria | |
|---|---|
| ☐ Abnormalities in the above-mentioned vital signs occur. (If it is not stabilized even after stopping mobilization.) | |
| ☐ Changes in consciousness | ☐ New/symptomatic arrhythmia |
| ☐ Ventilator asynchrony | ☐ Fall |
| ☐ Bleeding | ☐ Medical device removal or malfunction |
| ☐ Distress reported by patient or observed by clinician | |

# Early Mobility Protocol of Trauma ICU (PNUH ver. 1.0)

| Mobility level | Level 1<br>PROM | Level 2<br>AROM | Level 3<br>Sitting or dangling | Level 4<br>Standing | Level 5<br>Walking |
|---|---|---|---|---|---|
| **Level of RASS** | RASS: –5 to -2 | RASS: -2 to +1 | RASS: -1 to +1 | | |
| **Strength criteria** | MRC sum score 〈 36 | | MRC sum score ≧ 36 | | |
| **Mobilization** | ☐ (Semi-)fowler's of bed<br>☐ Position change (lateral to lateral) | ☐ High fowler's of bed (chair position of bed)<br>☐ Rolling / turning<br>☐ Boosting / scooting<br>☐ Lying to sitting<br>☐ Tilt table standing (use if TBI patients) | ☐ Chair position of bed<br>☐ Sitting on edge of the bed<br>☐ Transfer to chair with mechanical lift<br>***gradual withdrawal of assistance*** | ☐ Sit to stand<br>☐ Standing balance<br>☐ Weight shift<br>☐ Side step<br>☐ Transfer to chair<br>☐ Marching in place<br>***with appropriate aids*** | ☐ Gait training<br>☐ Increasing distance & frequency as tolerated<br>***with appropriate aids*** |
| **Exercise program** | ☐ Aerobic Exercise<br>· Passive ergometer (20 RPM)<br>☐ Resistance Exercise<br>· NMES<br>☐ ROM Exercise<br>· Passive ROM<br>· Muscle stretching ex. | **Same as level 1** with more active involvement<br>☐ Aerobic Exercise<br>· Assist & active ergometer<br>☐ Resistance Exercise<br>· Manual or elastic band (U/Ex. and L/Ex.)<br>· Bridge exercise<br>☐ ROM Exercise<br>· Assist & active ROM | **Same as level 2** with more active involvement<br>☐ Aerobic Exercise<br>· Active ergometer<br>· Burn machine<br>· Seated marching<br>☐ Resistance Exercise<br>· Dumbbell<br>· Sand weight (U/Ex. and L/Ex.) | **Same as level 3** with more active involvement<br>☐ Resistance Exercise<br>· Squat<br>· Heel raise<br>***with appropriate aids*** | **Same as level 4** with more active involvement<br>☐ Aerobic Exercise<br>· Step box (+/- metronome) |
| **Pulmonary rehabilitation** | ☐ Air stacking<br>☐ Hyperinflation<br>☐ MIE<br>☐ Postural drainage<br>☐ High frequency oscillation (HFO)<br>☐ Percussion | **Same as level 1**<br>☐ Diaphragmatic breathing<br>☐ Deep breathing: thoracic stretching, incentive spirometer<br>☐ Airway clearance: splint coughing, huffing & coughing, acapella<br>☐ Respiratory muscle training: threshold IMT/PEP<br>☐ Active cycle of breathing technique (ACBT) | | | |
| **Swallowing ex.** | ☐ NMES (submental placement) | **Same as level 1**<br>☐ shaker exercise, effortful swallowing, Mendelsohn maneuver, jaw open/close | | | |

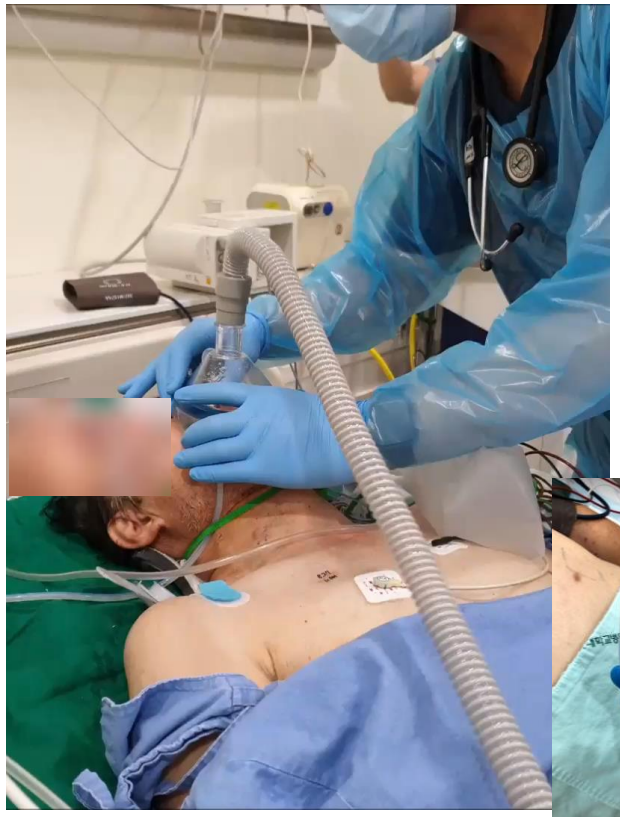
# Early mobilization

# Chest physiotherapy

Vibration

Percussion

Hyperinflation



MIE

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# Neuromuscular Electrical Stimulation

## Basic Concepts

# Muscular weakness and/or wasting in ICU

- **ICU-AW**
  - 'critical illness myopathy', 'critical illness polyneuropathy', and 'critical illness polyneuromyopathy'
  - Medical Research Council-Sum Score (MRS-SS), EMG-NCS

  - **Mechanical ventilator**
    - 5-7 days: 26% to 65%
    - >10 days: up to 67%
  - **ICU stay**
    - at least 24h: 11%
    - 7-10 days: 24-55%
- **"Sepsis + Multi-organ system failure(MOF)"**
  → nearly 100%

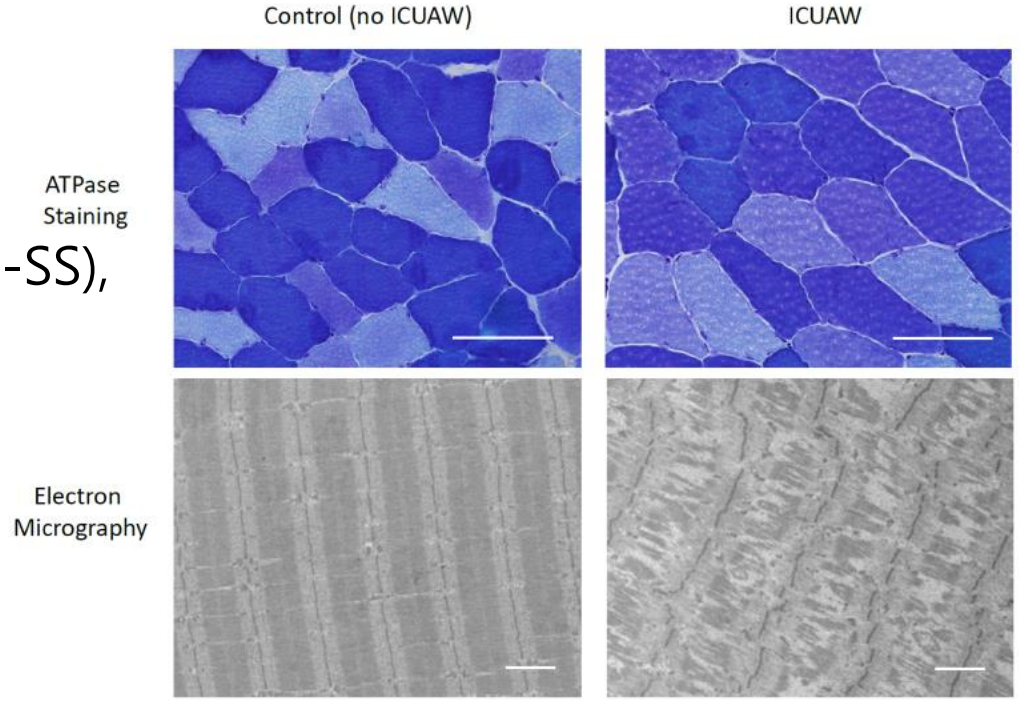



**Figure 2** ATPase stained histologic sections and representative electron micrographs of critically ill patients with and without intensive care unit acquired weakness. Fiber types are differentiated by color (dark blue = I, intermediate blue = IIb, light blue = IIa). Scale bar indicates 100 μm (ATPase stained histologic sections) and 2 μm (electron micrographs).

- type Ⅰ fibers → type Ⅱx fibers
- myosin filaments loss
- sarcomere structural damage



Schefold JC, et al. **Muscular weakness and muscle wasting in the critically ill.** J Cachexia Sarcopenia Muscle 2020;11:1399-412.
Hermans G, Van den Berghe G. **Clinical review: intensive care unit acquired weakness.** Critical care (London, England) 2015;19:274.

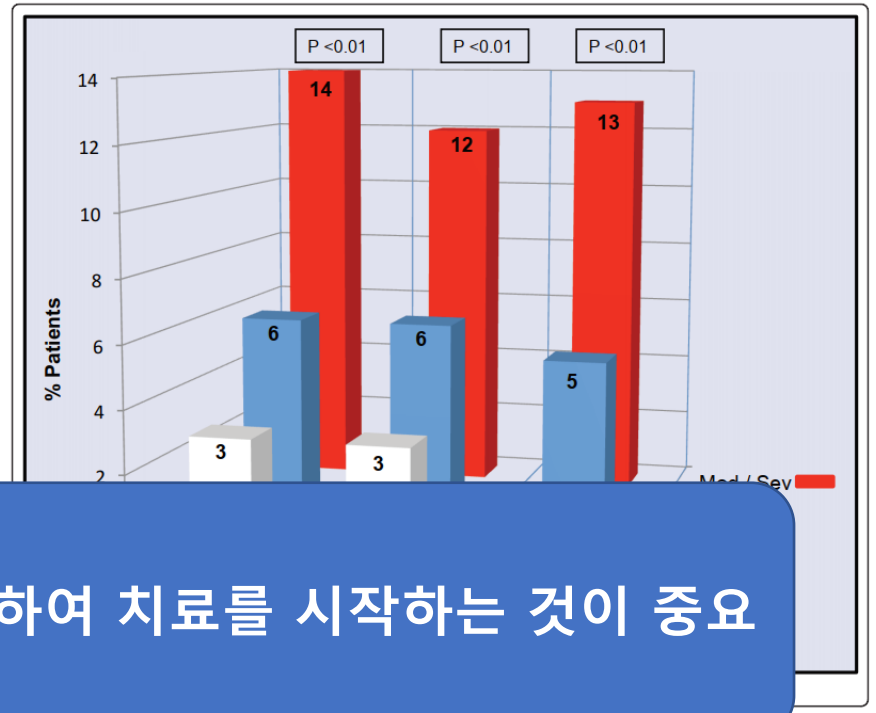
# Muscular weakness and/or wasting in ICU

- **Ventilator induced diaphragmatic dysfunction (VIDD)**
  - up to 80% of ICU-AW
  - Ultrasound, inspiratory muscle force(NIF, MIP), phrenic nerve conduction study

- **Dysphagia**
  - 3 to 62%
    (12.4% in a general ICU, 18% in emergency admissions to the ICU)
  - persistent dysphagia

    at **ICU discharge > 80%**

    at **hospital discharge > 60%**



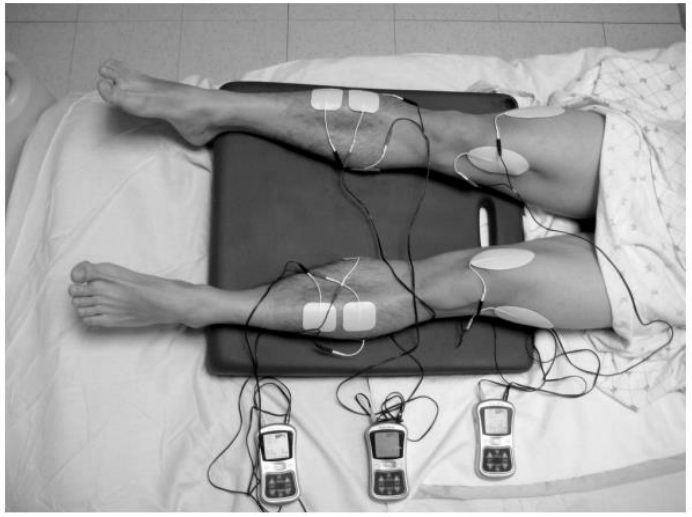

**ICU-AW, VIDD, dysphagia는 ICU에서 예방 및 조기 진단하여 치료를 시작하는 것이 중요**



Macht M, et al. **Postextubation dysphagia is persistent and associated with poor outcomes in survivors of critical illness.** Crit Care 2011;15:R231.

