Transcutaneous electrical nerve stimulation

Iain Jones MB ChB FRCA
Mark I Johnson PhD

Key points

Transcutaneous electrical nerve stimulation (TENS) is an inexpensive, self-administered technique with no known potential for overdose.

TENS is used as a stand-alone treatment for mild to moderate pain and as an adjunct to pharmacotherapy for moderate to severe pain.

Pain relief is maximal when strong non-painful TENS paraesthesiae are experienced beneath the electrodes, so patients may need to administer TENS throughout the day.

TENS selectively activates low-threshold peripheral afferents (A-β) which inhibits ongoing nociceptive transmission in the central nervous system.

Iain Jones MB ChB FRCA
Clinical Fellow Pain Management
Pain Management Services
Leeds Teaching Hospitals
Leeds, UK
Leeds Pallium Research Group
Leeds, UK

Mark I Johnson PhD
Professor of Pain and Analgesia
Centre for Pain Research
Faculty of Health
Leeds Metropolitan University
Civic Quarter
Leeds LS1 3HE, UK
Tel: +44 113 2832600
Fax: +44 113 2833124
E-mail: m.johnson@leedsmet.ac.uk
(for correspondence)
Leeds Pallium Research Group
Leeds, UK

Transcutaneous electrical nerve stimulation (TENS) is a non-invasive analgesic technique that is used to relieve nociceptive, neuropathic, and musculoskeletal pain.[1] During TENS, pulsed electrical currents are generated by a portable pulse generator and delivered across the intact surface of the skin via the self-adhering conducting pads called electrodes (Fig. 1). Patients can self-administer TENS and titrate dosage as required, as there is no potential for toxicity. In the UK, 'standard' TENS devices can be purchased without medical prescription for approximately £30. Factors predicting success with TENS are not known; so, any patient may respond to TENS.

Historical context

Using electricity to relieve pain is not new; for example, ancient Egyptians and Romans used electrogenic fish to treat ailments. The development of electrostatic generators increased the use of electricity in medicine, although popularity waned in the late nineteenth century because of variable clinical results and the progress of pharmacological treatments. Interest was reawakened in 1965 by Melzack and Wall, who provided a physiological rationale for electroanalgesic effects. They proposed that the transmission of noxious information could be inhibited by activity in large diameter peripheral afferents or by activity in pain inhibitory pathways descending from the brain. High-frequency percutaneous electrical stimulation of large diameter peripheral afferents was shown to relieve neuropathic pain and stimulation of dorsal columns to relieve chronic pain. Initially, TENS was used to predict the success of dorsal column stimulation implants until it was realized that TENS could be used as a successful modality on its own.

Definition

By broad definition, TENS is anything that delivers electricity across the intact surface of the skin to activate underlying nerves. A standard TENS device delivers biphasic pulsed currents in a repetitive manner using pulse durations of 50–250 μs and pulse frequencies of 1–200 pulses s^{-1} (Fig. 2). A number of TENS-like devices have come on the market in recent years with limited success.

Different TENS techniques are used to selectively activate populations of nerve fibres to elicit mechanisms leading to pain relief. The main techniques are conventional TENS (low intensity, high frequency), acupuncture-like TENS (high intensity, low frequency), and intense TENS (high intensity, high frequency) (Table 1). Conventional TENS is most commonly used in clinical practice and will be the main focus of this review.

Postulated mechanisms of action

Low-intensity non-noxious TENS paraesthesiae (conventional TENS) relieves pain by a segmental mechanism (Fig. 3). Higher intensity TENS increases the likelihood of activating extrasegmental descending pain inhibitory pathways and activating diffuse noxious inhibitory controls via counter irritant effects. TENS will also cause peripheral blockade of afferent impulses that have arisen from a peripheral structure.[1]

Segmental mechanisms

Evidence from animal studies shows that TENS reduces ongoing nociceptive cell activity and sensitization in the central nervous system when applied to somatic receptive fields. TENS-induced A-δ activity causes long-term depression of central nociceptive cell activity for up to 2 h.

