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The principles of neuromuscular electrical stimulation

Neuromuscular electrical stimulation is used as a treatment option in the management of continence problems. Julia Herbert outlines the principles on which this treatment is based

KEY WORDS
Neuromuscular electrical stimulation
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Neuromuscular electrical stimulation (NMES) is used to stimulate nerves and muscles to achieve a therapeutic response. It is used in the management of urinary stress incontinence, unstable (overactive) bladder, urge faecal incontinence and passive faecal incontinence. It is recommended that NMES should be combined with biofeedback and pelvic floor muscle exercise for muscle strengthening, and with bladder drill and medication for detrusor hyperactivity and hypoactivity (Laycock and Vodusek, 2002).

The competency document published by the Interprofessional Collaboration in Continence Care (see p53), identifies areas of knowledge a practitioner requires before using NMES for the treatment of incontinence. In particular he or she should have knowledge of the precautions and contraindications (Box 1).

Electrical Parameters It is valuable to revisit the principles on which NMES is based and understand how NMES works. There are a number of electrical parameters that are particularly relevant to the use of NMES in the clinical setting, some of these can be adjusted by the clinician to produce different treatment effects, others may be pre-set by the manufacturer.

Current Current is produced by a flow of electrons and is measured in ampères (amps). A current flows when an electromotive force (EMF) is applied to a complete circuit (a pathway along which electrons can move). In the clinical setting the EMF (measured in volts) is usually produced by mains electricity or a battery creating an electrical potential difference between two points.

There is a relationship between the flow of electrons, the electromotive force and the resistance of the circuit – usually the patient's tissues. The equation for expressing this relationship is Ohm's law (see below).

Electrical current is directional and may be described as direct (dc) – where it flows constantly in one direction, or alternating (ac) – where it changes direction repeatedly.

Most electrotherapy equipment gives a biphasic current, this is a direct current that has two phases during each impulse (positive and negative), giving the effect of a net zero direct current. This protects the tissues from a build up of electrochemicals, while allowing effective stimulation of the tissues.

The size of the electrical currents used clinically is small and is usually recorded in milliamps (mA).

Resistance This occurs when the conductors within a circuit offer some hindrance to the movement of electrons. Some conductive materials allow electrons to move more freely than others and are said to have low resistance. The unit of measurement for resistance is the ohm (Ω).

Resistance can cause a problem at the interface between the electrode and the skin as the skin has high resistance and is also well supplied with sensory nerve endings. This can make it difficult to input sufficient electrical energy into the tissues without the sensation becoming unbearable for the patient. A water-based lubricant can help to reduce the resistance between the skin and electrode.

Intensity This is a measure of how much energy is in the circuit and is closely related to the current. Intensity is also affected by the EMF and the resistance in the circuit. When using NMES as a therapeutic modality, intensity relates to how much energy is being given to the patient's tissues.

To be clinically effective, the electrical stimulus used for NMES needs to be of sufficient intensity and of sufficient duration to depolarise the nerve membrane.

Ohm's Law Ohm's law states that the size of an electric current varies directly with the voltage (EMF) and inversely with the resistance within the circuit. Ohm's law is expressed in the equation:

$$\text{Current (I)} = \frac{\text{Voltage (V)}}{\text{Resistance (R)}}$$

It is important to understand the relevance of this law in the clinical situation. If the resistance changes, which may happen if the patient moves during NMES treatment and the contact between the patient and the electrode is altered this will have a direct affect on either the current or the voltage.

Some NMES equipment gives the clinician the choice of fixing either the current or the voltage. If the voltage is fixed, any decrease in resistance in the circuit will produce an increase in the current to maintain the set voltage, this could result in a sudden peak of current that could be uncomfortable or even harmful to the patient's tissues. If the current is fixed, any change to the resistance in the circuit will produce a change in the voltage to keep the current at a constant level.

As the current level is responsible for the physiological effect of NMES, it is preferable to fix the current.

Frequency Frequency is the number of electrical impulses delivered in a given period of time and is measured in hertz (Hz). This is usually expressed over the time scale of one second and is referred to as pulses per second (pps). Clinically, the frequency is chosen to produce the desired effect within the tissues after an assessment of the patient.