# Neuromuscular electrical stimulation (NMES)

- **Therapeutic NMES**
  - ✓Repeated application of **current** to produce **contraction** of innervated muscle by **depolarizing local motor nerves.** Repeated application may produce effects—for example, **muscle strengthening.**



- **Functional NMES (FES)**
  - ✓The use of electrical **current** to directly enable a **functional movement.** (such as U/Es for **activities of daily living (ADLs)** or L/Es for **gait**)

# NMES

- **Motor point**
  - the **smallest amount of current** is required to produce **muscle contraction**
  - optimal sites for NMES to **maximize the evoked tension** and to **minimize pain**

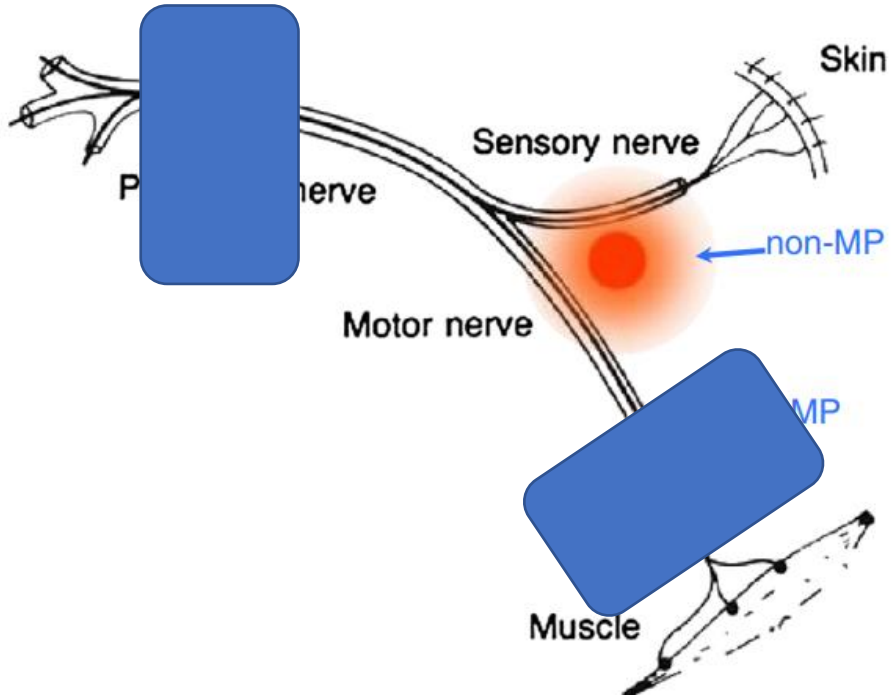



FIGURE 46.3 **Schematic representation of a mixed peripheral nerve with different stimulation sites.** The figure shows the selective activation of distal motor axons when stimulation via the motor point is provided (motor point stimulation). Stimulation on other sites (non–motor point stimulation) may require more current to reach the motor nerve branch and is more likely to concurrently excite sensory fibers conveying pain.



Gobbo M, Maffiuletti NA, Orizio C, Minetto MA. **Muscle motor point identification is essential for optimizing neuromuscular electrical stimulation use.** Journal of NeuroEngineering and Rehabilitation 2014;11:17.

# NMES

- activation threshold of the **alpha motor neuron axons**
  → contraction of muscle fibers (less excitable than motor nerve)
- **nerve endings more effectively** than the muscle
- only in the case of **denervated muscles** a direct muscle stimulation may occur

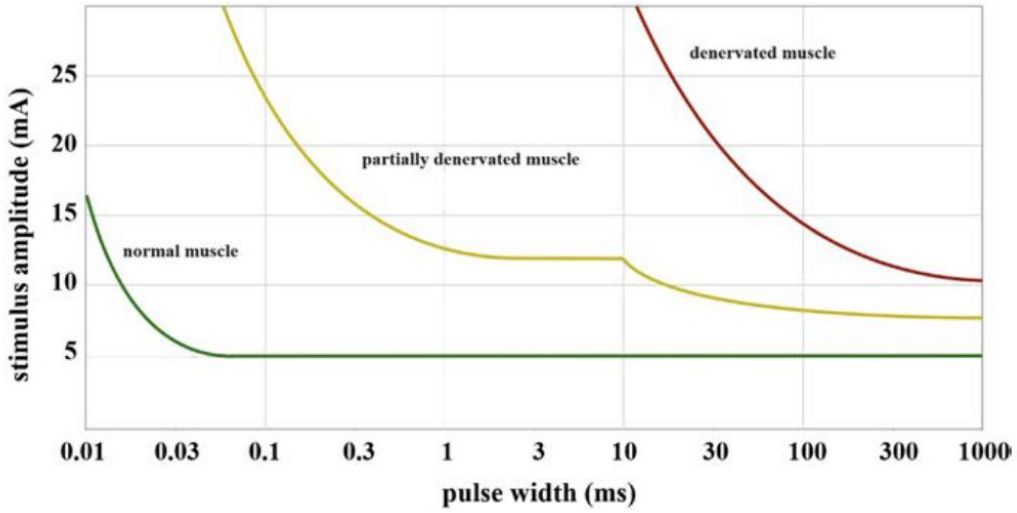
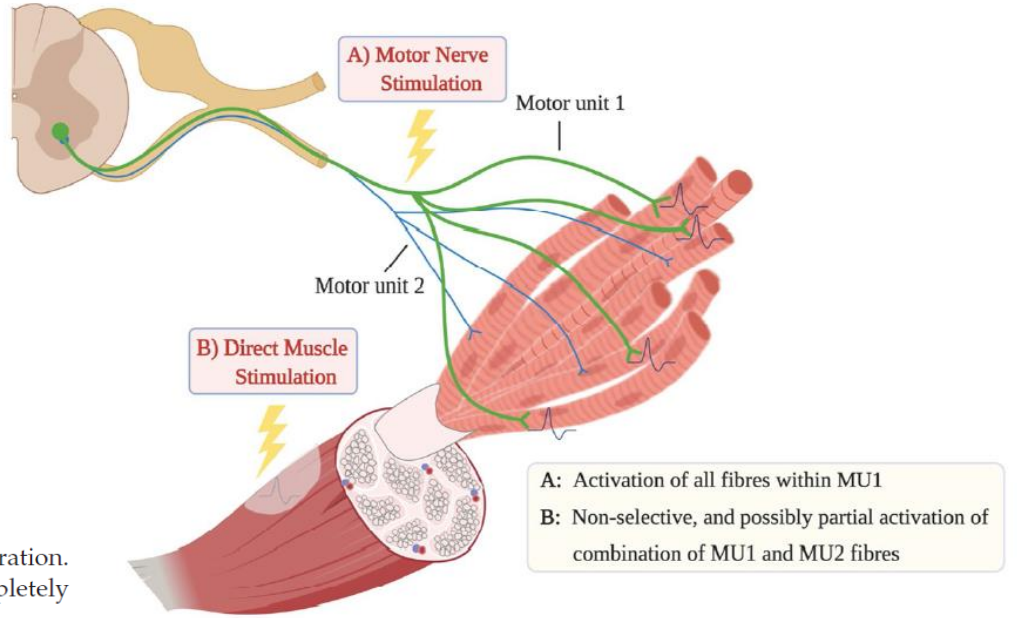



FIGURE 46.2 **Strength–duration curves.** The curves are obtained by plotting the relationship between pulse amplitude and pulse duration. The graphical representation allows to differentiate normally innervated muscles, partially denervated (or reinnervated) muscles, and completely denervated muscles.





Latronico N, Fagoni N, Gobbo M. **Chapter 46 - Neuromuscular Electrical Stimulation in Critically Ill Patients.** In: Prabhakar H, editor. **Essentials of Neuroanesthesia.** Academic Press; 2017. p 771-81.

Guo Y, E Phillips B, Atherton PJ, Piasecki M. **Molecular and neural adaptations to neuromuscular electrical stimulation; Implications for ageing muscle.** Mechanisms of Ageing and Development 2021;193:111402.

# NMES

- **Voluntary contractions**
  - a temporally **asynchronous**
  - spatially diffused pattern from **slow-twitch muscle fibers** to **fast-twitch muscle fibers**
  - from **small MUs** to **larger ones**

- **NMES**
  - temporally **synchronized**, spatially fixed, and **non-selective**
  - early recruitment of **a large number of fatigable fast-twitch fibers**

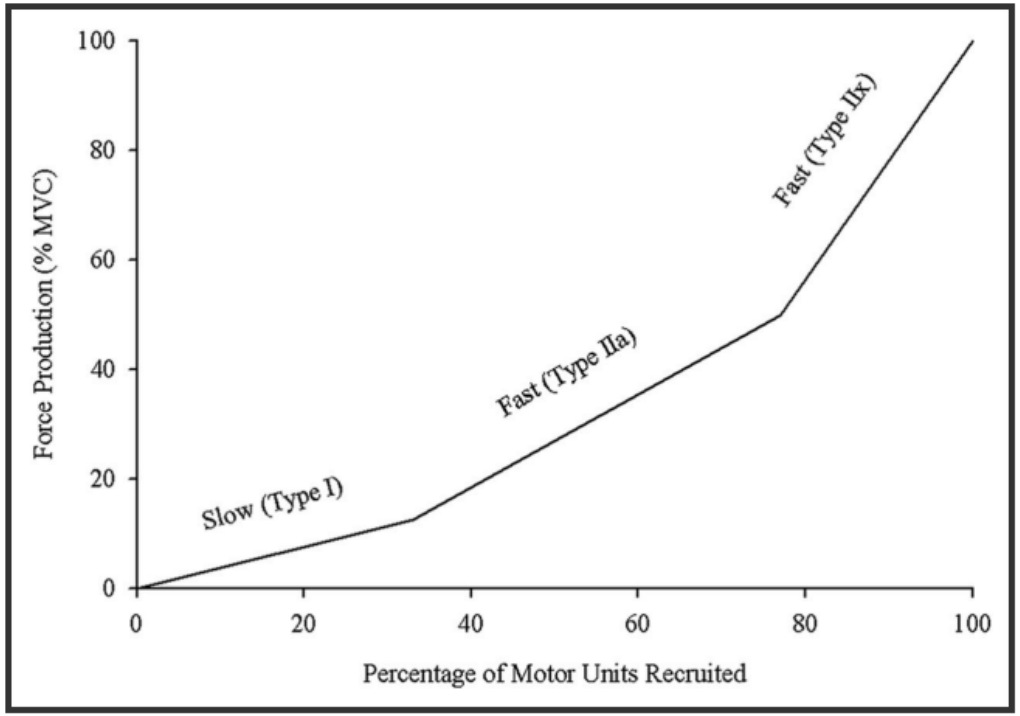
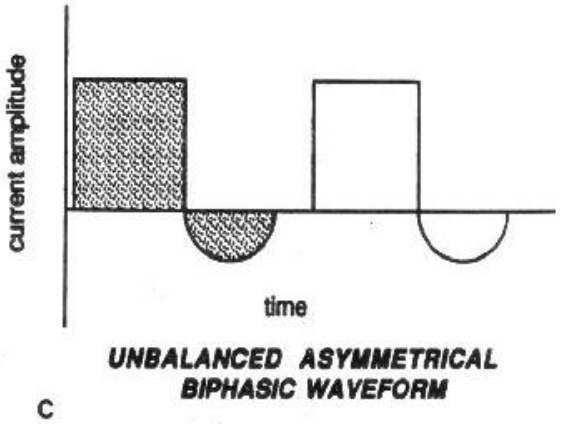



**Figure 1.**
Graphic representation of the orderly recruitment of motor units during voluntary activation of skeletal muscle as described by Henneman et al.[9] Slow (type I), Fast (type IIa), and Fast (type IIb) motor units are represented. MVC=maximal voluntary contraction.

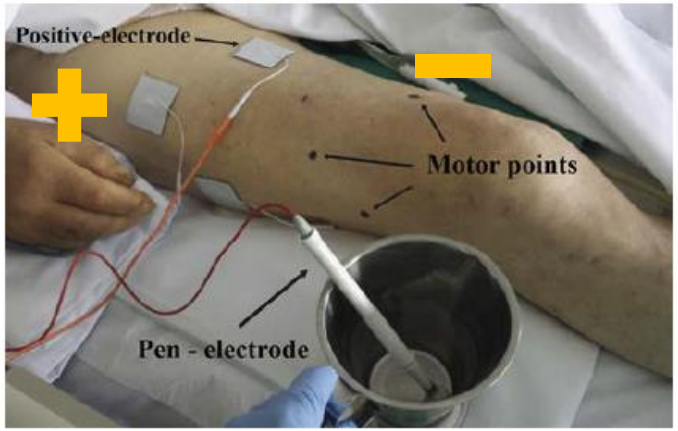


Gregory C, Bickel C. **Recruitment Patterns in Human Skeletal Muscle During Electrical Stimulation.** Physical therapy 2005;85:358-64.

