

TENS PROTOCOL

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INTRODUCTION

This protocol aims to provide an overview of Transcutaneous Electrical Nerve Stimulation (TENS), the choice of stimulation parameters and a guide to its application. The information on this website is primarily aimed as a guide for clinicians who want to use TENS for pain management. It should be stressed that this protocol is not designed to be exhaustive; for more detailed information on TENS, the reader is directed to a number of references at the end.

WHAT IS TENS?

TENS involves the application of electrical stimulation to the skin via surface electrodes to stimulate nerve fibres primarily for pain relief. In the field of electrotherapy, TENS is regarded as a low frequency current with most devices delivering currents at a frequency typically below 300Hz. Although TENS is primarily used for pain relief, there are several non-analgesic effects of this modality including its application for anti-emesis and wound healing. This protocol will only deal with the application of TENS for pain relief.

PAIN AND TENS

In a TENS electrode circuit, one electrode is positively charged (anode) and the other negatively charged (cathode). An action potential (nerve impulse) is initiated in the underlying nerve fibres by the flow of current between two TENS electrodes. TENS is believed to relieve pain by several mechanisms which involve the stimulation of specific types of nerve fibres:

1. Blocking the information travelling along the nociceptive fibres (i.e. those that produce pain) through stimulation of the large diameter afferent A β fibres; and,
2. Through the release of the body's endogenous opioids by stimulation of the small diameter afferent and motor fibres.

The type of nerve fibre stimulated, and thus the mechanism of pain relief, are determined by the stimulation parameters that are set on the TENS unit.

STIMULATION PARAMETERS

This section briefly describes the parameters of current, waveform, frequency, pulse duration and intensity; this is followed by a description of the four different modes of TENS that are basically different combinations of these parameters.

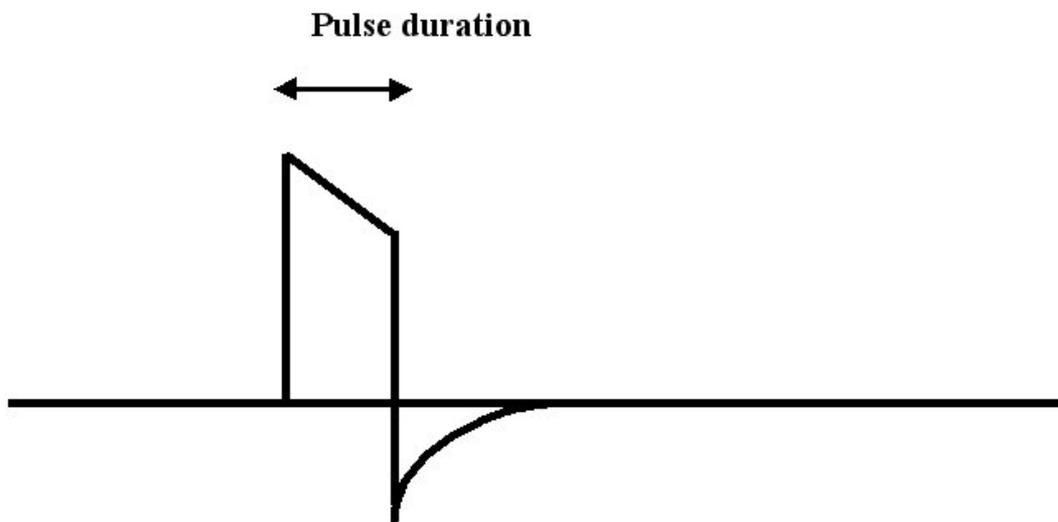
Current

TENS is a pulsed current, i.e. a current in which the unidirectional or bidirectional flow of current periodically ceases over time.

Waveform

The waveform of a current simply refers to its shape as seen on a graph of amplitude versus time. Usually TENS waveforms are described as asymmetrical biphasic rectangular or symmetrical biphasic rectangular; Figure 1 illustrates a typical TENS waveform.