Extrasegmental mechanisms

TENS-induced activity in small diameter afferents (A-δ) leads to activation of the

doi:10.1093/bjaceaccp/mkp021 Advance Access publication 26 June, 2009

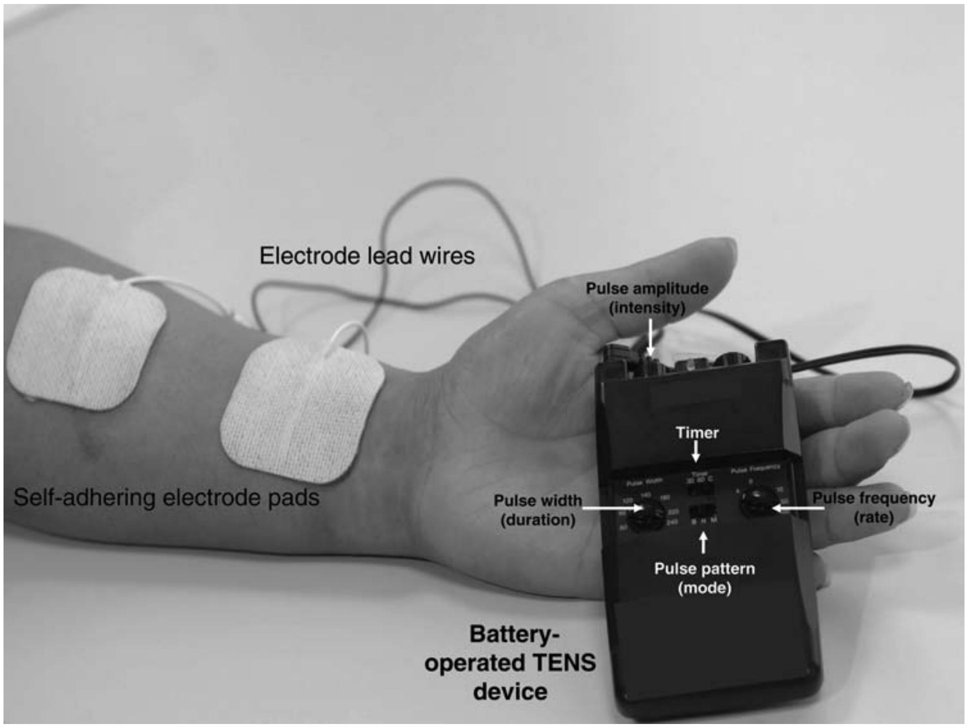

Fig 1 A battery-operated TENS device.

midbrain periaqueductal grey and rostral ventromedial medulla (i.e. descending inhibitory pathways) and inhibition of descending pain facilitatory pathways. Larger effects have been observed, when muscle rather than skin afferents are used.

Peripheral mechanisms

TENS generates nerve impulses that will collide and extinguish noxiously induced orthodromic impulses arising from peripheral

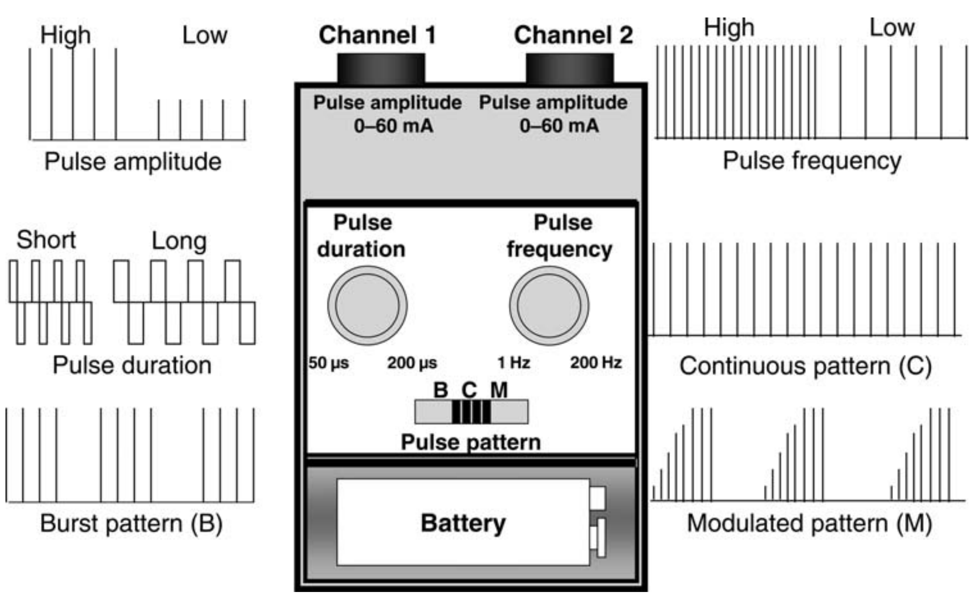

Fig 2 A standard TENS device delivers biphasic pulsed currents with durations of 50–250 μs and pulse frequencies of 1–200 pulses s^{-1}.