# Electrode - placement




- **monopolar electrode**
  - anode (+): proximally on the target muscle, over the innervating nerve
  - cathode (-): on the motor point of the target muscle
  - the waveform produces **more current flow** in either the positive or the negative direction (eg. biphasic **asymmetrical** unbalanced pulsed current)
- **bipolar electrode**
  - anode and cathode: proximal and distal ends of the muscles (or muscle group)
  - the waveform produces **equal current flow** in positive and negative directions



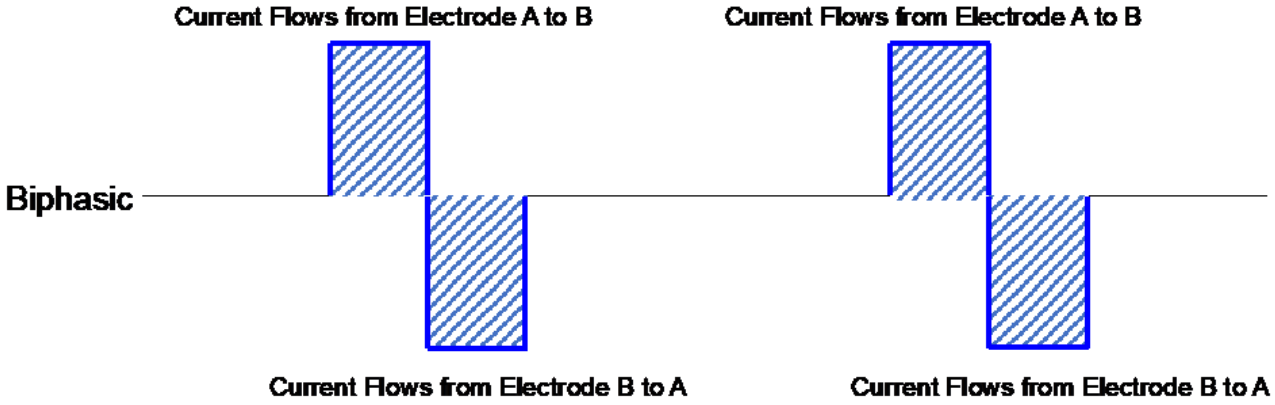
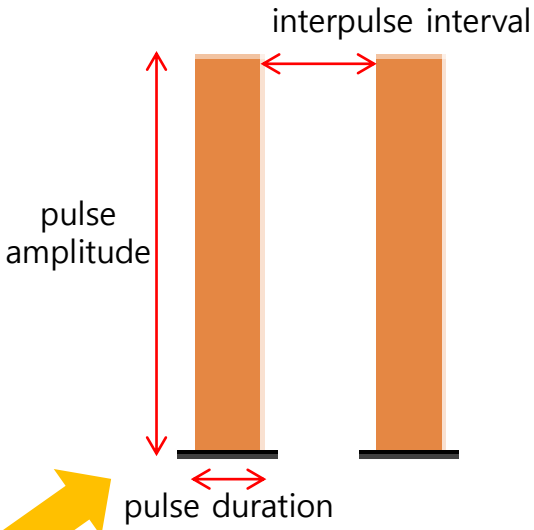



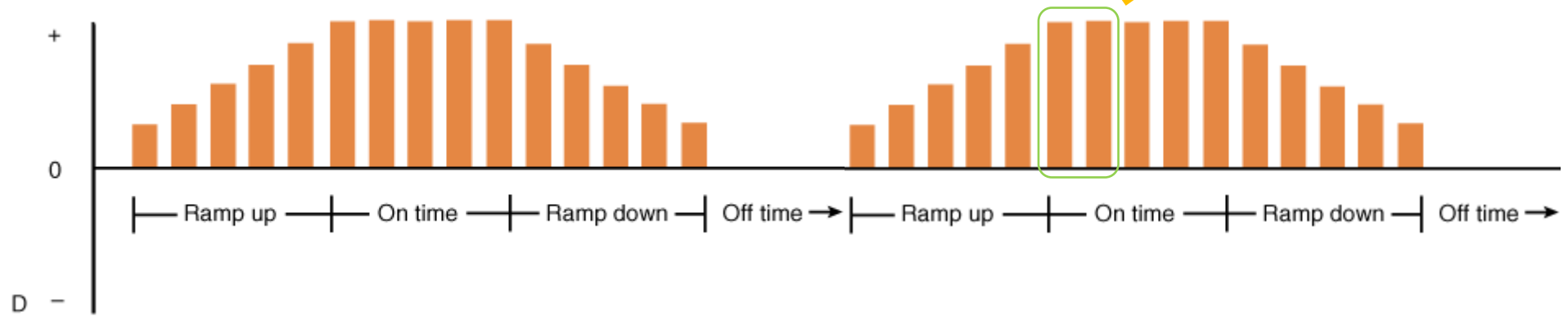

FIGURE 46.1 **Transcutaneous neuromuscular electrical stimulation.** The figure shows a commercially available pen-electrode (cathode) used for motor point identification. Self-adhesive pad electrodes (anodes) are placed proximally with respect to each muscle belly of the target muscles (vastus lateralis, rectus femoris, vastus medialis). The identified motor points for each muscle are highlighted.

Nussbaum EL, et al. **Neuromuscular Electrical Stimulation for Treatment of Muscle Impairment: Critical Review and Recommendations for Clinical Practice.** Physiotherapy Canada. Physiotherapie Canada 2017;69:1-76.

# NMES parameters

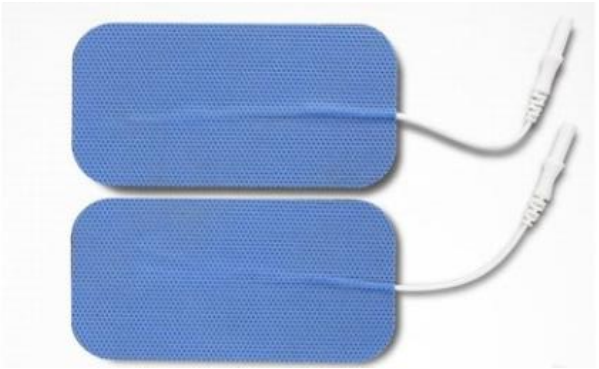
- **frequency (Hz):** the number of pulses in 1 second (30~70Hz)
- **pulse duration (pulse width, μs):** the time elapsed from when the current leaves the isoelectric line until it returns to baseline. (200~400μs)
- **pulse amplitude(intensity, mA or mV):** the magnitude of the current(or voltage) deviation from isoelectric line (< 50mA)
- **ON time(s):** the time over which a series of pulses is delivered
- **OFF time(s):** the time over which no current is delivered
- **ON:OFF ratio:** higher ratio → less muscle fatigue (1:2~1:8)
- **ramp-up/ramp-down time(s):** commonly 1-2 seconds

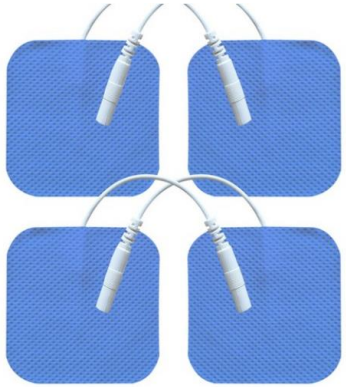


# Electrode - size

- target muscle size, depth, spread of current를 고려
- **lager** electrode (e.g., **5 x 10 cm**, 10 x 10 cm, or larger)
  - deeper current penetration, more comfortable (current density ↓)
  - larger muscles (e.g., quadriceps, hamstrings, lumbar spine)
- **smaller** electrode (e.g., **5 x 5 cm square** or 5 cm in diameter)
  - less comfortable (current density ↑), burn risk ↑
  - isolating specific muscles, medium-sized muscles (e.g., forearm, calf, shoulder girdle)







Nussbaum EL, et al. **Neuromuscular Electrical Stimulation for Treatment of Muscle Impairment: Critical Review and Recommendations for Clinical Practice.** Physiotherapy Canada. Physiotherapie Canada 2017;69:1-76.

# Electrode - placement

- parallel to the longitudinal direction of the muscle fibers
- cleaning of the skin
  → to reduce resistance to current flow
- if the desired muscle action is not elicited → move the electrodes

| Electrode | Placement Site Instructions | Diagram |
|---|---|---|
| Posterior Deltoid | • Use 2"X2" electrodes.<br>• Landmark the AC joint.<br>• One electrode goes to the back of this joint with the leads facing down.<br>• The other electrode is placed below the first electrode and slightly medial with one finger width between the first electrode |  |
| Anterior Deltoid | • Use 2" X 2" electrodes.<br>• Landmark the AC joint.<br>• One electrode goes to the front of the AC joint with the leads facing down.<br>• The other electrode goes below the first one with a minimum |  |

| Electrode | Placement Site Instructions | Diagram |
|---|---|---|
| Biceps | • Place hand wrist up with elbow bent.<br>• Electrodes are placed horizontally on the arm.<br>• Place one electrode just above the bend of the elbow with the leads facing the inside of the body.<br>• Place the second electrode a minimum of two finger widths above the first electrode. |  |
| Triceps | • Find the muscle belly.<br>• Electrodes are placed horizontally on the arm.<br>• One electrode is placed at the proximal portion (top most).<br>• One electrode is placed at the distal (bottom most) portion of the tricep. |  |

# Electrode - placement

| Electrode | Placement Site Instructions | Diagram |
|---|---|---|
| To open the hand | • Posterior side of forearm.<br>• Place one electrode below the elbow bone.<br>• Leads facing down.<br>• Place the second electrode just above the wrist joint. |  |
| Wrist Flexion | • Anterior side of forearm.<br>• Place one electrode on the medial side of the forearm with the lead down.<br>• Place the second electrode two finger spaces above the wrist. |  |

| Electrode | Placement Site Instructions | Diagram |
|---|---|---|
| Abdominals | • Use 2"x3" electrodes<br>• One electrode goes below the bottom rib.<br>• The Second electrode is placed underneath the first electrode. Landmark position by using the ASIS.<br>• Make sure not to place the electrode over folded skin. |  |
| Erector Spinae | • Electrodes are placed vertically<br>• Landmark the top of the hip bone and place the first electrode here<br>• The second electrode is placed two fingers above the first electrode |  |

# Electrode - placement

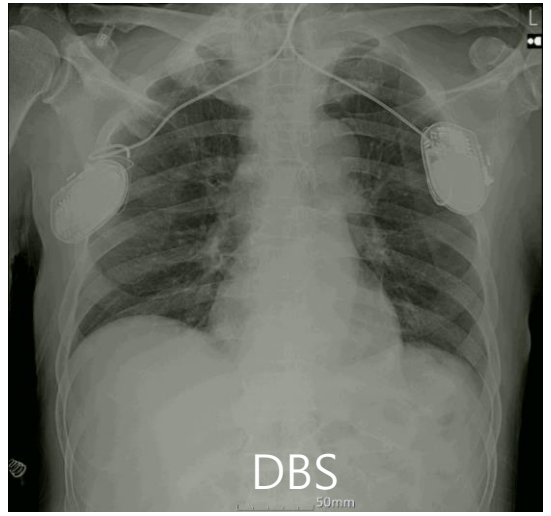
| Electrode | Placement Site Instructions | Diagram |
|---|---|---|
| Quadriceps | • The first electrode is placed horizontally two finger widths above the knee<br>• Make sure leads are facing the midline of the body (with some exceptions)<br>• The second electrode is placed a minimum of two finger widths apart centred in the quadriceps belly<br>• Use the largest electrode size for that individual |  |
| Hamstrings | • These electrodes are placed directly under the quadriceps's electrodes centered on hamstrings<br>• Leads are facing the midline of the body(with some exceptions |  |
| Tibialis Anterior | • Landmark this muscle by locating the tibial tuberosity (bony protrusion just below your knee) and the fibular head (bony protrusion lateral side of knee) and moving your fingers down and together until you feel the muscle belly. At this point place the first electrode vertically.<br>• Follow the muscle belly down and place the second electrode about 2/3 of the way down the shin with the leads facing toward the midline of the body |  |
| Gastrocnemius and Soleus | • Place first electrode horizontally just below the knee.<br>• Place second electrode minimum two finger widths below first electrode in the bulk belly of the soleus muscle.<br>• Alternate placement for gastrocnemius muscle= vertically placed electrodes on back of left leg (see diagram). |  |

