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Emergency Scenarios in Functional Neurosurgery

James Manfield
and Nicholas Park

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EMERGENCY SCENARIOS IN FUNCTIONAL NEUROSURGERY

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Abstract: Functional Neurosurgery modifies CNS circuits to effect change within or outside the nervous system. Most commonly, functional procedures are performed to treat movement disorders, chronic pain, spasticity and epilepsy. Whilst regarded as a predominantly elective subspecialty, emergent scenarios are encountered. The combination of their relative rarity coupled with the niche nature of the subspecialty may engender anxiety amongst neurosurgery trainees. This Element overviews some more common emergency scenarios which may be encountered comprising suspected malfunction of intrathecal drug delivery devices, deep brain and spinal cord stimulators. Status trigeminus and an approach to investigations with a neuromodulation device in situ are also covered.

Keywords: Functional Neurosurgery emergencies, intrathecal pump malfunction, deep brain stimulation emergencies, acute trigeminal neuralgia, neuromodulation device imaging

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Each section begins with an illustrative clinical vignette to exemplify a scenario an on call neurosurgery registrar/resident may plausibly encounter, followed by a more general discussion of the topic and management guidance.

Suspected Intrathecal Drug Delivery (ITDD) System Malfunction

A 54-year-old gentleman with secondary progressive multiple sclerosis underwent insertion of an intrathecal baclofen pump three years ago for management of lower limb spasticity, with beneficial symptomatic effect. He has contacted the hospital and now describes a 24-hour history of acute worsening of his lower limb spasms. He is admitted for further investigation.

ITDD Core Knowledge

ITDD devices enable direct CNS drug administration allowing for the use of much lower doses, thus reducing systemic side effects whilst maximising therapeutic benefit. They are FDA approved (US) to deliver three medications via intrathecal infusion, that is, baclofen (for spasticity, for example, in adult MS and paediatric dystonia), morphine and ziconotide (both for pain), although other analgesic agents are also used (1, 2). The most prevalent manufacturer is Medtronic (1), and most UK patients will have a SynchroMed™ system in situ. Device insertion for chronic pain (except cancer pain) is no long commissioned in England (except for cancer pain); however, replacements are permitted for established patients.

The devices comprise a programmable pump with integrated reservoir and battery inserted subcutaneously and connected to an intrathecal catheter (see Figure 1). The device is controlled by an external programmer and battery life is typically five to seven years.

Complications of ITDDs include those general to any implanted device, including infection and haematoma, and those specific to these devices which will be the focus here. Device malfunction may lead to either medication over- or underdose. Whilst both morphine and baclofen can produce narcosis and respiratory depression at toxic doses, only baclofen withdrawal is potentially life threatening.

Following initial assessment and resuscitation, a prompt, structured and systematic approach to the patient presenting with suspected ITDD malfunction is needed.

The history should establish whether the problem is related to loss of pump efficacy, as opposed to toxicity, and foremost exclude any concurrent medical problems which may instead be responsible for the presenting symptoms.

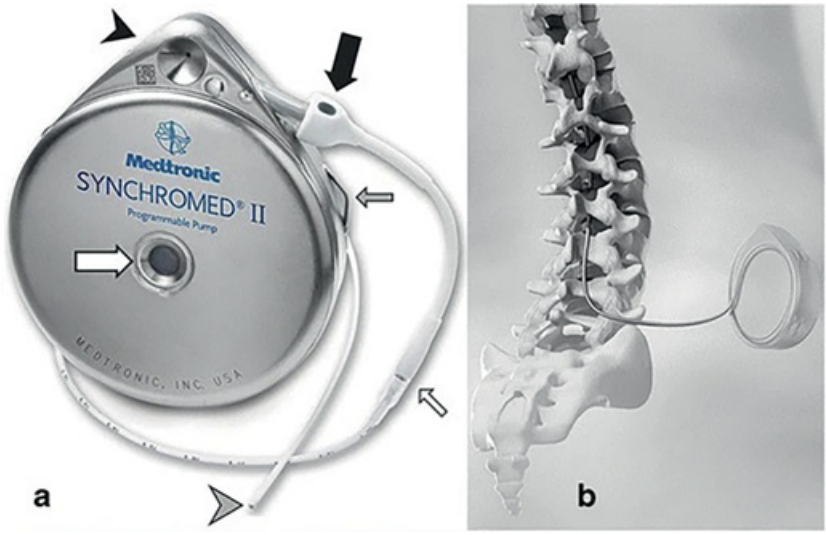

Figure 1 Medtronic Synchromed II programable pump system. External view (a) and drawing of implanted pump and intrathecal catheter (b). Pump with the catheter access port (*black arrowhead*), pump catheter connection (*thick black arrow*), refill membrane (*thick white arrow*) and suture loops for fixation (*thin arrow*), catheter–catheter segment connection (*thin white arrow*) and titanium catheter end (*grey arrowhead*).