Table 1 TENS techniques

	Physiological intention	Clinical technique
Conventional TENS	Selective activation of large diameter non-noxious afferents to elicit segmental analgesia	Low-intensity/high-frequency TENS at site of pain to produce ‘strong but comfortable TENS paraesthesiae’. Administer whenever in pain
Acupuncture-like TENS	Activation of small diameter (motor) afferents to elicit extrasegmental analgesia	High-intensity/low-frequency TENS over muscles, acupuncture points, or trigger points to produce ‘strong but comfortable muscle contractions’. Administer for 15–30 min at a time
Intense TENS	Activation of small diameter afferents to elicit peripheral nerve blockade and extrasegmental analgesia	High-intensity/high-frequency TENS over nerves arising from painful site to produce ‘maximum tolerable (painful) TENS paraesthesiae’. Administer for a few minutes at a time

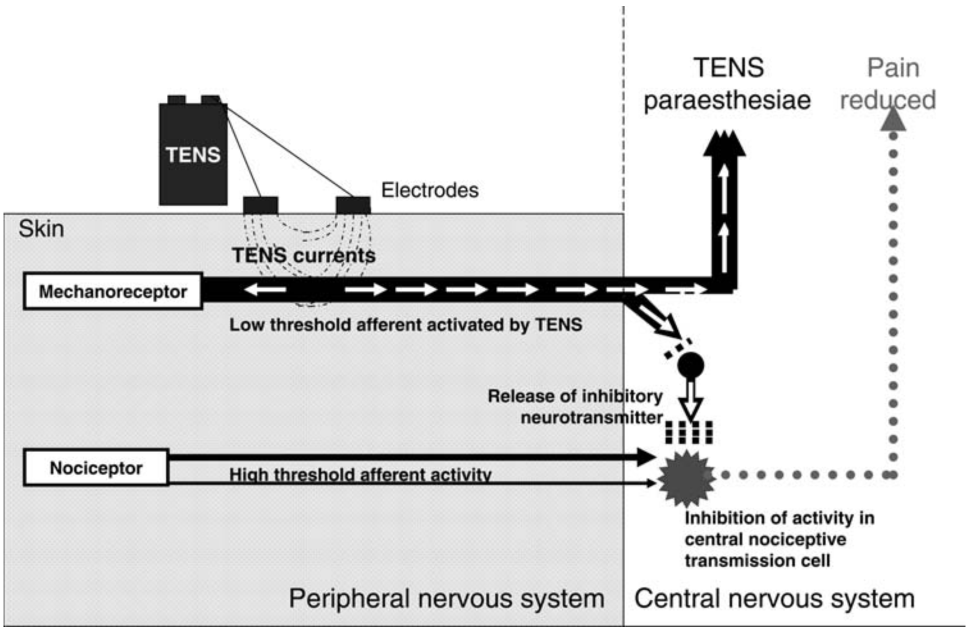

Fig 3 Postulated mechanisms of action for TENS-induced analgesia.

structures. Peripheral blockade of nociceptive impulses is more likely when TENS activates A-δ fibres (i.e. intense TENS). TENS-induced activity in large diameter afferents (i.e. conventional TENS) will block afferent activity in large diameter fibres that may be contributing to pain.