# Electrode - placement

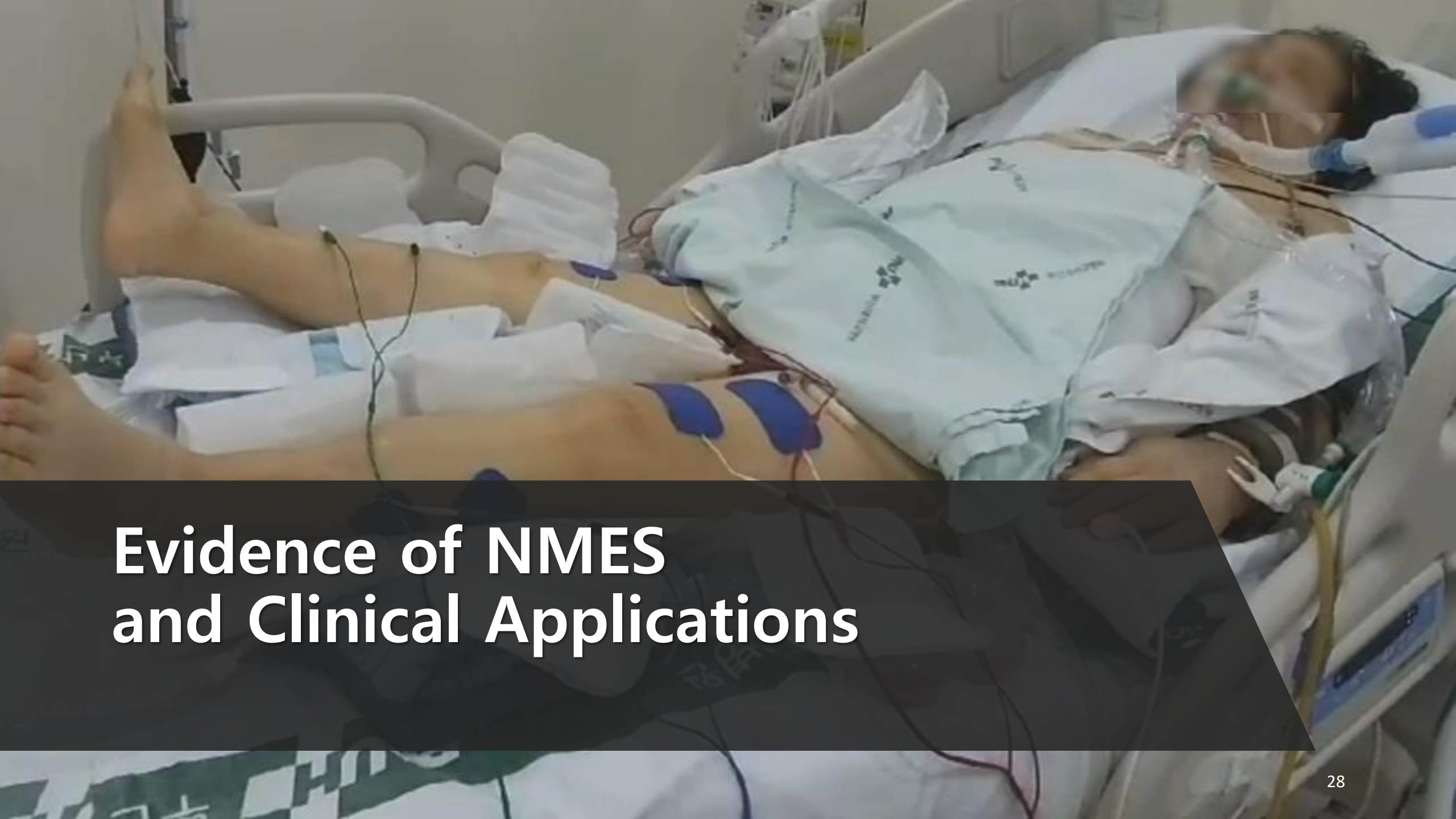
- https://www.axelgaard.com/Education

- **Complication**
  - skin response to NMES
    - redness, local edema, skin etching, skin injury d/t electrodes
    - unusual in awake patients

- **Contraindication**




1) interference with **electromedical devices**
   : internal pacemaker, intracranial electrical stimulator, radiofrequency stimulators(spinal cord stimulators)
2) interference with **systemic disease**
   : spastic paralysis, epilepsy (not adequately compensated)
3) local **pathological processes**
   : acute phlebitis, areas of damaged or irritated skin
   : near the carotid sinus, chest region in pts with arrhythmias & CHF, abdominal application in pregnancy



# Evidence of NMES and Clinical Applications

# NMES devices


**특징**

▸ Easy
- 2채널 방식
- 3단계만으로 전기 자극을 시작할 수 있어 쉽게 사용할 수 있습니다.

▸ Economic
- 근육 훈련과 통증 완화 기능이 함께 내장되어 있어 경제적입니다.

▸ Efficient
- 자극 부위별 최적의 프로그램이 내장되어 있어 효과적입니다.


• 규격

출 력 : Constant current, Maximum output 100mA
펄스파형 : Monophasic, Biphasic pulse
펄스 주파수 : 1–99Hz
펄 스 폭 : 20–700us 선을
웜 업 : 0–59분
쿨 다 운 : 0–59분
램 업 : 0–59분
램 다 운 : 0–9.9초
Burst On : 0.1 – 9.9초 (0.1초 단위), 10 – 59초 (1초 단위)
Burst Off : 0.1 – 9.9초 (0.1초 단위), 10 – 59초 (1초 단위)
최대 임피던스 범위 : 0–0.5kΩ
환자 허용 수준 : 0–100mA
최대 출력 : 0–100mA
펄스간 지연 시간 : 20~990us
Hand / Foot switch 지원

- marketed electrical simulators
  : preprogrammed protocols
  : protocol would not be updated after purchase

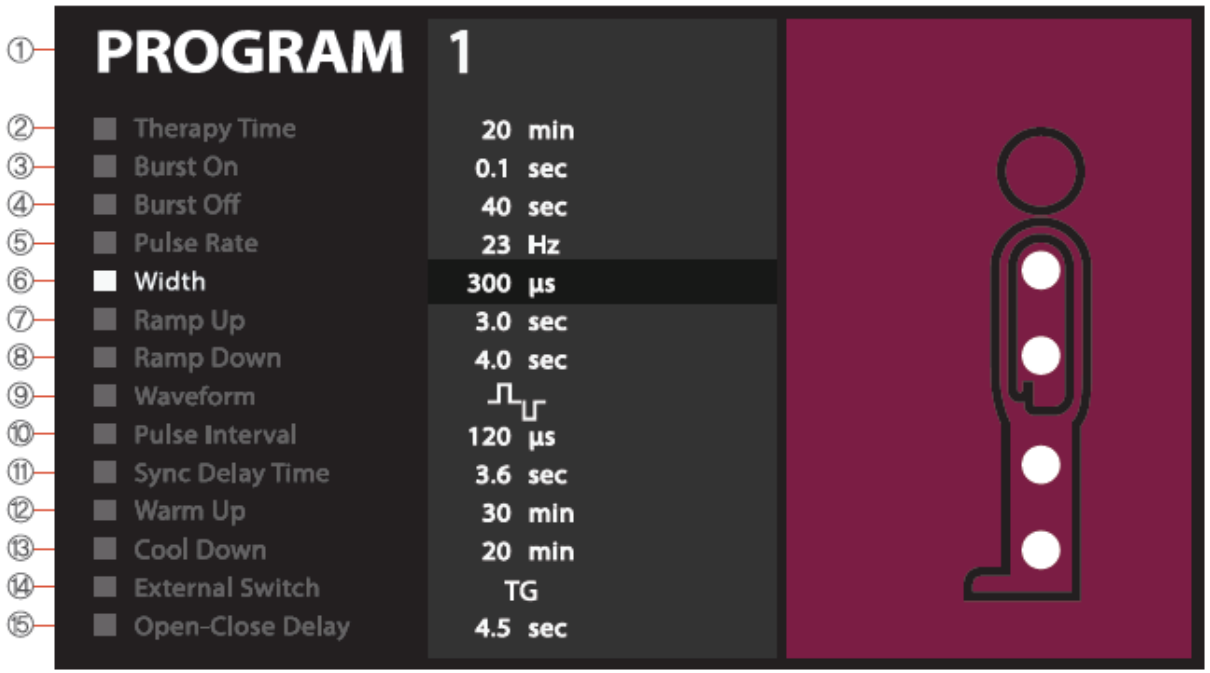
- stimulation amplitude, electrode placement 만 조정
  → NMES를 잘 이해하지 못해도 적용 가능.

- To achieve **desired clinical outcomes**, it is necessary to be able to **customize and modify** treatment based on the patient's characteristics.

# NMES devices

- manual setting
- + TENS






① PROGRAM : PROGRAM1, PROGRAM2 2가지 저장 번호를 나타냄

② Therapy Time : (0 ~ 99 Min / 1분 단위)

③ Burst On : (0.1 ~ 9.9 sec / 0.1 sec 단위), (10 ~ 59 sec / 1 sec 단위)

④ Burst Off : (0.1 ~ 9.9 sec / 0.1 sec 단위), (10 ~ 59 sec / 1 sec 단위)

⑤ Pulse Rate : (1 ~ 99 Hz / 1 Hz 단위)

⑥ Width : (20 ~ 700 µs / 10 µs 단위)

⑦ Ramp Up : (0 ~ 9.9 sec / 0.1 sec 단위)

⑧ Ramp Down : (0 ~ 9.9 sec / 0.1 sec 단위)

⑨ Waveform : (Biphasic, Monophasic)

: Biphasic , : Monophasic

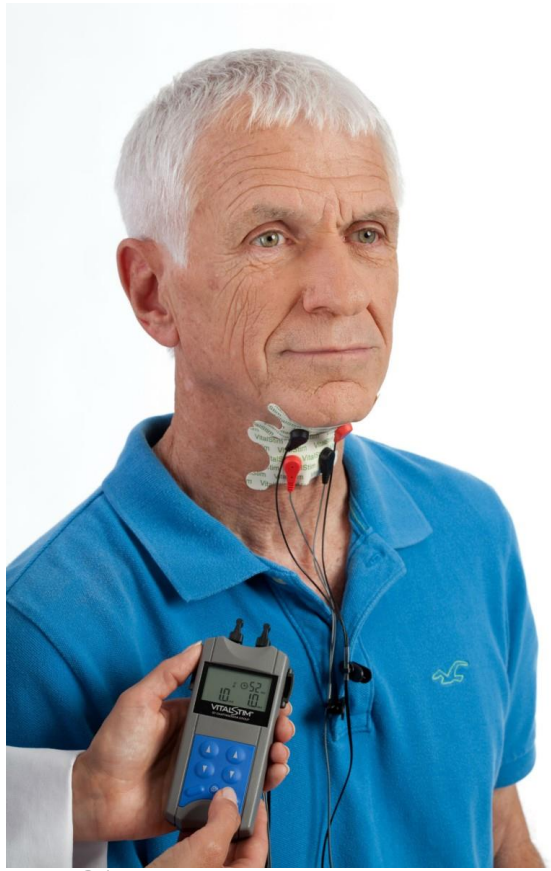
⑩ Pulse Interval : (20 ~ 990 µs / 10 µs 단위)

⑪ SyncDelay Time : (0 ~ 9.9 sec / 0.1 sec 단위), (10 ~ 59 sec / 1 sec 단위)

⑫ Warm Up : (0 ~ 59 min / 1 min 단위)

⑬ Cool Down : (0 ~ 59 min / 1 min 단위)

# NMES devices for dysphagia



| |  VitalStim Plus® |  Aspire² |  Unity™ |  Ampcare |  eSwallow |
|---|---|---|---|---|---|
| | $3400.00 DEVICE ONLY / $4450.00 DEVICE + COURSES 1 and 2 | $1381.00 DEVICE ONLY / $1776.00 DEVICE + COURSE | $888.00 DEVICE ONLY / $1183.00 DEVICE + COURSE | $599.00 DEVICE ONLY / $649.00 DEVICE + COURSE | $899.00 DEVICE ONLY / $1178.00 DEVICE + COURSE + SELF STUDY |
| hannels of stimulation | 4 | 1 | 2 | 2 | 2 |
| neuromuscular electrical stimulation | yes | yes | yes | yes | yes |
| ace electromyography | yes | yes | no | no | no |
| sEMG triggered stimulation | yes | yes | no | no | no |
| rechargeable | yes | yes | no | no | no |
| NMES programs | 1 VitalStim® protocol customizable programs | 4 Guardian® protocols 1 customizable program | 6 Guardian® protocols 1 alternative protocol | 3 Ampcare protocols | 1 eSwallow protocol |

# NMES devices for dysphagia


**개인용 치료기기**

- NMES (strength, dysphagia)
- TENS

- Low price, unknown parameter




# Safety

- **safe** for critically ill patients
- should be applied by **well trained professionals**
- proper **evidence-based parameters**

**Table 2 -** Description of selected studies

| Study | Groups | Patients (n) | Main objective of study | Intervention parameters | Outcome for safety |
|---|---|---|---|---|---|
| Rodriguez et al.[23] | G1: NMES on one side of the body (contralateral side as control) | Total: 16 | To assess the effects of NMES on the muscle strength of patients with sepsis under IMV | Frequency 100Hz; pulse duration 300$\mu$s; amplitude 20 - 200v; biphasic impulse; intensity controlled by visible or palpable contraction; stimulus applied twice per day for 30 minutes<br>Brachial biceps and quadriceps vastus medialis muscles<br>Application from IMV day 2 until extubation | Adverse effects: superficial burn in a single patient after the first NMES session due to improper configuration |
| Abu-Khaber et al.[25] | G1: conventional treatment<br>G2: conventional treatment + NMES | Total: 80<br>G1: 40<br>G2: 40 | To assess the effects of NMES on the peripheral muscles of critically ill patients | Frequency 50Hz; pulse duration 200$\mu$s; biphasic symmetrical impulse; duration 15 seconds (1 second rise and 1 second fall); intensity controlled by visible or palpable contraction; stimulus applied once per day for 60 minutes<br>Bilateral quadriceps<br>Application from IMV day 2 to ICU discharge | Adverse effects: six patients (15%) reported a prickling sensation, which was not clinically significant |
| Akar et al.[26] | G1: active mobilization + NMES<br>G2: NMES<br>G3: active mobilization | Total: 30<br>G1: 10<br>G2: 10<br>G3: 10 | To compare the efficacy of active mobilization, active mobilization + NMES and NMES alone on muscles, ventilation weaning and NMES response to inflammation among critically ill patients with COPD | Frequency 50Hz; amplitude 20mA and 25mA; symmetrical biphasic square waves; duration 6 seconds (1.5 second rise and 0.75 second fall); stimulus applied five times per week<br>Bilateral deltoid and quadriceps<br>Application from IMV day 2 to ICU discharge | Hemodynamic variables: HR significantly decreased in G2; no changes in RR before or after intervention in any group |
| Stefanou et al.[27] | G1: high frequency<br>G2: medium frequency | Total: 36<br>G1: 18<br>G2: 18 | To investigate the effects of NMES on the mobilization of endothelial progenitor cells among critically ill patients with sepsis | G1: frequency 75Hz, 6 seconds on and 21 seconds off; G2: frequency 45Hz, 5 seconds on and 12 seconds off; biphasic impulse and pulse width 400$\mu$s; intensity defined as the maximum tolerated<br>One single 40-minute session<br>Vastus lateralis and peroneus longus | Hemodynamic variables: slight increase of HR and RR; MAP remained the same in both groups. Slight increase in blood lactate in both groups |

NMES - neuromuscular electrical stimulation; G - group; IMV - invasive mechanical ventilation; ICU - intensive care unit; COPD - chronic obstructive pulmonary disease; HR - heart rate; RR - respiratory rate; MAP - mean arterial pressure



Sachetti A, Carpes MF, Dias AS, Sbruzzi G. **Safety of neuromuscular electrical stimulation among critically ill patients: systematic review**. Rev Bras Ter Intensiva 2018;30:219-25.

