Implantable technology for pain management

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Abstract

Neuropathic pain is a well-recognized chronic pain condition. This can have a significant impact in patients' quality of life. Neuromodulation is defined by the International Neuromodulation Society as 'the therapeutic alteration of activity in the central or peripheral nervous system either electrically or pharmacologically'. Electrical stimulation can be performed at the motor cortex, deep brain, spinal cord, dorsal root ganglion, peripheral nerve and peripheral nerve field. Pharmacological modulation is achieved by directly infusing drugs to the central nervous system. Although neuromodulation has become increasing popular, it is still currently believed to be underused in treating neuropathic pain. This modality has provided us with a non-pharmacological approach to manage patients with neuropathic pain. Patients should have been assessed by a multidisciplinary team before undergoing neuromodulation. This review highlights the present and future management of patients with chronic intractable pain using neuromodulation.

Keywords Burst stimulation; dorsal root ganglion stimulation; high-frequency stimulation; neuromodulation; spinal cord stimulation; wireless spinal cord stimulation

Royal College of Anaesthetists CPD Matrix: 1D02, 3E00

Learning objectives

After reading this article, you should be able to:

- explain the difference between electrical and chemical neuromodulation
- understand the patient selection and role of neuromodulation in managing chronic intractable pain
- explain the different theories underlying the mechanism of action of neuromodulation
- explain the different types of spinal cord stimulators, such as Dorsal root ganglion stimulator, High-frequency stimulator and Burst stimulator

Introduction

Neuromodulation is a rapidly expanding field of medicine to treat pain, functional disorders such as epilepsy, rectal and urinary incontinence. National Institute of Health and Care Excellence (NICE) technology assessment has recommended neuromodulation as a cost effective modality in managing certain neuropathic pain conditions.[1] The strengths of neuromodulation are its specificity, reversibility and programmability. Its benefits are long-term improvement in functional status, pain relief and reduction in the demand for healthcare resources. Thus, its superior clinical results, along with its long-term cost-effectiveness, demonstrate that neuromodulation has many clinical and economic benefits in an era of rising healthcare costs.

The present conception of neuromodulation originated over half a century ago, in the mid-1960s, when Melzack and Wall's gate-control theory was proposed. This theory is based on the idea of a gate that is controlled by large and small fibres of pain neurons depending on their activation. In 1967, Shealy successfully managed to implant a platinum electrode in the subarachnoid space, which was attached to an external power source supplying electrical stimulation. A year later, Medtronic was the first company to introduce spinal cord stimulation (SCS) at a commercial scale using radiofrequency.

Neuromodulation for treating chronic debilitating pain can be classified into two forms, electrical and chemical. Electrical neuromodulation is achieved by placing an electrode at a target nerve both central and peripheral and connected to implantable pulse generator (IPG), whereas spinal chemical neuromodulation involves placing one or more drugs directly into the central nervous system such as epidural, intraventricular and intrathecal. Intrathecal drug delivery system (ITDD) involves placing a catheter in the cerebral spinal fluid, allowing the medication to be administered directly into the central nervous system and therefore reducing the side effects.

Intrathecal drug delivery (Figure 1)

ITDD involves a pump acting as a drug reservoir that is placed in the subcutaneous tissue and connected to the intrathecal space via a catheter. The pump is powered by a computer-programmed rotor or a hydraulic-driven continuous flow pump.

Although there are no international criteria for selecting patients for ITDD, patients can generally be divided into cancer and non-cancer pain. Cancer pain is fundamentally different from non-cancer pain; for example, patients with cancer often have a poor prognosis (shorter life span), different pain modalities/sites, and lower quality of life. Previous studies have only considered cancer patients with a life expectancy of more than three months; however, in 2012, the Polyanalgesic Consensus Committee (PCC) revisited their previous recommendations and urged clinicians to meticulously consider those with a life expectancy less than 3 months for ITDD (Table 1).[2] There are many indications for using ITDD in non-cancer pain, primarily pain originating from the spine (failed back surgery syndrome, spondylosis, compression fracture) and complex regional pain syndrome. The PCC panel have suggested the recommended medications to treat patients with chronic pain.

Contraindications for ITDD

- Systemic infection.
- Bleeding diathesis.