Waveform Waveform is the shape of the electrical impulse. There is little clinical research that has examined the clinical effect of using different shapes of impulse.

Pulse duration This is often incorrectly referred to as pulse width, but it is a measurement of time not size. It is the length of time that each electrical impulse lasts for, this is usually measured in milliseconds (ms) or microseconds (μs). Altering the pulse duration is dependent on the patient's comfort and the desired therapeutic effect.

Duty Cycle This refers to the ratio between the time that the stimulation is on and off. During the on time the NME stimulator will deliver a train of electrical impulses at the set frequency of impulses per second.

To prevent the muscle fibres becoming over-fatigued, the off time or rest phase will allow the motor units (consisting of a motor neurone and innervated muscle fibres) to repolarise and recover. This off time should always be at least equal to that of the on phase. Very weak, easily fatiguable pelvic floor muscle will require a rest phase that is at least twice that of the on phase.

There is some confusion as to the optimum duty cycle for the treatment of detrusor overactivity. Many researchers suggest that a continuous cycle with no rest phase is best. However, Laycock and Vodusek (2002), recommend that a duty cycle of 10 seconds on, three seconds off will minimise the likelihood of fatigue.

Another option, called ramping, is to set a gradual increase in the intensity at the start of each phase of stimulation. A ramp may also be applied at the end of the on time. During the ramp the level of stimulation will not produce a contraction of the muscles. If this phase is very long it will reduce the overall therapeutic time for the stimulation.

Effects of therapeutic NMES When an electrical impulse is received at the neuromuscular junction (the junction between the ends of a myelinated nerve fibre and a muscle fibre), the response of a single motor unit to one action potential or impulse, is referred to as a twitch contraction. If a second impulse is received before the motor unit relaxes the motor unit will produce a further twitch contraction that fuses to the previous contraction. This is called a summate or fused contraction. When a train of impulses is received at a sufficient frequency for that particular type of motor unit, the summate contraction then becomes a tetanic or smooth contraction.

The striated muscles of the human body are composed primarily of two types of fibre. Type I is slow acting or slow twitch, slow oxidative muscle fibre, which has the characteristic of being fatigue resistant. This is the muscle fibre that is developed by long-distance runners.

Type II muscle fibre is described as fast acting or fast twitch, fast glycolytic which has the characteristic of providing bursts of intensive energy for short periods of time. This is the type of muscle developed by sprinters.

Fall and Lindstrom (1991) describe the effects of using different electrical frequencies to produce effects in fast and slow muscle fibre types. They suggest that slow fibres would best respond to frequencies of 10–20 Hz, whereas fast fibres would respond to 30–60Hz.

These parameters are used for the striated muscles of the pelvic floor, which is composed of about 70 per cent slow twitch and 30 per cent fast twitch fibres (Gilpin et al, 1989). However, according to Laycock and Vodusek (2002), it should be noted that if high frequencies are used, for example above 40Hz, the fast fibres will not relax between impulses and will produce a tetanic contraction. If a high frequency is maintained for several seconds it is capable of fatiguing fast fibres. Consequently most therapeutic muscle stimulation programmes are based on using a duty cycle with a rest phase to allow recovery of the motor units, and it is suggested that frequencies should not exceed 40–50Hz.

Conclusion There is little agreement on the optimum treatment parameters, but assessment of the client by a clinician who has a sound knowledge of the basic principles of NMES should result in an informed choice of the treatment parameters to be used. ■

BOX 1. PRECAUTIONS AND CONTRAINDICATIONS TO NEUROMUSCULAR

CONTRAINDICATIONS
- Acute inflammation of the perineum, vagina or anus
- Pacemaker
- Pregnancy
- Excessive vaginal bleeding
- Severe atrophic vaginitis
- Lack of sensation (internal or external)
- Pelvic malignancy
- Inability to understand or tolerate treatment

PRECAUTIONS
- Immediately postpartum
- Poor skin condition
- Diminished internal or external sensation
- Previous malignancy
- Body piercing
- Intra uterine device
- Haemophilia
- Epilepsy
- Sexual abuse

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