# NMES in ICU

- prevention of **atrophy**
  - type 1 and type 2 muscle fiber
- improvement of **skeletal muscle weakness**
  - the synthesis of muscle proteins ↑
  - muscle microcirculation ↑
- prevention of **shoulder subluxation**

- **non-invasive**
- does not require **patients' cooperation** or stable **cardiac or respiratory function**



Maffiuletti NA, Roig M, Karatzanos E, Nanas S. **Neuromuscular electrical stimulation for preventing skeletal-muscle weakness and wasting in critically ill patients: a systematic review**. BMC medicine 2013;11:137-.

# Muscle strength

Contents lists available at ScienceDirect

Australian Critical Care

journal homepage: www.elsevier.com/locate/aucc

Review paper

Effects of neuromuscular electrical stimulation in critically ill patients: A systematic review and meta-analysis of randomised controlled trials

- 6 RCTs, 718 patients
- medial or surgical ICU
- mean age 60 ± 15.2y, (male 60.6%)
- **'NMES only' vs 'NMES + early mobilization/exercise'**
- **no significant effects:** muscle strength, ICU mortality, duration of MV, ICU length of stay

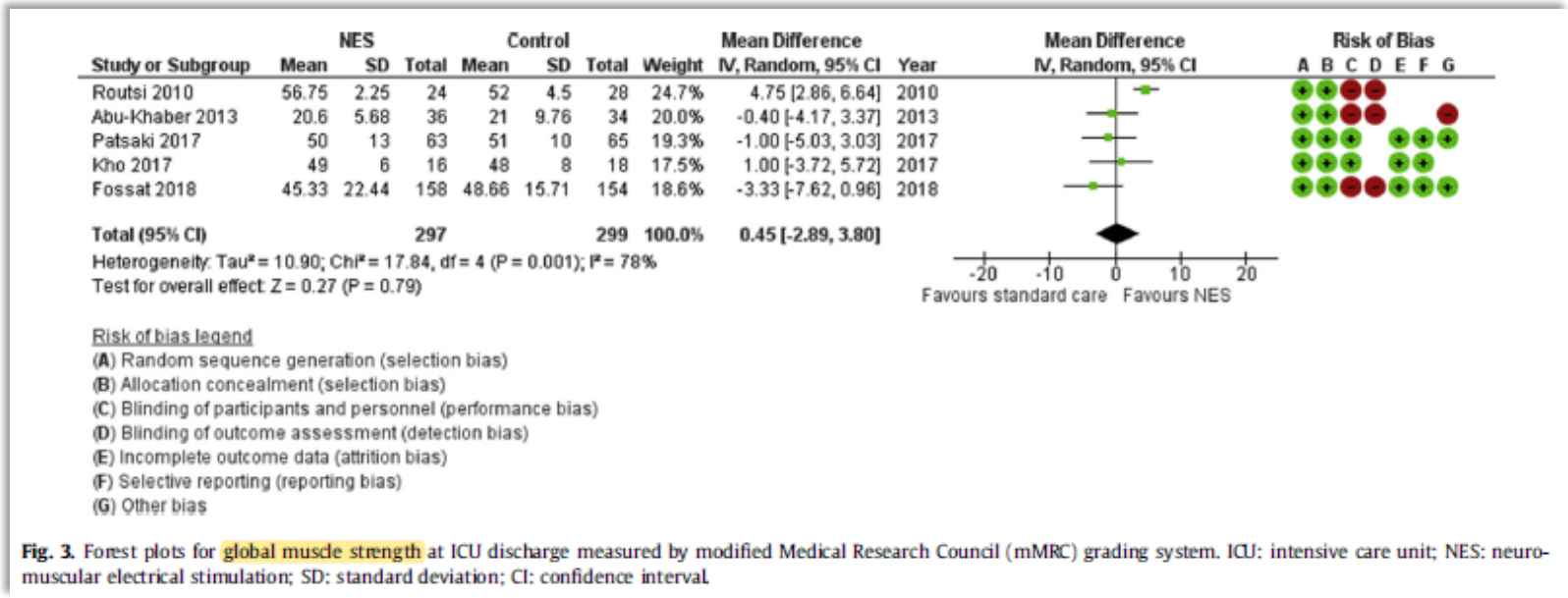



**Fig. 3.** Forest plots for global muscle strength at ICU discharge measured by modified Medical Research Council (mMRC) grading system. ICU: intensive care unit; NES: neuromuscular electrical stimulation; SD: standard deviation; CI: confidence interval.

# Muscle strength

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Review

## Intervention effect of neuromuscular electrical stimulation on ICU acquired weakness: A meta-analysis

Miao Liu [a, b], Jian Luo [b, *], Jun Zhou [a], Xiaomin Zhu [a]

[a] School of Nursing, Yangtze University, Hubei, China
[b] Affiliated Union Hospital of Tongji Medical College, Huazhong University of Science and Technology, Hubei, China

- 11 RCTs, 576 patients
- **'NMES' vs 'sham NMES'**
- enhancing muscle strength, shortening the MV duration, ICU LOS, hospital LOS

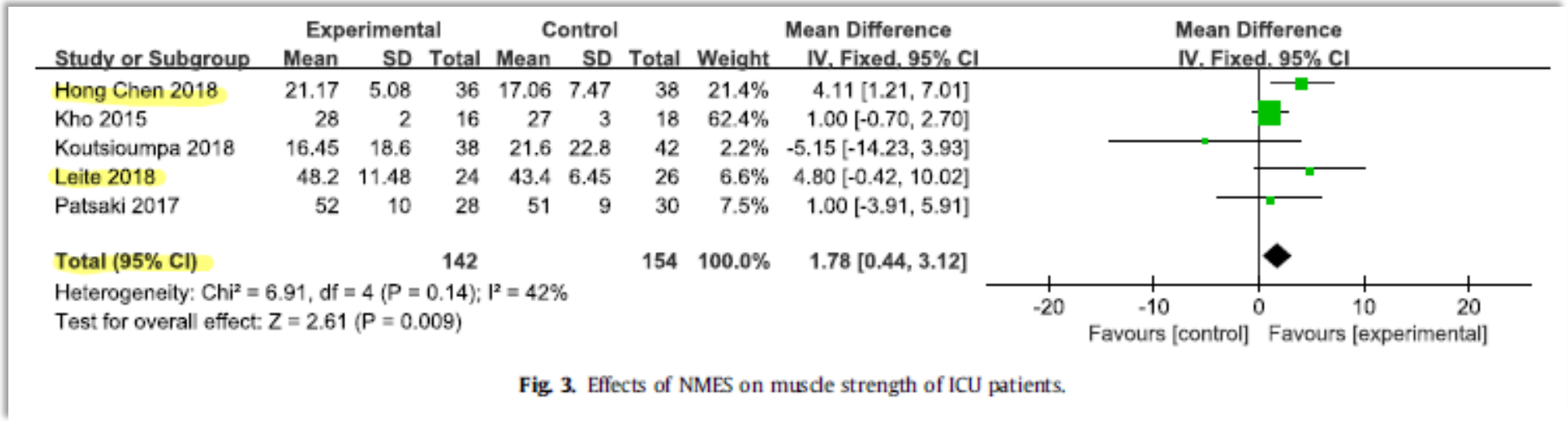
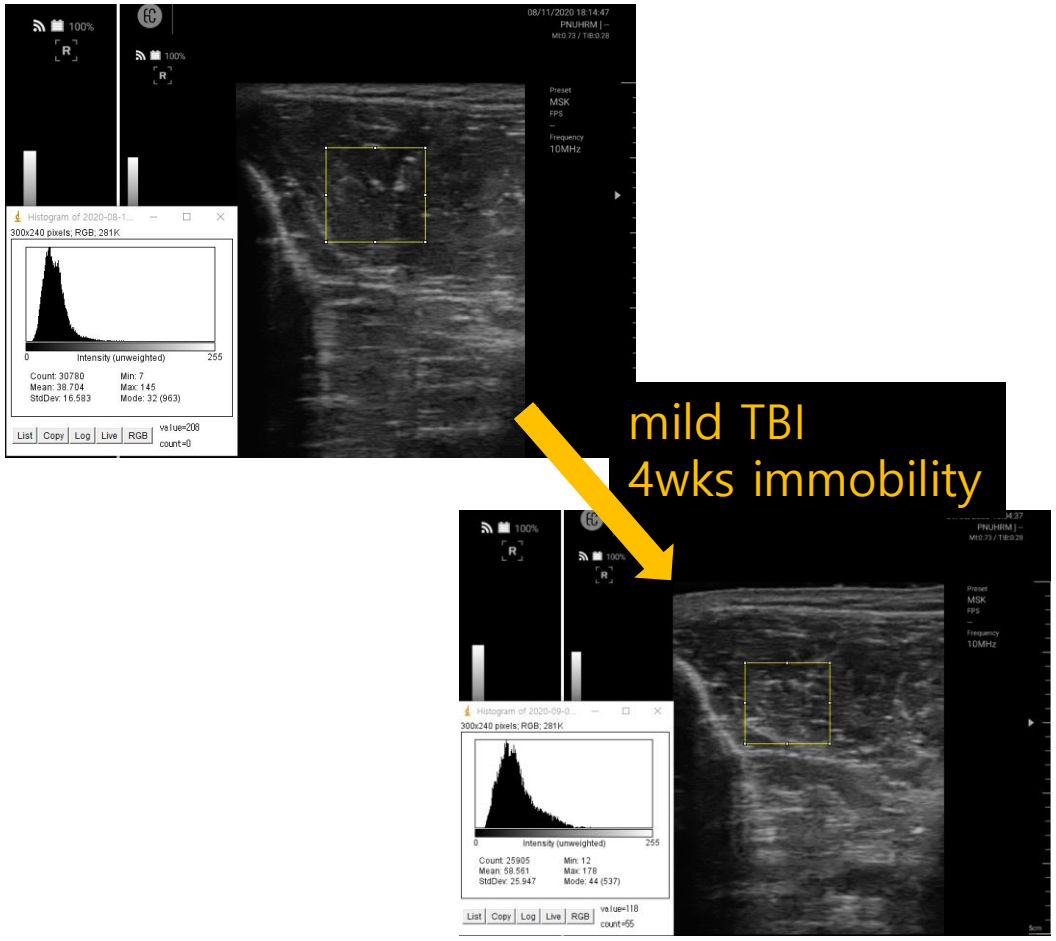