Figure 1 TENS Waveform



A biphasic waveform means that current flows in both directions, therefore each electrode acts as a cathode (negative) for some part of the waveform. The waveform therefore has two components (or phases), a positive and a negative component which

represent the change in current flow. TENS waveforms usually have a zero net direct current (DC); this means that the amount of charge under the positive portion of the waveform is equal to the amount of charge under the negative portion of the waveform. The production of a zero net DC reduces the likelihood of chemical skin irritation; a direct current can potentially cause skin irritation due to the build up of ions of one charge under the electrodes.

Frequency

The frequency of a current refers to the number of pulses delivered per second; therefore a frequency of 200Hz means that 200 pulses are delivered per second.

Pulse Duration/Width

The unit of pulse duration is usually given in microseconds (μs) which are units of time, hence it is more correct to use the term 'duration' rather than 'width'. The pulse duration is usually defined as the duration of only the positive component of the waveform. TENS pulse durations are in the μs range ($1\mu\text{s} = 1 \times 10^{-6}\text{s}$).

Intensity/Amplitude

Intensity refers to the magnitude of current or voltage applied by the TENS unit. TENS units are typically designed with a constant current or constant voltage output. Basically this means that either the voltage or current (respectively) will vary to maintain a constant current or voltage amplitude (within limits) as the impedance (resistance) of the electrode-patient system changes. The intensity of a constant current unit is measured in milliamps and the intensity of a constant voltage unit is measured in volts.

Selecting a TENS unit

There are some factors that should be considered when selecting a TENS machine:

- There are typically four TENS modes used in clinical practice. Any commercially available unit should provide the necessary parameter ranges to allow all four modes to be set on the same unit. This requires variable frequency, pulse duration, and intensity settings, and burst versus continuous output.

- Units should have the parameter settings covered or in a position that they cannot be accidentally adjusted. This is important, as a sudden increase in intensity may produce an uncomfortable sensation beneath the electrodes.
- The size and shape of the controls/dials are important if the user has limited range of movement in the fingers, e.g. as a result of arthritis.
- The unit should be compact enough to facilitate the user wearing it while mobile when attached via a belt clip.
- The number of site(s)/area of pain will determine whether a single or dual channel unit is more appropriate.

TENS MODES

The four modes of TENS are described in this section.

Conventional TENS

Conventional or High frequency/Low intensity TENS is the most commonly used mode of TENS. The stimulation parameters are a low intensity, a high frequency typically above 100Hz and a short pulse duration (50-80µs). This combination of parameters stimulates the Group II (Aβ) afferent nerve fibres. Conventional TENS produces a sensation of comfortable paraesthesia (pins and needles) with no muscle contraction; although if the electrodes are placed over a motor point, some contraction is visible with higher stimulation intensities. As the Group II fibres are stimulated, this TENS mode achieves analgesia primarily by spinal segmental mechanisms, i.e. pain gate theory. Therefore the analgesia is of relatively rapid onset because local neurophysiological mechanisms are responsible; however, the analgesia tends to be comparatively short, typically lasting only for up to a few hours post treatment.

Acupuncture-like TENS

Acupuncture-like or Low frequency/High intensity TENS parameters include a low frequency (usually 1-4Hz), a high intensity (high enough to produce visible muscle contractions) and a long pulse duration (~200µs). Acupuncture-like TENS primarily stimulates the Group III (Aδ) and IV (C) nociceptive fibres and small motor fibres. As the mechanism of pain relief associated with this TENS mode requires afferent signals from muscle receptors, the electrodes should be positioned to produce visible muscle

contractions, e.g. over a myotome related to the painful area. The user will therefore experience paraesthesia and muscle contraction (twitching type) with this mode. As muscle contractions occur, additional sensory information is carried from the muscle spindle via muscle afferents. This mode of TENS is believed to operate primarily through the release of endogenous opioids via the descending pain suppression system; therefore, there is a relatively longer onset to analgesia but the analgesia typically lasts longer with this mode than with Conventional TENS.

Burst Train TENS

The Burst Train mode of TENS is really a mixture of Conventional and Acupuncture-like TENS, and comprises a baseline low frequency current together with high frequency trains of pulses. Typically, the frequency of the trains is 1-4 Hz with the internal frequency of the trains around 100Hz. Some patients prefer this to Acupuncture-like TENS because the pulse trains produce a more comfortable muscle contraction.