Neurotransmitters

TENS effects are mediated by many neurotransmitters, including opioids, serotonin, acetylcholine, norepinephrine, and gamma-aminobutyric acid. Low- but not high-frequency TENS has been shown to involve μ-opioid and 5-HT_2 and 5-HT_3 receptors. High- but not low-frequency TENS has been shown to involve δ-opioid receptors and reduce aspartate and glutamate levels in the spinal cord.[2]

Whether these mechanisms translate into clinically meaningful differences in pain outcome in humans is a matter for debate. Studies using pain-free volunteers have shown that TENS hypoalgesia is greater than with sham TENS, but the relationship between pulse frequency and outcome is equivocal.[3]

Clinical application

All new TENS patients should be given a supervised trial of TENS. This ensures that TENS does not aggravate pain and will provide an opportunity to troubleshoot problems arising from poor response. In the first instance, conventional TENS is administered because it is commonly used by long-term TENS patients. An early review of progress can serve to ensure correct application, provide further instruction, and to recall TENS devices, which are no longer, required.

Electrodes should be positioned on sensate skin on relevant dermatomes. Usually, TENS paraesthesiae is directed into the painful area (Fig. 4), although this is not appropriate if tactile allodynia is present because TENS may aggravate the pain. Alternative positions are main nerves proximal to the site of pain, paravertebrally at appropriate segments, or at contralateral ‘mirror’ sites. During

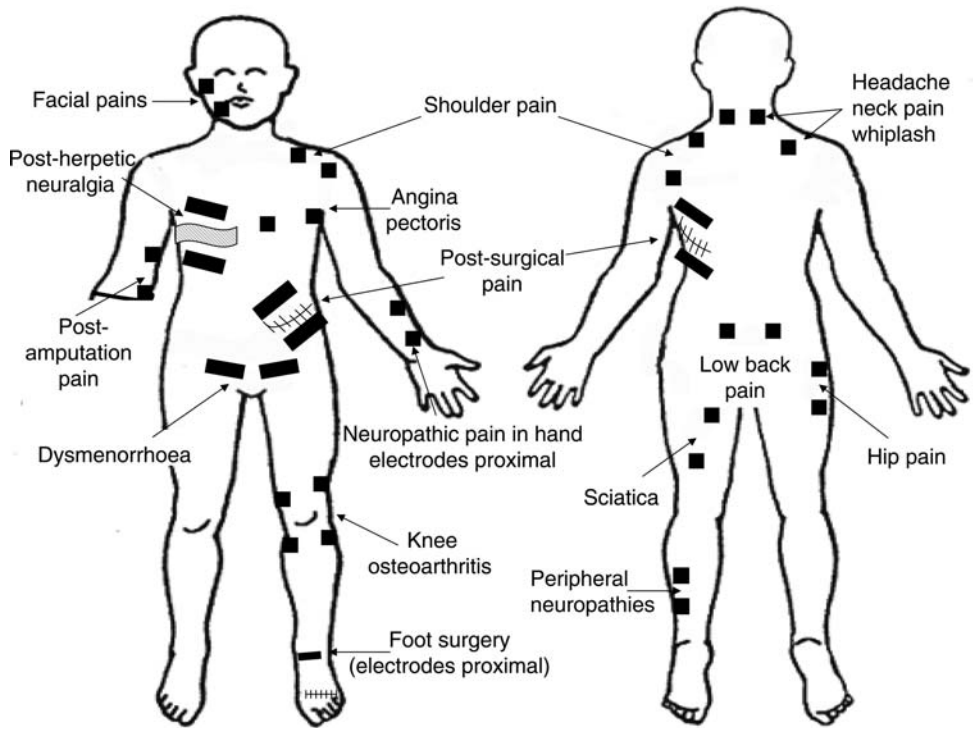

Fig 4 Frequently used sites for TENS therapy.

conventional TENS, a strong non-painful electrical paraesthesia is necessary, so the user is required to titrate TENS amplitude to the desired level.

Patients should not use TENS in water or when operating hazardous machinery such as driving. Children as young as 4 yr old can tolerate TENS, providing that they are able to comprehend instructions.

Contraindications and precautions

Serious adverse events from TENS are rare. Occasional reports of mild electrical burns with TENS-like devices are due to an inappropriate technique. Some patients experience mild autonomic responses and minor skin irritation beneath electrodes. TENS can interfere with monitoring equipment and should not be placed close to transdermal drug delivery systems.