**Fig. 3.** Effects of NMES on muscle strength of ICU patients.

# Muscle strength

- TBI patients



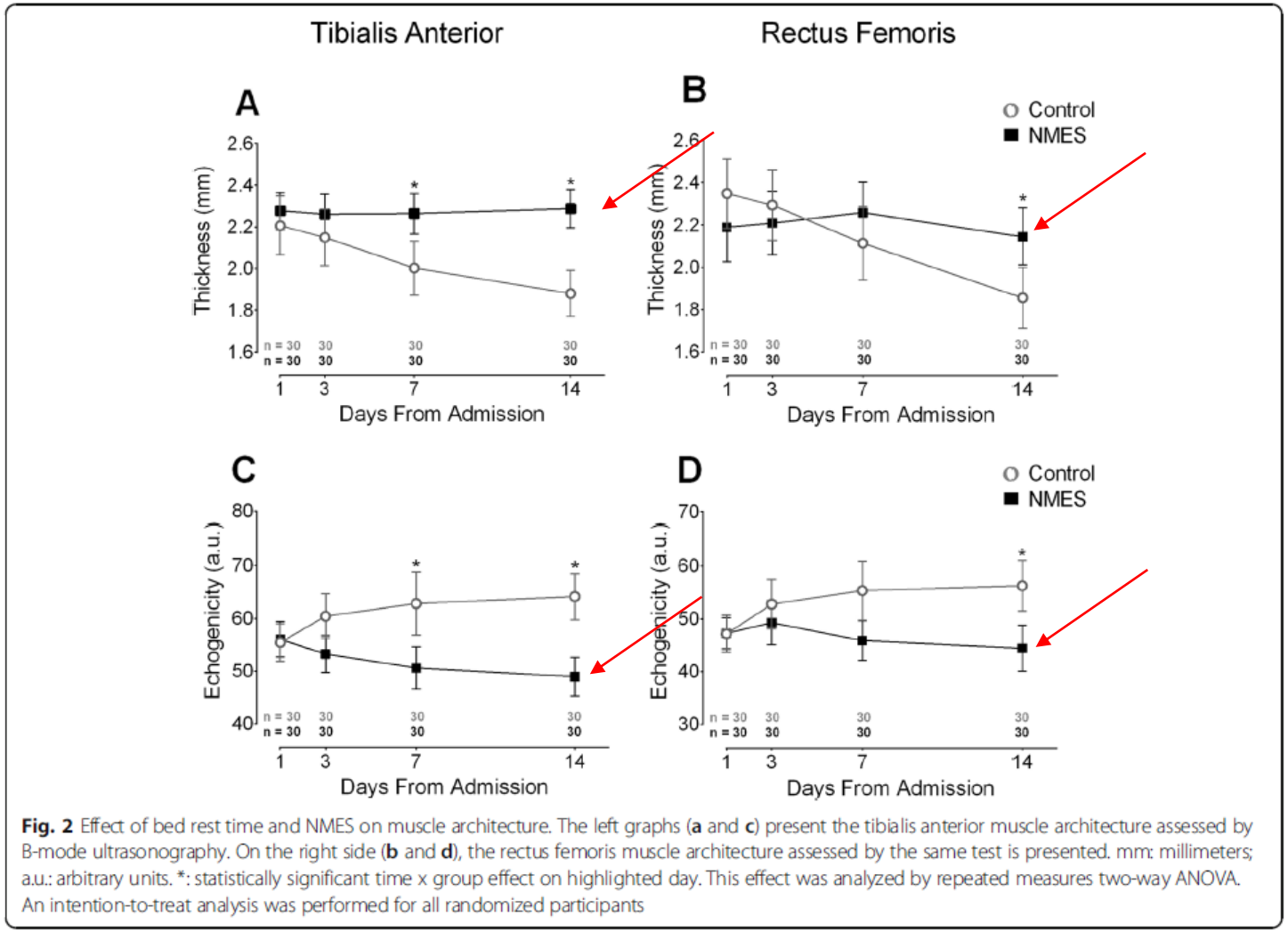
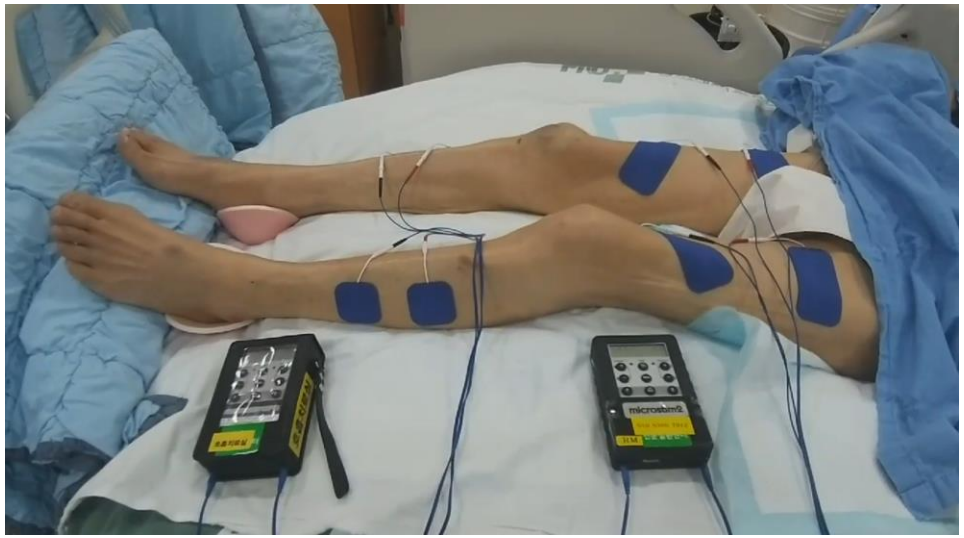




**Fig. 2** Effect of bed rest time and NMES on muscle architecture. The left graphs (**a** and **c**) present the tibialis anterior muscle architecture assessed by B-mode ultrasonography. On the right side (**b** and **d**), the rectus femoris muscle architecture assessed by the same test is presented. mm: millimeters; a.u.: arbitrary units. *: statistically significant time x group effect on highlighted day. This effect was analyzed by repeated measures two-way ANOVA. An intention-to-treat analysis was performed for all randomized participants

Silva PE, et al. **Neuromuscular electrical stimulation in critically ill traumatic brain injury patients attenuates muscle atrophy, neurophysiological disorders, and weakness: a randomized controlled trial.** J Intensive Care 2019;7:59.

# Muscle strength

- Limb position
  - **mid-range** of muscle length to produce the strongest muscle contraction (e.g. knee, 65° flexion, sitting position)
  - very weak muscles
    - MMT - Trace, Poor grade: gravity-assisted or **gravity neutral** position
    - MMT - Fair grade: **gravity-resisted** position



# Muscle strength - parameter recommendtions

- **quadriceps**, hamstring, calf
- frequency: 50Hz
- pulse duration: 350~400μs
- ON-OFF ratio: 1:2~1:3
  (ON 6~12s, OFF 8~24s)
- intensity:
  max tolerated intensity
- duration: 30~60min/d, daily

**Table 15** Summary of the Literature and Recommendations for Use of NMES in Critical Illness and Advanced Disease States

| Indication | Parameter Recommendations | Outcome Measures Demonstrating Benefit |
|---|---|---|
| Advanced COPD, heart failure, sepsis, consciousness disturbance, malignant disease, and during mechanical ventilation | **Electrode placement:** LE muscle groups bilaterally; primarily quads, frequently also hams and calf muscles<br>**Limb position:** ICU patients in supine with knee supported in 30–40° flex;[166,167] CHF patients sitting with knee flex 90°;[168,169] COPD patients sitting with knee flex 65–90°170–172<br>**Waveform:** biphasic low-frequency PC<br>**Frequency:** 50 Hz[166,169–180]<br>**Pulse duration:** 350–400 μs<br>**Work–rest cycle:** COPD patients, ON:OFF 6–8:12–24 s (1:2 or 1:3 ratio; shorter ON times paired with shorter OFF times); ICU and CHF patients, ON:OFF 2–5:4–10 s (1:1 or 1:2 ratio; shorter ON times paired with shorter OFF times)<br>**Treatment schedule:** 30–60 min/d. Alternatively, 30 min, gradually increasing to 60 min.[169,170,175,177,180] Total time divided among the muscle groups.<br>**Session frequency:** COPD patients, 5–7 d/wk for 6–8 wk; ICU patients, daily until extubation or D/C from ICU; CHF patients, 5–7 d/wk for 8–10 wk.<br>**Current amplitude:** individual max tolerated intensity. For COPD patients, a strong muscle contraction is the minimum acceptable response; in the ICU, a muscle contraction is not always observed. | • Muscle protein degradation (urinanalysis; biomarker analysis)[181,182]<br>• Thigh circumference (CT)[167,183]<br>• Cross-sectional area (by CT but not when measured by anthropometry or DEXA scan)[169,172,175,184,185]<br>• Strength of LE muscles (isometric or isotonic dynamometry, MRC score),[169,170,172–174,176,178,179,185–192] Ex capacity (6MWT, Incremental Shuttle Walking Distance, Endurance Shuttle Walk Test)[168,170,171,173,174,178,180,186,189,190]<br>• Prevention of muscle atrophy (US, biopsy)[166,168,177,182]<br>• Levels of function (transfers, PFIT)[179,190,192,193]<br>• Cardiopulmonary function ($O_2$ uptake, min ventilation, heart rate, Borg Symptom Score, spirometry)[168,171,186,192]<br>• Breathlessness (MRC dyspnoea scale, SGRQ, Borg Scale, Maugeri Foundation Respiratory Failure Questionnaire)[178,189]<br>• Duration of weaning from ventilation and decreased ICU length of stay[185,193]<br>• QOL (SF-36, Chronic Respiratory Questionnaire, Maugeri Foundation Respiratory Failure Questionnaire)[168–171,178,189–191]<br>• Safety and feasibility[194] |

# PNUH

- early day of ICU admission
- sedated patient
- severe weakness and atrophy (MMT < poor)
- neurological disorder (e.g. TBI, stroke, SCI)

→ **"NMES"**

- awakening and good cooperation
- MMT ≥ poor

→ **"NMES + exercise"**

- **NMES는 적은 인력으로 치료 양적인 측면에서 긍정적인 요소를 제공**
- **근력이 호전될 수록 운동시간을 늘려가는 방향으로 적용.**

# Respiratory muscle

- **pectoralis major and rectus abdominis m.**
  - frequency 50Hz, pulse duration 300μs
  - ramp on 1s, ON time 3s, ramp down 1s, OFF time 10s
  - session duration 30min
- **"NMES + Rehab"** vs "sham NMES + Rehab"

→ **muscle thickness(US) was preserved, shorter ICU LOS**

**Fig. 2.** Representative image of the positioning of electrodes on the straight muscles of the abdomen and chest to perform the protocol.

**Table III.** Comparison of muscle thickness between groups

| | Intervention group ($n=11$) | | | | Conventional group ($n=14$) | | | | Interaction effect (group vs time) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | End | | | Baseline | End | | | | |
| Variables | Mean (SD) | Mean (SD) | Difference in mean (95% CI) | $p$-value[a] | Mean (SD) | Mean (SD) | Difference in mean (95% CI) | $p$-value[a] | Difference between groups (95% CI) | Adjusted $p$-value[b] |
| CT | 0.44 (0.28) | 0.49 (0.28) | 0.05 (−0.00 to 0.10) | 0.083 | 0.42 (0.17) | 0.35 (0.16) | −0.06 (−0.10 to −0.02) | <0.001 | 0.11 (0.04 to 0.18) | <0.001 |
| AT | 0.47 (0.28) | 0.51 (0.26) | 0.04 (−0.02 to 0.10) | 0.505 | 0.43 (0.19) | 0.36 (0.17) | −0.07 (−0.10 to −0.04) | <0.001 | 0.09 (0.06 to 0.12) | <0.001 |

[a]Intra-group effect using a generalized estimating equations (GEE) model with Bonferroni's correction; [b]intergroup effect using a generalized estimating equations (GEE) model with Bonferroni's correction adjusted for APACHE II, sepsis end ICU stay. All ultrasound measurements expressed in cm.
CT: chest muscle thickness; AT: abdominal muscle thickness; 95% CI: 95% confidence interval; SD: standard deviation.



Dall' Acqua AM, et al. **Use of neuromuscular electrical stimulation to preserve the thickness of abdominal and chest muscles of critically ill patients: A randomized clinical trial.** J Rehabil Med 2017;49:40-8.

# Respiratory muscle

- Control
  **vs Quadriceps NMES vs Diaphragm NMES**
- Diaphragm parameter
  - frequency 30Hz
  - ramp on 1s, ON time 1s, ramp down 1s, OFF time 20s
  - session duration 45min
- Electrode placement
  - 7th-8th intercostal space
  - Rt./Lt. side of the xiphoid proc. and midaxillary line

(a) (b)

FIGURE 2: Neuromuscular electrical stimulation: (a) quadriceps and (b) diaphragm.

TABLE 2: Comparison of the variables analyzed between groups.

| Variables | CG ($n$ = 26) | DG ($n$ = 17) | QG ($n$ = 24) | $p$ |
|---|---|---|---|---|
| Sedation (hours) | 7.6 ± 4.64 | 11.5 ± 10.55 | 12.2 ± 11.25 | 0.3248 |
| MV duration (hours) | 15.8 ± 5.75[a] | 27.5 ± 12.16[b] | 23.3 ± 10.61[b] | 0.0001 |
| ICU length of stay (days) | 12.8 ± 7.83 | 12.4 ± 4.45 | 9.7 ± 4.92 | 0.0998 |
| Hospital length of stay (days) | 25.4 ± 12.04[a] | 29.3 ± 13.59[a] | 18.2 ± 11.28[b] | 0.0031 |
| Minute volume (L/min) | 9.8 ± 5.4 | 11.7 ± 5.2 | 10.3 ± 4.7 | |
| Last minute volume (L/min) | 11.9 ± 3.9 | 14.1 ± 6.9 | 12.8 ± 5.1 | 0.995 |
| Minute volume (L/min), ext. day | 13.1 ± 7.4 | 15.2 ± 7.2 | 13.2 ± 5.9 | |
| First MIP ($cmH_2O$) | −24.6 ± 14.13[a] | −23.2 ± 10.88[a] | −21.7 ± 11.68[a] | |
| Last MIP, ICU discharge ($cmH_2O$) | −25.9 ± 9.59 | −37.9 ± 10.31[b] | −40.4 ± 8.71[b] | 0.00003 |
| MIP, extubation day ($cmH_2O$) | −25.9 ± 9.79 | −29.1 ± 15.33 | −30.8 ± 10.7 | |
| First RSBI (rpm/l) | 57.9 ± 40.42 | 43.2 ± 18.29 | 54.0 ± 34.15 | |
| Last RSBI, ICU discharge (rpm/l) | 52.1 ± 28.85 | 35.9 ± 14.17 | 48.9 ± 32.4 | 0.88708 |
| RSBI (rpm/l), extubation day | 53.6 ± 20.96 | 44.0 ± 19.45 | 56.9 ± 28.57 | |
| First MRC | 36.2 ± 5.55[a] | 32.7 ± 7.22[a] | 33.2 ± 8.47[a] | |
| | | | | 0.00044 |
| Last MRC, ICU discharge | 43.4 ± 6.45[b] | 41.8 ± 11.14[b] | 48.2 ± 11.48[b] | |
| Barthel | 15.8 ± 14.04[a] | 23.8 ± 24.97[a] | 40.6 ± 30.08[b] | 0.0049 |
| FSS-ICU | 14.6 ± 8.01[a] | 21.5 ± 10.16[a] | 29.1 ± 12.38[b] | 0.001 |
| In-bed transfers | 2.2 ± 1.48[a] | 3.2 ± 1.60 | 4.5 ± 2.00[b] | 0.0003 |
| Supine-to-sit transfer | 2.0 ± 1.41[a] | 3.1 ± 1.55 | 4.3 ± 1.86[b] | 0.0001 |
| Sitting at the bedside | 2.4 ± 1.65[a] | 3.5 ± 1.54 | 4.8 ± 1.83[b] | 0.001 |
| Unsupported sitting | 3.6 ± 1.71[a] | 4.8 ± 1.57 | 5.2 ± 1.75[b] | 0.0037 |
| Locomotion | 1.1 ± 1.33[a] | 2.3 ± 1.85 | 3.6 ± 2.33[b] | 0.0001 |
| GCS, ICU discharge | 13.0 ± 1.64 | 12.7 ± 1.92 | 13.2 ± 1.87 | 0.5480 |

Leite MA, et al. **Effects of Neuromuscular Electrical Stimulation of the Quadriceps and Diaphragm in Critically Ill Patients: A Pilot Study.** Crit Care Res Pract 2018;2018:4298583.