Brief, Intense TENS

This mode of TENS uses a high frequency (100-150Hz), long pulse duration (150-250 μ s) at the patient's highest tolerable intensity for short periods of time (< 15 minutes). This mode can be used for painful procedures such as skin debridement, suture removal etc.

Continuous, Burst and Modulated Outputs

Typically, most TENS units will allow the user to choose between continuous, burst and modulated outputs. The continuous and burst outputs are self-explanatory, the latter is used in Burst Train TENS as described above. The modulated output means that there is a variation in either pulse duration, frequency or amplitude parameters in a cyclic fashion. Indeed, some units have modulation of two or all three of these parameters. If the output is set for amplitude modulation, a cyclic modulation in amplitude is produced which increases from zero to a pre-set level then back to zero again. This choice of modulated output has been included by manufacturers apparently to overcome accommodation of nerve fibres and to provide more comfort to the patient.

CONTRAINDICATIONS

It is essential to screen potential TENS users for any relevant contraindications prior to the initial application. There are only a few contraindications to TENS and common sense prevails with the majority of them.

(i) Lack of normal skin sensation. A simple sharp/blunt test will determine if cutaneous innervation is intact. The danger of placing electrodes over skin which has a deficient sensation is that greater stimulus intensities will have to be employed which may cause skin irritation and even a burn. It is important to remember that treatment will be ineffective if the appropriate afferent nerves are not stimulated. If sensation is absent in a specific area, the electrodes may be placed proximal in an area which has intact sensation.

(ii) Patients who are incompetent or who do not comprehend the therapist's instructions should not be treated. If a patient is required to operate a TENS unit themselves, it is desirable that they are responsible individuals.

(iii) Electrodes should never be placed over the eyes or on the anterior aspect of the neck over the carotid sinuses. Stimulation in latter area may cause a drop in blood pressure. The carotid sinuses are located at the origin of the internal carotid arteries; they contain baroreceptors which detect changes in blood pressure.

(iv) Many texts include pregnancy as a contraindication to TENS but this requires clarification. This generally refers to placement of electrodes over the pregnant uterus, however some sources recommend not using TENS for any painful area during pregnancy despite the fact that no adverse reaction to TENS during pregnancy appears to have been reported to date. However, it is prudent not to place TENS electrodes over the trunk or pelvis during the first trimester. TENS electrodes should not be placed over the pregnant uterus except if TENS is used for labour pain.

(v) TENS has been shown to interfere with certain types of cardiac pacemakers. Therefore if TENS is indicated for this type of patient, the clinician is advised to consult with the patient's cardiologist before embarking on a TENS trial. It would be advisable to perform an initial trial with concomitant ECG/ Holter monitoring when a patient with a pacemaker is considered for TENS treatment.

(vi) If the patient has an allergic reaction to the electrode gel or tape, this can usually be ascertained in the first treatment. If this occurs, the clinician should change to another type of electrode/tape.

(vii) Patients who have epilepsy should be treated at the discretion of their clinician.

(viii) Patients should be advised not to wear TENS while driving or operating machinery.

THE APPLICATION OF TENS

Figure 2 provides a summary of the recommended steps involved in the application of TENS for the first time.

A detailed physical assessment, recording of relevant medical history and diagnosis of the pain are essential before proceeding with any treatment. It is very important that TENS is demonstrated to a patient by a suitably qualified health professional, e.g. Chartered Physiotherapist or Physician. If the patient is taking pain medication, the initial TENS trial should be performed when the analgesic effects of the medication have worn off, otherwise a normal analgesic effect of the patient's medication may be mistaken for a positive treatment response. Once the patient is satisfactorily screened

for contraindications, the TENS treatment should then be adequately explained to the patient. Ideally this should include the therapist attaching the electrodes over a visible body area on the patient (e.g. the arm/forearm) and applying the current to allow the patient to experience the sensation. The patient should be positioned comfortably with the affected limb/body part suitably supported and instructed not to move, nor touch the electrodes during the treatment. The skin should be cleansed with soap and water or an alcohol swab to remove surface lipids.