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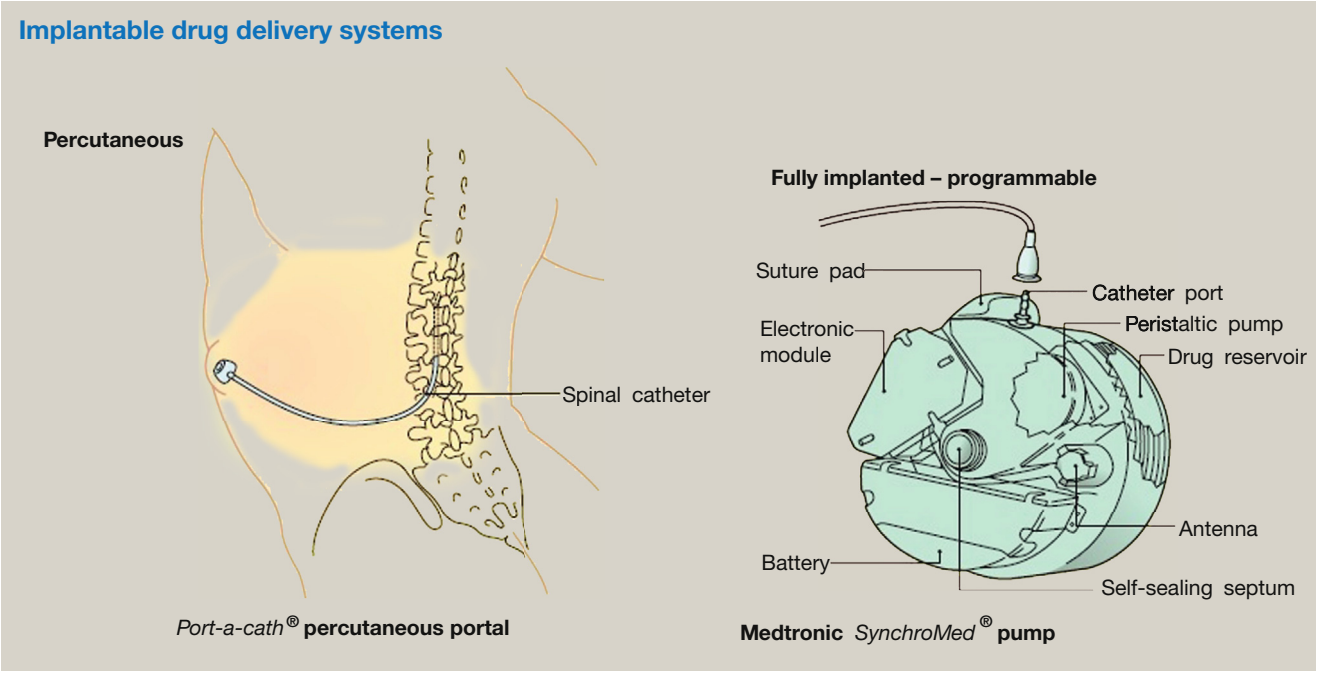

Figure 1

- Failure to obtain consent.
- Altered spinal anatomy (relative).
- Local infection (relative).
- Pre-existing leg oedema (relative).

Complications of ITDD (specific)

- Intrathecal granulomas: can be avoided by adhering to concentrations and rate recommended by the PCC.
- MRI scanning issues: the magnetic field can stop the rotary pump or gives a big bolus. The pump needs to be emptied and stopped before MRI and rechecked and restarted after the MRI.
- Leg oedema.

Vigilance for catheter obstruction, dislodgement, migration and drug related complications such as long-term opioid use and other pharmacological agent-related complications should be monitored.

Spinal cord stimulation

Mechanism of action[3]

The mechanism of SCS in treating chronic refractory pain has not yet been fully elucidated and the exact mechanism still remains unknown. There are theories proposed based on animal work.

- Gate-control theory: this mechanism was first proposed by Melzack and Wall, whereby activating the dorsal column nerves inhibits nociceptive pain impulses in the dorsal horn, was eventually found to be partially true, due to the fact the acute nociceptive pain is not completely inhibited by SCS.
- Supraspinal inhibition: supraspinal centres are involved in the effects of implantable spinal stimulators, in which the dorsal column-brainstem loop is the key factor. Barchini et al. studied the underlying mechanism of the supraspinal

Recommendations of PCC (2012) in managing chronic pain using intrathecal drug delivery

	A	B	C
First line	Morphine	Ziconotide	Morphine + Bupivacaine
Second line	Hydromorphone	• Hydromorphone + Bupivacaine *Alternatively* • Hydromorphone + Clonidine	Morphine + Clonidine
Third line	Clonidine	Ziconotide + Opioid + Fentanyl	Fentanyl + Bupivacaine
Fourth line	Opioid + Clonidine + Bupivacaine	Bupivacaine + Clonidine	
Fifth line	Baclofen		

Table 1