# Respiratory muscle

Dualpex 961 Phrenics (Quark®).

- **Transcutaneous electrical diaphragmatic stimulation (TEDS)** vs Standard weaning protocol
- **Cervical SCI** (AIS A, total 10)
- Parameters
  - frequency 30Hz, pulse width 1ms,
  - ramp up 0.7ms, intensity 60mA
  - Rt./Lt. midaxillary line, 7th-8th intercostal line
  - twice/day, 20min, 7d/week
  - **manually trigger**

→ duration of MV ↓, ICU LOS ↓

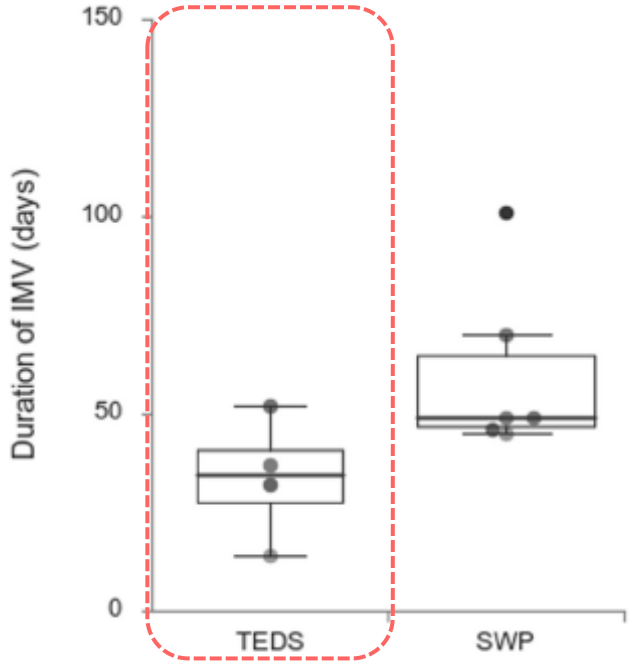



**Fig. 2 The ordinate indicates the duration of invasive mechanical ventilation (IMV) in days.** SWP standard weaning protocol, TEDS transcutaneous electrical diaphragmatic stimulation.

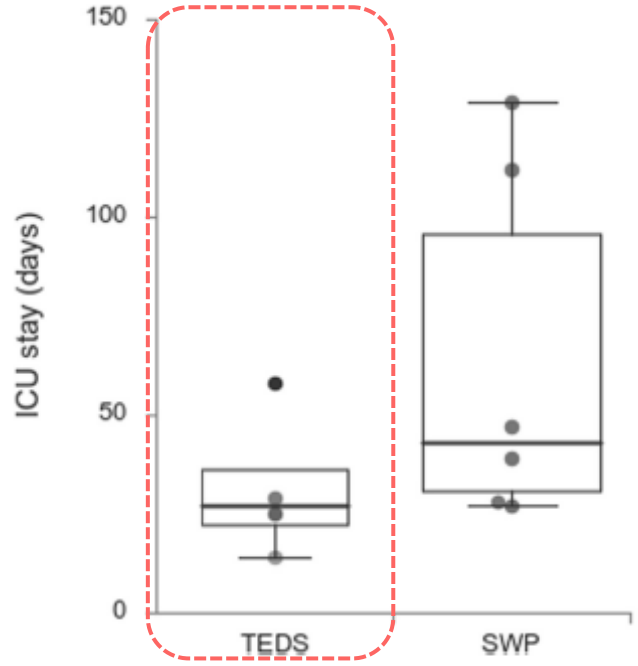
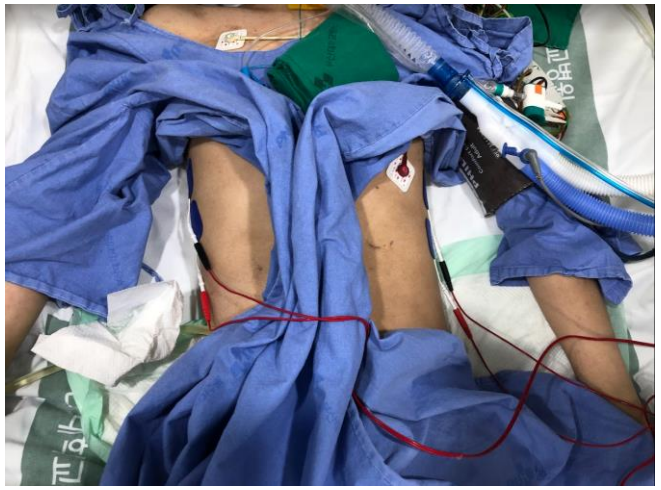


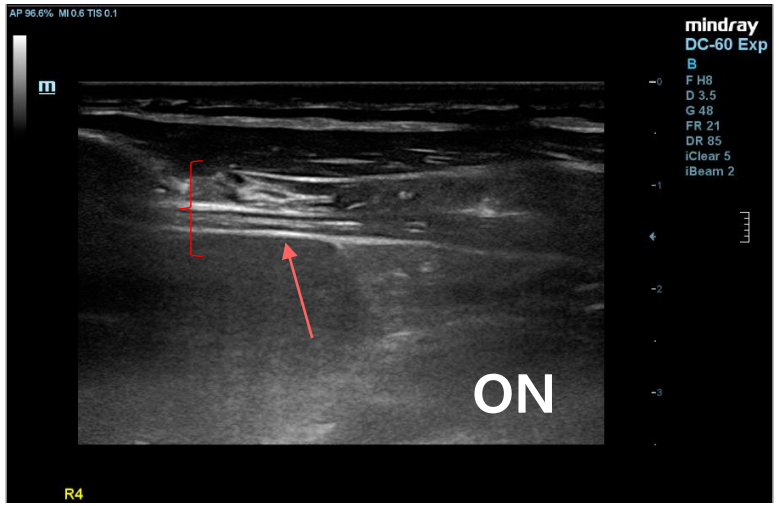

**Fig. 3 The ordinate indicates the duration of length of stay in intensive care unit (ICU) in days.** SWP standard weaning protocol, TEDS transcutaneous electrical diaphragmatic stimulation.



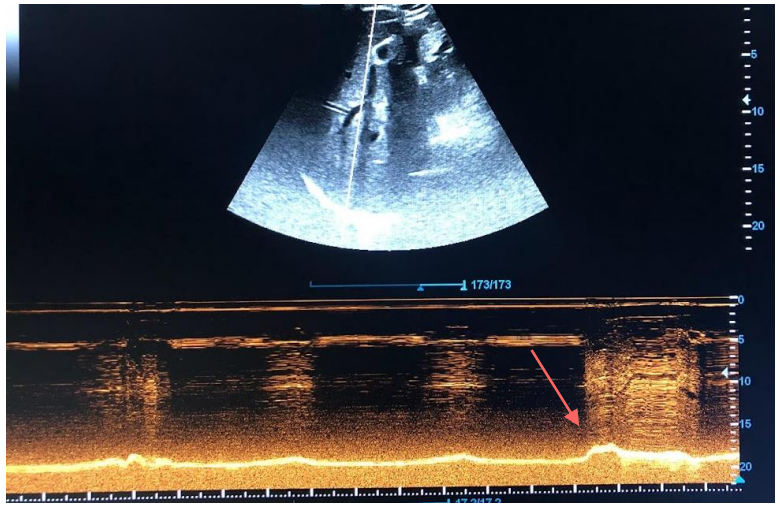
Duarte GL, et al. **Transcutaneous electrical diaphragmatic stimulation reduces the duration of invasive mechanical ventilation in patients with cervical spinal cord injury: retrospective case series.** Spinal Cord Ser Cases 2021;7:26.

- M/22, TBI /c CNS infection, difficult to wean pt.
- midaxillary line, zone of apposition









- frequency 30Hz
- pulse duration 300μs
- ramp on 1s, ON time 2s, ramp down 1s, OFF time 10s

# PNUH

- cervical spinal cord injury
- post-extubation management: weak cough pt.
- long-term MV

# Dysphagia

- **Treatment in ICU**
  - **Swallowing exercise**
  - **Electrical stimulation of swallowing muscle**
  - **Smaller cannula in trachoestomized patients**
  - Smaller (thinner) gastric feeding tube
  - Surface EMG swallowing biofeedback

**Fiberoptic endoscopic evaluation of swallowing (FEES) in ICU**

# Dysphagia

- **NMES of swallowing muscle**
  - **Motor contraction**
    - intensity increased until **muscle contraction** occurs strength swallowing related **muscle of hyolaryngeal complex**
  - **Sensory approach**
    - lowest current level at which the **patient feels tingling sense**
    - sensory stimulation effects on the **long-term reorganization to trigger swallowing reflex**



POORJAVAD, Marziyeh, et al. **Surface electrical stimulation for treating swallowing disorders after stroke: a review of the stimulation intensity levels and the electrode placements.** *Stroke research and treatment*, 2014.

# Dysphagia

- **NMES of swallowing muscle**
  - **Ampcare parameter: manual setting**

| | VitalStim Plus® | Aspire² | Unity™ | Ampcare | eSwallow |
|---|---|---|---|---|---|
| | $3400.00 DEVICE ONLY / $4450.00 DEVICE + COURSES 1 and 2 | $1381.00 DEVICE ONLY / $1776.00 DEVICE + COURSE | $888.00 DEVICE ONLY / $1183.00 DEVICE + COURSE | $599.00 DEVICE ONLY / $649.00 DEVICE + COURSE | $899.00 DEVICE ONLY / $1178.00 DEVICE + COURSE + SELF STUDY |
| channels of stimulation | 4 | 1 | 2 | 2 | 2 |
| neuromuscular electrical stimulation | yes | yes | yes | yes | yes |
| surface electromyography | yes | yes | no | no | no |
| sEMG triggered stimulation | yes | yes | no | no | no |
| rechargeable | yes | yes | no | no | no |
| NMES programs | 1 VitalStim® protocol customizable programs | 4 Guardian® protocols 1 customizable program | 6 Guardian® protocols 1 alternative protocol | 3 Ampcare protocols | 1 eSwallow protocol |

# Dysphagia


- **NMES of swallowing muscle**
  - **Electrode placement: submental region**
    suprahyoid muscle group – ant. diagastric and mylohyoid, geniohyoid m.