Selection of TENS Parameters

A number of points must be considered before making a decision on which TENS parameters to select:

(i) What type of pain is involved? Quite often the patient's symptoms will dictate which pulse frequency to use. For example, if a patient has sustained an acute soft tissue injury of the shoulder, a low frequency current may exacerbate the symptoms by causing pulsing contractions in the traumatised muscle.

(ii) Where to place the electrodes? If treating a bony area devoid of muscle tissue, there is no point using Acupuncture-like TENS because muscle contractions are desirable for this mode of TENS.

(iii) It is always advisable to commence treatment using Conventional TENS. Most patients find the 'tingling, buzzing' sensation associated with this type of TENS more comfortable than the sensation and muscle contractions experienced with Acupuncture-like TENS. Even if pain relief is achieved with Conventional TENS, Acupuncture-like TENS should still be tried for at least one treatment during the TENS programme and any variation in the length and amount of analgesia noted. It is good practice to try out both Conventional and Acupuncture-like TENS because often dramatic differences are noted in the same patient.

The intensity of the TENS should be increased slowly and the patient asked to report the onset of any sensation under the electrodes. Once this is reported, the intensity should be increased slowly until this sensation is 'strong but comfortable'. The patient should be warned that if the intensity is too high then the most beneficial effects will not be achieved. In the application of Acupuncture-like TENS, the production of muscle contractions is desirable but the patient should be able to tolerate the intensity.

Treatment Time

The first TENS treatment should be kept short (< 30 mins) to allow the patient to get used to the sensation and to allow the therapist to monitor any adverse reactions, e.g. allergies to electrode tape/gel or if the patient simply cannot tolerate electrical stimulation. After the initial treatment, TENS can be applied up to an hour at a time. Personal experience has led the author to advise a maximum treatment period of one hour at a time. If TENS is being used at home, the patient should be advised to use the TENS as often as required but only for one hour at a time. If a unit is worn for several consecutive hours, as some sources recommend, the skin underneath the electrodes often gets irritated. Taking half hour breaks between applications will reduce the likelihood of skin irritation. Further, with Acupuncture-like TENS, the patient will experience muscle contractions and therefore with prolonged stimulation they may experience muscle fatigue. However, there are two good examples of conditions where TENS is applied continuously: labour pain and post-operative pain.

Electrode Placement Sites

One of the primary factors responsible for a poor response to TENS treatment is ineffective electrode placement. The therapist must therefore be prepared to try several sites before deciding on an optimal placement site; thus some degree of 'trial and error' is involved in this aspect of the treatment regime which will ultimately serve to provide a more successful treatment. Essentially, there are four broad

categories of anatomical site to which TENS electrodes can be applied - painful area, peripheral nerve, spinal nerve roots and other specific points (acupuncture, trigger and motor points). Irrespective of the electrode site that is chosen, stimulation will ultimately result in the passage of afferent information into the central nervous system. In each of the four categories, an appropriate degree of anatomical knowledge is essential in order to achieve effective stimulation.

(i) Painful area

Positioning electrodes over or close to the painful site itself is probably the most commonly used electrode site. As it is desirable with Conventional TENS to achieve a sensation of paraesthesia over the affected area, electrodes may be placed at proximal and distal ends of the painful area. If sensation is diminished or absent, the electrodes can be placed just proximal to this site (over normal innervated skin) in order to stimulate the afferent sensory nerves travelling to the spinal cord from the affected area. There are occasions when the application of electrodes at the painful site would prove uncomfortable for the patient, e.g. hypersensitivity following a peripheral nerve injury. In such situations, it may also be more appropriate to place the electrodes proximal to the area of hypersensitivity.

(ii) Peripheral nerve

The electrodes may also be placed over a peripheral nerve which has a cutaneous distribution in the painful area. For example, pain experienced on the dorsum of the lateral aspect of the hand and the first and second digits can be treated with electrodes placed over the superficial radial nerve along its course on the lateral aspect of the lower one third of the forearm.