Source: Delhaas et al. 2017(3) under the terms of the Creative Commons Attribution 4.0 International License.

Typically, loss of efficacy of a baclofen pump will manifest as an increase in spasticity or spasms, and analgesic pump as worsening pain control. Other characteristic symptoms of baclofen withdrawal include itching without rash and irritability (1). Unchecked symptoms may progress over 24–72 hours to include seizures, rhabdomyolysis, malignant hyperpyrexia and rarely death. Any recent programming changes, trauma and exposure to magnetic fields or MR imaging should be elicited. The devices are also designed to alarm if malfunctioning and this should be established. It is noteworthy that almost any systemic upset can result in worsening spasticity and tolerance does occur with intrathecal baclofen and opiates, as with other routes of administration.

If no other cause for the symptoms is found, the next step is to interrogate the pump via the programmer. Logs should be examined for replacement indicators, motors stalls and error messages. Units which insert or manage these devices should have clear standard operating procedures for suspected dysfunction, including staff trained in use of the programmers available out of hours. If needed, input from company representatives can be sought particularly when

abnormalities are highlighted. It is important to note that the pump can only detect a motor issue; thus, if the catheter is for instance obstructed or disconnected, this will not be highlighted. If no errors are identified, a bolus dose can be programmed (typically 50–100 mcg of IT baclofen) and the patient observed for an improvement in tone or other symptoms. If there is no benefit and baclofen withdrawal suspected, then an oral dose should be given, for example 10–20 mg PO initially. If symptoms progress, an intrathecal injection of typically 50 mcg (X-ray guidance may aid in avoiding puncture of the catheter) and/or intravenous benzodiazepines under appropriate monitoring may be further required for temporisation. IV hydration is also prudent to mitigate against the renal effects of rhabdomyolysis. In general, oral baclofen alone cannot be relied upon as the sole treatment for intrathecal baclofen withdrawal (4), and definitive management comprises timely reinstitution of intrathecal therapy. Early advice must be sought from the patient's treating team or a consultant with specific expertise (often neurorehabilitation or neurology), even if out of hours.

If there is a good response to the bolus, then an infusion dose increase is likely to be the favoured solution. Otherwise, at this stage a reservoir aspiration can be considered, although this is best performed by a clinician with prior experience of the procedure. Manufacture kits are available for this purpose, as well as refilling the reservoir, and include a non-coring Huber type needle. This can be performed aseptically with a syringe and 22-gauge needle, analogous to a shunt tap; however, traditional coring needles may damage the reservoir. The volume of fluid aspirated can be confirmed to be what is expected as an additional check of apparatus function, with an accepted tolerance of around 15% (5). The reservoir position can be identified by palpation, otherwise X-ray guidance may be employed if necessary (see Figure 2).

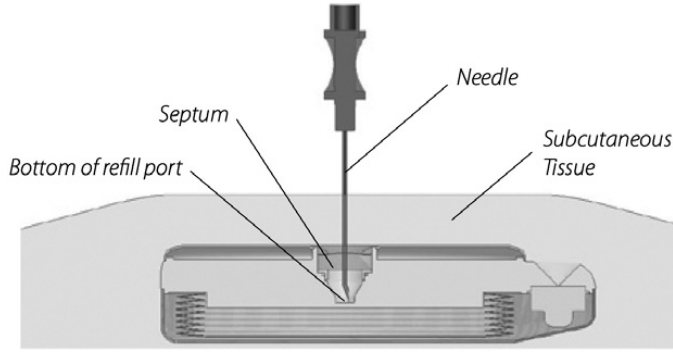

Figure 2 Cross-sectional representation of the Medtronic SynchroMed ii 20 ml pump to illustration aspiration from the refill port.
(Reproduced with Permission from Medtronic)

Antero-posterior and lateral radiographs may exclude any disconnection, kinking or migration of apparatus (see Figures 3 and 4), although not all catheters are radio-opaque (particularly so the more modern ones). If so, or radiographs are technically inadequate, then computed tomography (CT) images can be obtained. With windowing adjustment, the catheter can usually be seen clearly. If real-time fluoroscopy is available, pump rotor function can be observed after programming a 90-degree pump rotor rotation. This confirms the rotor arm is moving and effectively excludes mechanical pump dysfunction. As an alternative to fluoroscopy, plain films before and after a test bolus may convey the same information assuming the rotor can be adequately visualised. However, if correct reservoir volumes have been confirmed on aspiration and pump telemetry is normal, then this is probably not necessary (5).

