UniTENSional pacemaker interactions with transcutaneous electrical nerve stimulation

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Transcutaneous electrical nerve stimulation (TENS) is a technique used to relieve pain by applying electrical energy to peripheral nerves via skin electrodes placed over the region of maximal pain. The technique has been available since the 1970s and is widely used for the treatment of acute and chronic pain in a variety of clinical settings (e.g. musculoskeletal pain, back pain, cancer pain, postoperative pain, neuropathic pain, dysmenorrhoea, and angina pectoris). Despite the lack of solid data of efficacy from randomized clinical trials, it has gained popularity with both patients and healthcare professionals as TENS devices are portable, easy to use, have relatively few side effects or contraindications, and allow the users autonomy over their pain control, with relief of pain that may last after TENS application. It is believed that the mechanism of action is explained by the ‘gate control theory’ described by Melzack in 1965. Based on the principle that there is a gateway in the dorsal horn of the spinal cord which controls or regulates pain messages that are then sent to and from higher levels of the brain, thus reducing the perception of pain. Pain may thereby be alleviated by using peripheral stimulation, such as rubbing, vibration, heat or cold, or as in the case of TENS, electrical stimulation, directly over the area of pain. Other postulated mechanisms of the pain relief mediated by TENS include the promotion of endorphin release and possibly coronary vasodilation in angina pectoris. Several types of TENS applications, differing in frequency, amplitude, pulse width and waveform are used in clinical practice. The two most common application modes are: (i) high frequency or conventional TENS (continuous stimulation at a frequency ≥ 80 Hz, low intensity sufficient to produce a comfortable tingling sensation) and (ii) low frequency or the so-called acupuncture-like TENS (bursts at a frequency of ≤ 10 Hz, high intensity sufficient to elicit muscle twitching). Patient response to different stimulations are variable, and TENS settings are therefore usually individualized.

Due to the ubiquitous applications of TENS, patients equipped with pacemakers (PMs) or implantable cardioverter defibrillators (ICDs) may potentially be exposed to this therapy. Carlsson et al. studied 27 patients implanted with a single- or dual-chamber PM subjected to TENS with electrodes placed above each mamilla and found inhibition of ventricular pacing in 52% of patients (and in as many as 81% of patients when maximal sensitivity was programmed). Inhibition of PMs by TENS has already been described by Eriksson et al. in 1978 in four PM patients. A subsequent study of 51 PM patients reported no interaction with TENS, as long as the TENS electrodes were not placed parallel to the PM electrode vector. It should also be mentioned that TENS was not applied to the chest wall and only at a distance from the PM (to the lumbar area, cervical spine, left leg, and lower arm area ipsilateral to the PM). Position of the TENS electrodes with respect to the PM is probably important, not only in terms of orientation of the patches (which determines the electrical vector and thus affects the amplitude of the sensed signal according to the orientation of the PM/ICD lead dipole), but also in terms of distance from the leads. In a recent report in 30 ICD patients from the group of the University of Gothenburg (who are also the authors of the article), TENS applied at the hip level resulted in less frequent interference than at the mamillary level (23 vs. 53%).

Interference of alternating electromagnetic fields with PMs results in oversensing with either inhibition of pacing or, in the case of high frequency signals (e.g. > 5 Hz), noise reversion. In the study by Carlsson et al., TENS applied at 2 Hz was found to result in less frequent interference than at 80 Hz. However, this finding only applies to inhibition of pacing, as interference was only tested for by analysing the surface ECG during pacing in the VVI mode at ≥ 90 bpm (above intrinsic heart rate). Therefore, noise reversion (which results in asynchronous pacing at the programmed lower rate) could not be identified in their study. Noise reversion may be a problem in PM patients, as it results in loss of atrioventricular synchrony (which is particularly important for cardiac resynchronization therapy) and also carries a risk of pro-arrhythmia in the case of ventricular pacing during the
TENS is proposed in Table 1.

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<th>Patient considerations</th>
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<td>TENS should be avoided in pacemaker-dependent and in ICD patients (consider SCS as an alternative as it probably carries a lower risk of interaction).</td>
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<td>Spend sufficient time in explaining the proper use of TENS to the patient, as well as the possible interactions their PM/ICD might experience.</td>
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Testing for interaction

- Always test for device interaction
- Prior to using TENS for the first time
- In case of modification of TENS parameters (e.g., electrode position)
- In case of major changes in pacemaker configuration
- During in-office testing, continuously monitor device electrograms and marker channels for oversensing during TENS application
- Test different TENS settings (frequency, amplitude)
- Test at different programmed device sensitivities
- Perform a 24-h Holter for evaluating pacemaker inhibition or noise reversion (asynchronous pacing)

TENS considerations

- Place TENS electrodes as far away as possible from the pacing leads
- If possible, place TENS electrodes perpendicular to the pacing lead dipole and at close proximity to each other (to reduce the electrical field)
- Use TENS of lowest possible amplitude (that gives acceptable results)

Device programming

- Use bipolar sensing if possible
- Activate mode switch function
- Programme lowest acceptable sensitivity

As an alternative to TENS, spinal chord stimulation (SCS) may be used to alleviate pain and probably carries a lower risk of interaction with PMs and ICDs due to lower stimulation amplitude. Bipolar SCS for refractory angina pectoris has been found to be safe in a report of 18 PM patients as well as in a case report of a patient with an ICD. However, this therapy is invasive and relatively costly and is usually restricted to patients without other treatment options. It would be desirable that PM/ICD manufacturers develop algorithms that allow better discrimination of electromagnetic interference from cardiac signals. Also, different TENS protocols that may result in less interaction with PMs and ICDs should be explored.

Conflict of interest: none declared.

References