(iii) Spinal nerve roots

Thirty-one pairs of spinal nerves emerge from the vertebral column via the intervertebral foramen. Each spinal nerve is formed by the union of ventral (motor)

and dorsal (sensory) roots which unite in the intervertebral foramen to form a mixed spinal nerve. Placement of electrodes parallel to the vertebral column (paraspinal application) and over the intervertebral foramen will allow for stimulation of the appropriate roots of spinal nerves which supply the affected dermatome, i.e. the area of skin which receives its nerve supply from a specified spinal nerve.

(iv) Acupuncture, motor and trigger points

The final category for electrode placement is a group of points referred to as *specific points* of which there are essentially three types - acupuncture, motor and trigger points. A motor point is the point of entry of a motor nerve into a muscle and is characterised by high electrical conductance and low skin resistance. Motor points are thus used for optimal stimulation of a muscle and therefore may be effectively employed as electrode placement sites when applying Acupuncture-like TENS when muscle contraction is desirable. Trigger points are areas characterised by tenderness on palpation and the production of referred pain. In contrast, acupuncture points are well defined specific points which Traditional Chinese Medicine (TCM) asserts can be stimulated to treat disease.

The ultimate choice of electrode site depends upon accurate assessment of the cause and location of the pain and also the type of TENS to be used. If Conventional TENS is used, the desired sensation is that of a comfortable paraesthesia, therefore it follows that it is undesirable to place the electrodes over a bony prominence (e.g. the malleoli) as this would produce a rather uncomfortable sensation for the patient. In contrast, when Acupuncture-like TENS is used, it is desirable to produce visible muscle contractions, therefore placement of electrodes should be over a muscle related to the area of pain (can use appropriate motor point/myotome).

Types of Electrode

Self-adhesive and carbon electrodes are the two most common types of electrode. The latter can be used applied using a wet gel or hydrogel pad, either with or without the use of tape. Self-adhesive electrodes are now widely available in a broad range of shapes and sizes, which makes it easier to apply TENS for a variety of pain conditions. The main factors that determine the type of electrode used include allergic reaction, cost, ease of use and availability.

Application and Attachment of Electrode

The self-adhesive electrode is the easiest type of electrode to apply. If wet gel is used, care must be taken that it is spread evenly over the surface of the electrode. Alternatively if a hydrogel pad is used, care must be taken that there are no air bubbles.

It is essential that there is uniform skin-electrode contact to ensure equal distribution of the current. If micropore tape is used to secure electrodes as in a carbon rubber electrode and gel application, it is important that the strips of tape cover the electrode evenly. The tape should be removed in the direction of the hair growth in the area to avoid discomfort to the patient and also to reduce the possibility of skin irritation/infection due to the removal of body hair. In some cases, it may be appropriate to remove body hair before applying the electrodes if it prevents tape or electrodes from adhering.

It is important to know that inter-electrode distance will affect both the current density and depth of penetration of the current. Current density decreases with distance from the electrodes due to a high electrical impedance of the deeper tissues. If the inter-electrode distance is decreased, current density in the area between the electrodes will increase and the depth of penetration decreases. Conversely with a greater inter-electrode distance, the current density is less but the depth of penetration is greater.

Position of Anode and Cathode

The patient will typically feel a stronger sensation under the cathode (red electrode) compared to the anode – this is because the cathode is the active electrode. As a general rule, the cathode should be positioned closest to the spinal cord. However, if applying TENS to an acupuncture or motor point, the cathode should be placed over that specific point.