Guidelines produced by the UK Chartered Society of Physiotherapy list cardiac pacemakers and bleeding disorders as contraindications.[4] TENS manufacturers list cardiac pacemakers, pregnancy, and epilepsy as contraindications because it may be difficult to exclude TENS as a potential cause of a problem from a legal perspective. Many centres regard these as contraindications. However, some specialists believe that it is possible to use TENS in these patient groups, providing that it is not applied locally and the situation is discussed with the relevant medical specialist and patient. Patient progress should be carefully monitored.

Pacemakers and cardiovascular problems

TENS has been shown to interfere with pacemaker function. For example, Holter monitoring has demonstrated interference with a cardiac pacemaker; in both instances, the sensitivity of the pacemaker was reprogrammed to resolve the problem. The manufacturers regard TENS as a contraindication in this situation and many centres have adopted this. Some specialists will utilize TENS in the presence of a pacemaker, providing that it is applied away from the chest area, but it is recommended that this is done in close consultation with a cardiologist and not undertaken by non-specialists. TENS is often used over the chest for angina with much success; again, the situation should be discussed with a cardiologist.

Electrodes should never be applied on anterior and posterior areas of the chest as this may compromise pulmonary ventilation due to excessive stimulation of the intercostal muscles. Electrodes should not be placed over areas where there has been recent haemorrhage as the currents may cause further haemorrhage. TENS should not be applied directly over ischaemic tissue, thrombosis, or both because of the potential for embolism.

Pregnancy

TENS should not be administered over the abdomen or pelvis during pregnancy because the effects of TENS on fetal development are still unknown and currents could inadvertently cause uterine contractions and induce premature labour. Potential hazards away from these sites seem minimal, but many still regard this as a contraindication.

Epilepsy

Practitioners should be cautious when giving TENS to patients with epilepsy and should not apply electrodes to the neck or head. TENS-induced seizures in a post-stroke patient have been reported, so TENS should be used with care in these patients.

Inappropriate electrode sites

TENS should not be applied over the anterior neck as this may produce a hypotensive response, laryngeal spasm, or both. TENS should not be delivered over the eyes as it may cause an increase in intraocular pressure.

Malignancy

It is advised not to apply TENS directly over areas of active malignancy except in palliative care and under the supervision of a specialist. A recent case series highlighted the potential benefit of TENS for cancer bone pain.[5]

Dermatological conditions or frail skin

TENS electrodes should not be applied on areas of broken or damaged skin, such as open wounds, although they can be applied over healthy tissue surrounding a wound.

Dysaesthesia

TENS should not be applied to skin with diminished sensation because nerve damage is likely to diminish TENS effectiveness and the patient may be unaware that high-intensity currents are causing skin irritation. Caution is needed when using TENS in the presence of mechanical allodynia as TENS may exacerbate the pain.

Evidence for clinical effectiveness

The Compendium of Audit Recipes published by the Royal College of Anaesthetists identifies patient satisfaction as a key target of performance. Many patients report satisfaction with TENS treatment. Clinical experience suggests that TENS is useful as a stand-alone treatment for mild to moderate pain and in combination with pharmacotherapy for moderate to severe pain. Clinical research is less convincing. Systematic reviews of TENS are often inconclusive. Negative findings in randomized controlled trials (RCTs) have been attributed to inadequate sample sizes, inappropriate TENS technique, underdosing of TENS, measuring outcome after TENS had been switched off, and using pain as an outcome when participants in sham and active TENS groups had access to additional analgesics.

Postoperative pain

Reports that TENS reduced postoperative pain and analgesic consumption were not confirmed by an early systematic review.[6] A subsequent meta-analysis of 21 RCTs found a reduction in analgesic consumption in favour of TENS only when trials met criteria for adequate TENS technique (i.e. a strong, sub-noxious electrical stimulation at the site of pain).[7] A Cochrane review of 24 RCTs concluded that stimulation of the P6 acupoint on the wrist using acupuncture, TENS, and related stimulation techniques was better than placebo in reducing nausea and vomiting within 6 h of surgery.

Labour pain

TENS is applied to areas of the spinal cord that correspond to the input of nociceptive afferents associated with the first and second stages of labour. Despite favourable reports from parturients and midwives, systematic reviews on TENS and labour pain conclude that evidence for TENS analgesia during labour is weak. Two good quality RCTs found that women favoured active TENS compared with sham TENS under double-blind conditions.