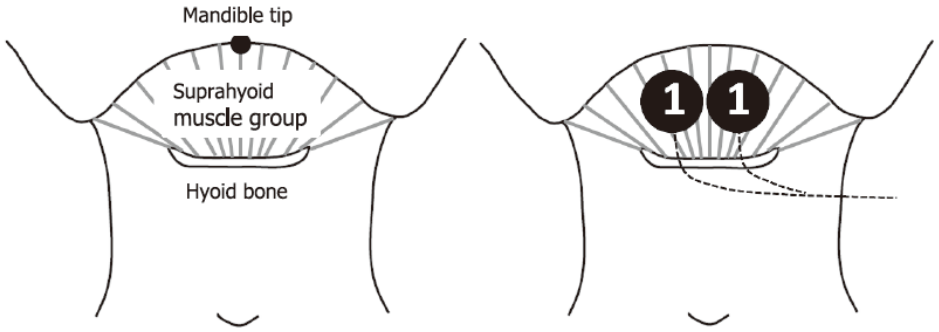



**Table 1.** Ampcare ESP™ neuromuscular electrical stimulation (NMES) stimulation parameters.

| | |
|---|---|
| Frequency (Hz) | 30 |
| Phase duration (μsec) | 50 |
| Ramp up (seconds) | 1 |
| Ramp down (seconds) | 0 |
| Cycle on time (seconds) | 5 |
| Cycle off time (seconds) | Initially 25, reduced to 20 and then 15 seconds if patient able to reliably generate a swallow during each 'on-time' |
| Program duration (minutes) | 30 (with breaks after each 10-minute block) |
| Intensity | 0–20 depending on patients' individual tolerance |

# Dysphagia

- **NMES of swallowing muscle**
  **+ Laryngeal exercises**
  **(chin to chest(shaker), effortful swallowing)**

# Transcutaneous electrical nerve stimulation (TENS)

- **musculoskeletal and neuropathic pain**
  - **'gate control' theory** of pain
  - produces pain relief **by releasing endorphins in the spinal cord**

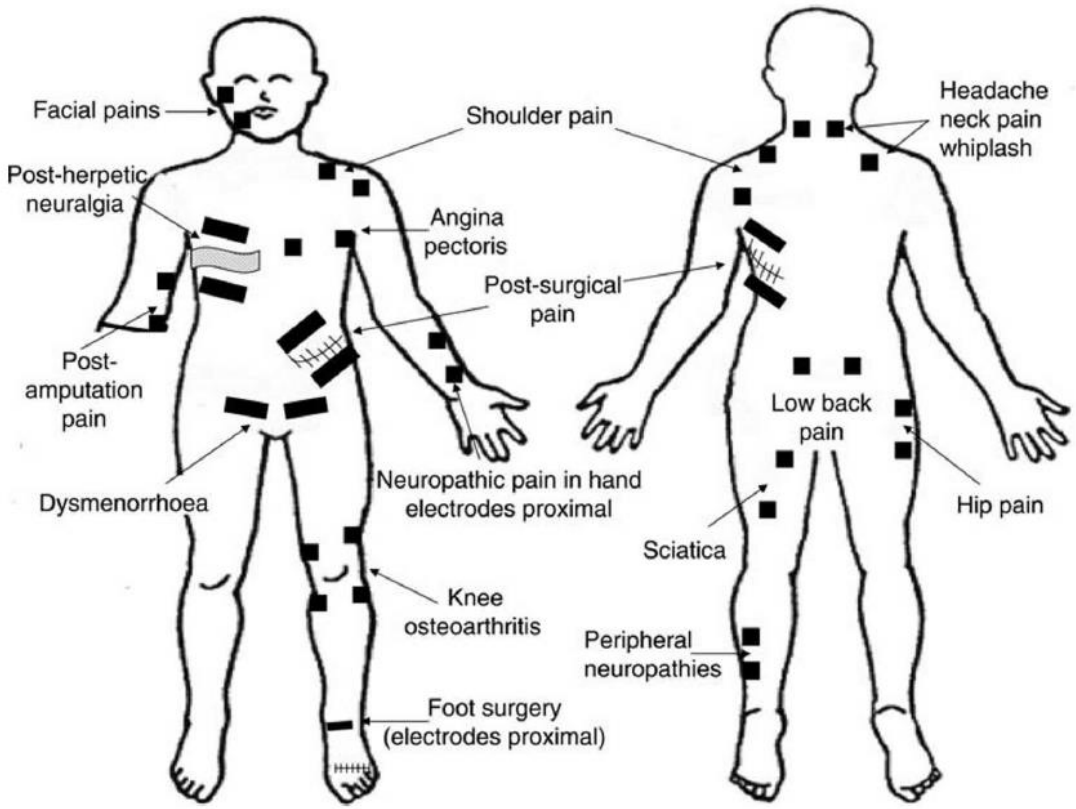



Fig 4 Frequently used sites for TENS therapy.



Jones I, Johnson MI. **Transcutaneous electrical nerve stimulation**. Continuing Education in Anaesthesia Critical Care & Pain 2009;9:130-5.

# TENS

- **Multiple rib fractures**: better subjective pain relief, improvement in peak expiratory flow rates, arterial blood gases
- **Post-thoracotomy pain** control, increased **lung function** ($FEV_1$, FVC, $PaO_2$, $PaO_2$)

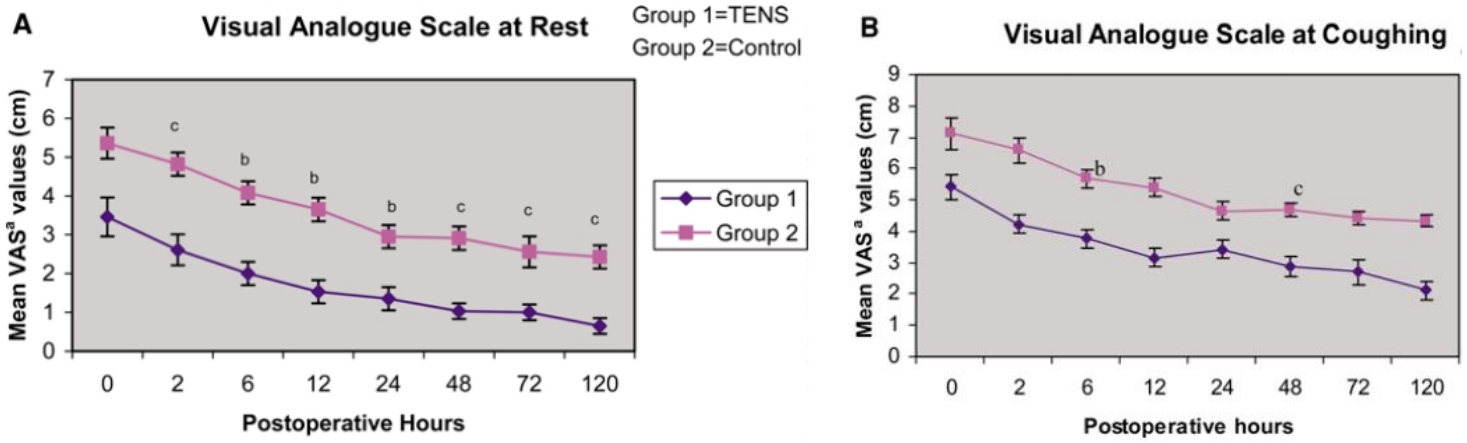



**Figure 1.** Patient with transcutaneous electrical nerve stimulation (TENS). Electrodes are attached 2 cm above and 2 cm below the thoracotomy incision area.



Karmakar MK, Ho AM. **Acute pain management of patients with multiple fractured ribs.** J Trauma 2003;54:615-25.
Erdogan M et al. **Randomized, Placebo-controlled Study of the Effect of TENS on postthoracotomy pain and pulmonary function.** World J Surg 2005;29:1563-70.

# TENS


**Red Flags**
Age > 65yrs
Respiratory history (smoker, COPD),
Respiratory compromise
(e.g.: ↑WOB; ↑RR; ↓SpO2
≥3 rib #s)

**Initial Assessment**
Assess particularly for pain and ability to deep breath/cough/SpO2
+ CXR and analgesia

**Re-assessment** (at least 30mins post initial analgesia)
Inability to deep breathe/cough or Ongoing pain or poor effort on incentive spirometry/vital capacity

CALL 991
ACTIVATE "ChIP" AND Provide MRN
Patient to be reviewed by on call Surgical and ICU registrar and likely admission.

CHIP page will alert:
- Surgical team
- Trauma CNC
- Pain team (within hrs)/ Anaesthetics (after hrs)
- Physiotherapy (PT)
- ICU Liaison RN and Registrar

If patient for admission....
AMO1= Surgery. AMO2 as appropriate (e.g. Geris)
Appropriate Bed Allocation (HFNP capability)

**1. Respiratory Adjuncts:**
Consider HFNC:
(Start at 50L/min Flow with $FiO_2$ 30-40%) documented with $SpO_2$ in notes
*Does not exclude Haemo/pneumothorax– but discuss with surgical fellow
NIV and ICU review if fails

**2. Regular Analgesic regime:**
- Oral: Targin, Paracetamol, NSAIDs and PRN oxycodone
Consider combination with:
- IV PCA / transdermal patch
- Paravertebral Block or Epidural as appropriate

**3. Complication Prevention:**
Early Mobilisation
Chest physio – deep breathing exercises, directed coughing

Patient education – DB&C, use of PRN analgesia, support/splint pillows

**4. Surgical fixation:**
Consider for extensive fractures e.g. flail chest

Discharge Planning from ward:
Wean HFNC/Analgesia (per patient condition)
Discharge home when pain well controlled & respiratory function optimised
Patient / family education to include return to ED if breathing or pain worsens
GP F/U within 3 days.



Kourouche S, Buckley T, Munroe B, Curtis K. **Development of a blunt chest injury care bundle: An integrative review.** Injury 2018;49:1008-23.

# TENS

Neuromodulation: Technology at the Neural Interfa

Received: July 17, 2018 Revised: August 27, 2018 Accepted: September 16, 2018

(onlinelibrary.wiley.com) DOI: 10.1111/ner.12878

## Electrical Stimulation and Recovery of Gastrointestinal Function Following Surgery: A Systematic Review

James A. Penfold*; Cameron I. Wells*; Peng Du, BE, PhD†; Ian P. Bissett, MBChB, MD*‡; Gregory O'Grady, MBChB, PhD*†‡

- electrode
  : near the incision line
- ileus were improved in 57% (4/7) of studies

**Table 2.** Transcutaneous Electrical Nerve Stimulation Clinical Outcomes.

| Author | Randomization (Y/N) | Blinding (Y/N) | Participants | Jadad score (RCT) | Newcastle-Ottawa score | Results |
|---|---|---|---|---|---|---|
| Hymes et al. (36) | No | No | 130 treatment<br>154 control | N/A | 7 | 60–80% subjective pain reduction<br>"Striking reduction in ileus and reduced hospital stay" |
| Hymes et al. (37) | Yes | Yes | 214 treatment<br>213 control | 1 | N/A | ES 0% ileus rate vs. control 13% ileus rate |
| Cooperman et al. (38) | Yes | Yes | 26 treatment<br>24 control | 1 | N/A | "Significant pain relief ($P < 0.008$)"<br>"No significant difference in ileus and PO atelectasis" |
| Perdikis et al. (39) | No | No | 20 treatment | N/A | N/A | Ileus "deflation";<br>• 4/20 in 6 hours<br>• 10/20 in 12 hours<br>• 16/20 in 24 hours<br>• 17/20 in 26 hours<br>'3x failures submitted to laparoscopy ' |
| Rosenberg et al. (31) | Yes | Yes | 6 treatment<br>6 control | 1 | N/A | "3x higher narcotic usage in control group"<br>"$P < 0.05$ decrease in narcotic usage for treatment group PO D1/D2"<br>"No decrease in POI" |
| Sodipo et al. (40) | Yes | No | 15 treatment<br>15 control | 1 | N/A | "30x higher total amount of narcotics in control group"<br>"$P < 0.02$ decrease in Pethidine usage for treatment group PO D1/D2"<br>"Presence of ileus was the same" |
| Vermeulen et al. (41) | No | No | 30 treatment | N/A | N/A | 25/30 clinically audible bowel sounds within 4 hours of stimulation<br>Passage of flatus;<br>• 29% in 12 hours of stimulation<br>• 83% in 24 hours of stimulation<br>• 91% in 72 hours of stimulation |

N/A, not applicable; ES, electrical stimulation; PO, postoperative; d, day.



Penfold JA, Wells CI, Du P, Bissett IP, O'Grady G. **Electrical Stimulation and Recovery of Gastrointestinal Function Following Surgery: A Systematic Review.** Neuromodulation 2019;22:669-79.

# 관련 수가

- **ICU-AW(CIP, CIPNM), peroneal neuropathy (foot drop) 등과 같은 말초신경손상**

| | | | | | |
|---|---|---|---|---|---|
| 사-113 | | 전기자극치료 Electrical Stimulation Therapy | | | |
| | MM060 | 가. 마비근 치료 | 62.76 | 5,230 | 4,700 |
| | MM061* | 나. 근력강화 치료 | 62.76 | 5,230 | 4,700 |
| | | 주 : 전방 십자인대 재건술 후 대퇴사두근 근력강화 목적으로 재활치료와 병행하여 실시한 경우에 산정한다. | | | |

- **중추신경계 손상 환자**

| | | | | | |
|---|---|---|---|---|---|
| 사-126 | MM151 | 기능적전기자극치료 Functional Electrical Stimulation Therapy<br>주 : 기능적전기자극치료는 환자에게 최소 20분 이상 실시한 경우에 산정한다. | 185.90 | 15,500 | 13,920 |

**+ 삼킴검사에서 흡인소견 (PAS 8)**

| | | | | | |
|---|---|---|---|---|---|
| 사-131 | MZ008 | 연하재활 기능적전기자극치료 Functional Electrical Stimulation for Rehabilitative Dysphagia Therapy<br>주 : 1. 중추신경계질환 등으로 인한 연하장애환자에게 30분 이상 훈련을 실시한 경우에 산정한다.<br>2. 1일 2회 이상 실시한 경우에도 외래는 1일 1회, 입원은 1일 2회만 산정한다. | 191.27 | 15,950 | 14,330 |


# Summary

- NMES는 부작용 없이 안전하고 쉽게, ICU 입실 초기 적용 가능.
- 입원 초기 NMES를 적용, 환자의 상태에 따라서 운동치료 추가.
  - strength (limb and respiration), dysphagia
  - TENS
- 치료에 대한 근거 및 표준화된 프로토콜에 대해선 연구 필요.


감사합니다.