COMMON PROBLEMS AND THEIR SOLUTIONS

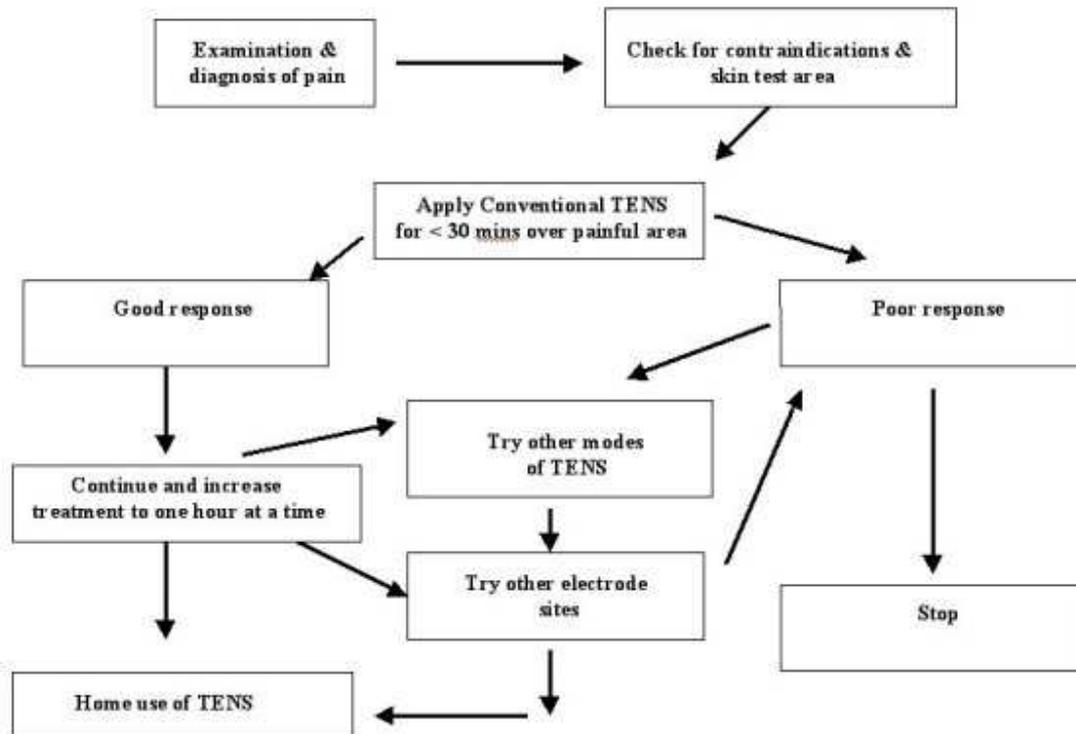
Skin Irritation

First, determine the cause of the irritation, e.g. allergic reaction to electrode/tape/gel or wearing TENS for prolonged period. It is very important to allow the skin to heal before applying the electrodes over irritated skin. While the skin is healing, the electrode can be applied at a different site, e.g. over the peripheral nerve or spinal nerve roots. If the user is allergic to the electrode, try another type. Hypoallergenic electrodes/tape are available from several manufacturers. Always allow the skin to breathe after wearing TENS for the recommended one-hour period. This means that the electrodes should be removed completely.

No Pain Relief

There are a certain number of people who will not respond to TENS but it is important to try the various TENS modes and electrode placement sites before concluding that the user is a non-responder. It is recommended to follow the step by step procedure as detailed in the sections above and illustrated in Figure 2. It is very important to always compare the results of Conventional and Acupuncture-like TENS. In addition, the therapist must experiment with different electrode placement sites. If all these options have been exhausted and there is still no pain relief obtained, then TENS will not work for the user.

Figure 2 Overview of TENS Procedure



Electrodes Dry Out

Self-adhesive electrodes can be wet with a few drops of water and then let air dry to increase their adhesiveness. It is important to follow the manufacturer's instructions for this procedure.

Skin's Resistance to TENS

Some skin moisturisers and creams will increase the skin's resistance to electrical current. This will result in having to increase the intensity very high before feeling any sensation. It is therefore very important to prepare the skin before application of the electrodes, i.e. clean the skin with soap and water or an alcohol swab.

If Acupuncture-like TENS is not Tolerated

Some individuals cannot tolerate the high intensity required to produce visible muscle contractions when using Acupuncture-like TENS. If this is the case, try switching to Burst Train mode. Some studies have shown that users will tolerate higher intensities with the latter mode while still achieving the desired muscle contraction. Alternatively, switch the output to burst instead of continuous while keeping the Acupuncture-like TENS settings.

REFERENCES

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