Technical aspects of transcranial electrical stimulation: Hardware, devices, and procedures

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Technical aspects of transcranial electrical stimulation

Outline

Part 1: Devices
Part 2: Electrode Hardware
Part 3: Procedures

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Low Current tES Devices

• Wide range of marketed devices
  – Currently a limited set of certified low current tES-stimulators available
  – Important to use a professionally engineered medical device designed to deliver current to the head/spine
Key features to look for:

- **Constant and controlled current delivery**
  - Exactness of current delivered is critical
  - Voltage controlled (constant voltage) devices are not appropriate for tES

- **Reasonable and safe current ceiling**
  - Devices do not need to be able to stimulate at 1 amp for tES

- **Blinding and sham features**
  - For research or clinical trial applications

- **Current ramp function**

- **Programmable (if desired)**
  - Current intensity, duration of stimulation, etc.

- **Impedance/contact quality**

- **Other safety features**
  - Battery operation, low battery warning, abort function, etc.
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Part 1: Devices
Part 2: Electrode Hardware
Part 3: Procedures
Electrode Hardware

• Conventional Electrodes
  – Electrode Assembly
  – Electrode Size
  – Electrode Type
  – Wires

• HD/Multi-electrode
  – Electrode Assembly
  – Electrode Size
  – Electrode Type
  – Wires
Electrode Hardware

- Conventional Electrodes
  - Electrode Assembly
  - Electrode Size
  - Electrode Type
  - Wires

- HD/Multi-electrode
  - Electrode Assembly
  - Electrode Size
  - Electrode Type
  - Wires
Conventional Electrode Assembly

- Electrode
- Sponge
- Wire
Conventional Electrode

- Biocarbon Electrodes
  - Most common
Conventional: Sponge Size

• A variety of sizes
  – 5x5 cm
  – 5x7 cm
  – 5x10 cm
  – 10x10 cm
  – Other sizes available

• Why different sizes?
  – Control of current concentration/intensity
  – Method for altering the “general” focality of current delivery
Sponge/Electrode Integrity

- Biocarbon Electrodes and Sponges

- Conventional 1x1
  - Rubber electrodes
  - Sponge pads
    - Single use
    - Multi-use
Electrode Wires

- Manufacturer specific device connection
- Common electrode connection terminal
- Careful to remove by grasping at terminal, not the wire
Electrode Hardware

- Conventional Electrodes
  - Electrode Assembly
  - Electrode Size
  - Electrode Type
  - Wires

- HD/Multi-electrode
  - Electrode Assembly
  - Electrode Size
  - Electrode Type
  - Wires
HD or multi-electrode assembly

• Electrodes

• Electrode holders
Electrode Type

- **Ag/AgCl Electrode**
  - Must be replaced after two uses in center position of “4x1 montage”
Ag/AgCl Electrode Integrity

- Chipped Ag/AgCl electrodes
  - Do not use
  - Can also break during insertion holder

- Ag/AgCl electrodes must be replaced after certain number of uses
  - Excessive corrosion/blackening of electrodes should cue replacement
  - An electrode “use log” is helpful for tracking number of uses in the center position
Electrode Holder

• Plastic Holder for positioning of electrode
• Fits within standard EasyCap or other similar EEG-style caps

Image: Villamar et al., 2013
Wires

• Fragile
• Highest point of failure
• Methods for reducing wire strain
  – Wrapping wires around electrode holder
  – Clipping wire junction to the participants shirt or chair
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Procedures

• Conventional Application
  – Contact Medium
  – Electrode Location
  – Electrode Orientation
  – Electrode Drift
  – Scalp Contact
  – Impedance

• Ag/AgCl Application
  – Electrode Location
  – Contact Medium
  – Impedance
Procedures

• Conventional Application
  – Contact Medium
  – Electrode Location
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• Ag/AgCl Application
  – Electrode Location
  – Contact Medium
  – Impedance
Contact Medium: Saline: 0.9% Solution

- Proper saturation of sponge
  - ~8 mL recommended for 5 x 7 cm
  - Eye dropper gives best control over delivery (~4 mL/side)
- Do NOT over saturate
  - Bridging
- Do **NOT** apply stimulation to a dry sponge
  - Sponges designed to hold saturation ~20 minutes
- **NEVER** use water
Electrode Paste

• Alternative to Saline
  – Pros
    • Stability over time
    • Less likely to “drip”
    • Sensation differences
      – Decreased sensation with 3+mm layer
  – Cons
    • More difficult to obtain low impedance levels
      – Necessary to massage paste into scalp area prior to placing paste covered electrode
    • Thick (~3mm) coating of paste must be maintained
      – Easy to press electrode such that paste thickness is decreased
Electrode Location

International 10 – 20 Measurement System

Diagram showing various electrode locations on a head for measurement purposes.
Electrode Drift

• When using straps to secure electrodes
  – Straps may drift over time if not properly secured
  – Fine or oily hair have higher rate of drift
  – Use the heads anatomy to your advantage
  – Use cross-straps and chin straps if needed on a particular montage
  – Keep securing strategy consistent across all subjects
  – Place marks at the bottom edges of electrodes and measure pre-post drift
Electrode Drift: Models

Woods et al., Brain Stimulation 2015
Impedance

- Greatest impediment to impedance:
  - Hair

- Do not over-soak sponges with saline

- Use all plastic hair clips to secure hair if needed

- Attempt to provide as much contact with the skin as possible

- Be careful not to stray from the intended electrode site
Impedance/Contact Quality

- Impedance-based device
  - Aim for <15 kOhm before start of stimulation
  - Impedance will improve during stimulation
  - Good to record impedance at beginning, middle, and end of stimulation period

- Contact quality device
  - Within ‘<10 bars’ of optimal
  - Rapid improvement with stim
Procedures

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• Ag/AgCl Application
  – Electrode Location
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Ag/AgCl electrode location: Cap Fit

• Easy Caps or other similar caps
  – Head-size specific
  – Measure head circumference
  – Select appropriate size

• Mark at least Cz and the center location of the 4 x 1 montage using the 10-20 location prior to cap placement
Contact Medium: Conductance Gel

• Conductance gel (e.g., Signa gel) will saturate the skin over time
  – As the gel saturates the skin, impedance improves
  – Use gels tested by manufacturers to be safe for stimulation

• Careful not to overfill holder such that gel escapes bottom of holder
  – Avoid shunting
Impedance: < 1.5 Quality Units

• Greatest impediment to impedance:
  – Hair
  – Expose scalp using end of blunt tipped syringe
  – Keep impedance consistent across electrodes

• Attempt to minimize air pockets in gel

Image: Villamar et al., 2013
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Rigor and reproducibility are in the details

- Minimize variation in application
- Use measurable approaches to application
- Choose a device designed for application of tES on the head/spine
- Do NOT oversaturate sponges
- Record impedance/contact quality
- Record electrode drift
- Careful about strap tightness
- 10-20 location is an easy and consistent guide for electrode placement
- Report exact details of application methods