Other acute pain conditions

A Cochrane review found that TENS reduced symptoms of primary dysmenorrhoea when administered using high-frequency currents. RCTs support potential efficacy for angina, acute orofacial pain, painful dental procedures, fractured ribs, and acute lower back pain. There is insufficient good quality evidence to make definitive conclusions at present.

Chronic pain

Clinical experience suggests that TENS may relieve any type of chronic pain, yet systematic reviews are inconclusive for chronic pain, low back pain, cancer-related pain, rheumatoid arthritis of the hand, post-stroke shoulder pain, whiplash and mechanical neck disorders, and chronic recurrent headache. Meta-analyses for osteoarthritic knee pain[8] and for chronic musculoskeletal pain[9] have been more positive, suggesting that TENS is superior to sham TENS for pain and stiffness. Non-randomized controlled clinical trials have found benefit for many types of chronic pain. Patients may need to administer TENS throughout the day to achieve best effects.

Recent developments

Developments in technology have resulted in a proliferation of TENS-like devices on the market, including interferential current therapy, microcurrent electrical therapy, transcutaneous spinal electroanalgesia, H-wave therapy, Pain®Gone, transcranial electrical stimulation, and transcutaneous electrical acupoint stimulation

(ReliefBand). Most have met with limited success.[10] Recently, hand-held TENS-like devices without self-adhering electrodes have been developed to scan the skin for regions of low skin impedance to target TENS treatment more effectively.

Conclusion

TENS is used extensively in health care because it is inexpensive, safe, and can be administered by patients themselves. Success depends on appropriate application. Systematic reviews have been compromised by poor quality RCTs. Better quality trials are needed to determine differences in the effectiveness of different types of TENS and to compare cost-effectiveness with other analgesic interventions.

References

1. Johnson M. Transcutaneous electrical nerve stimulation. In: Watson T, ed. *Electrotherapy: Evidence-based Practice*. Edinburgh: Churchill Livingstone, 2008; 253–96
2. Sluka K. TENS mechanism of action. In: Schmidt RF, Willis WD, eds. *Encyclopedia of Pain (Muscle Pain Management)*. Berlin: Springer-Verlag, 2007; 2406–9
3. Chen C, Tabasam G, Johnson M. Does the pulse frequency of transcutaneous electrical nerve stimulation (TENS) influence hypoalgesia? A systematic review of studies using experimental pain and healthy human participants. *Physiotherapy* 2008; **94**: 11–20
4. Chartered Society of Physiotherapy C. Guidance for the clinical use of electrophysical agents. London: Chartered Society of Physiotherapy, 2006
5. Searle RD, Bennett MI, Johnson MI, Callin S, Radford H. Letter to editor: transcutaneous electrical nerve stimulation (TENS) for cancer bone pain. *Palliat Med* 2008; **22**: 878–9
6. Carroll D, Tramer M, McQuay H, Nye B, Moore A. Randomization is important in studies with pain outcomes: systematic review of transcutaneous electrical nerve stimulation in acute postoperative pain. *Br J Anaesth* 1996; **77**: 798–803
7. Bjordal JM, Johnson MI, Ljunggreen AE. Transcutaneous electrical nerve stimulation (TENS) can reduce postoperative analgesic consumption. A meta-analysis with assessment of optimal treatment parameters for post-operative pain. *Eur J Pain* 2003; **7**: 181–8
8. Bjordal JM, Johnson MI, Lopes-Martins RA, Bogen B, Chow R, Ljunggren AE. Short-term efficacy of physical interventions in osteoarthritic knee pain. A systematic review and meta-analysis of randomised placebo-controlled trials. *BMC Musculoskelet Disord* 2007; **8**: 51
9. Johnson M, Martinson M. Efficacy of electrical nerve stimulation for chronic musculoskeletal pain: a meta-analysis of randomized controlled trials. *Pain* 2007; **130**: 157–65
10. Johnson M. Transcutaneous electrical nerve stimulation (TENS) and TENS-like devices. Do they provide pain relief? *Pain Rev* 2001; **8**: 121–8

Please see multiple choice questions 21–25