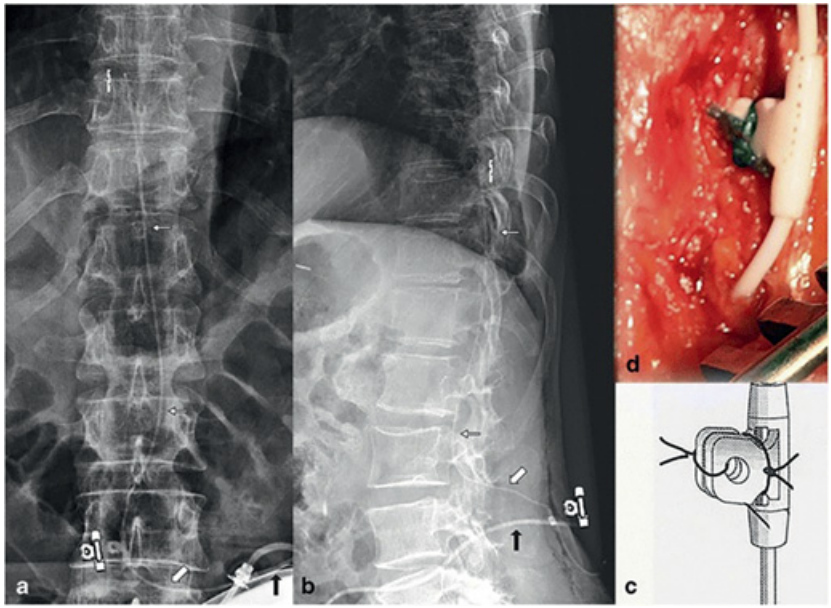

Figure 3 AP (**a**) and lateral (**b**) plain radiographs of the lumbar spine, in vivo image (**d**) and artist rendering (**c**) of the typical *folded* fixation anchor (with *anchor symbol*), large diameter catheter pump segment (*black arrow*), small diameter outside spinal canal (*thick white arrow*) and intrathecal (*small white arrow*, *catheter end symbol*) segment of the ITDD catheter.

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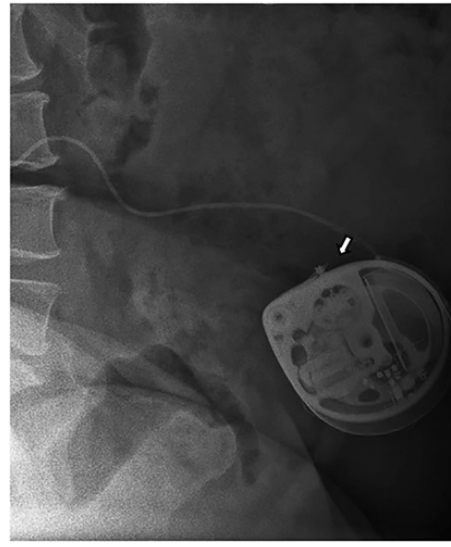

Figure 4 Radiograph depicting disconnection at the pump–catheter site (*white arrow*).

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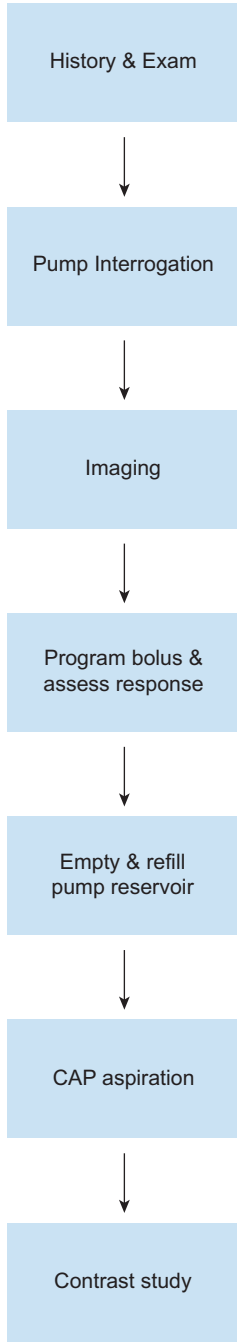
Finally, a catheter access port (distinct from the drug reservoir port) aspiration can be attempted to confirm CSF flow and a small volume (<5 mls) aspirated. (NB: This requires a 24-gauge or smaller needle for the Medtronic pumps.) Resistance or absence of flow suggests a catheter issue and indicates surgical revision. Morphine pumps in particular are prone to intrathecal granuloma formulation, which may cause obstruction. MRI is the investigation of choice here and can be performed subject to conditions. If the flow is normal, then a leaking or displaced catheter can be investigated via radio-opaque contrast injection. The catheter must first be emptied to prevent unintentional overdose. This procedure is often not diagnostic however, as the pressure and volume of contrast instilled can still bypass leaks and kinks (5). A CSF sample can also be sent to exclude infection if this is within the differential diagnosis.

Several suggested troubleshooting algorithms have been published in the literature (1, 5, 6), and a further suggestion is given here (see Algorithm 1). This can be followed sequentially until the nature of the problem becomes apparent. Suspected or confirmed pump or catheter dysfunction will require timely surgical revision. Any algorithm will need to be adapted by individual centres depending on the specific pump used as well as the availability of diagnostic tests and ITDD expertise, including out of hours.



Algorithm 1 Example ITDD troubleshooting stepwise workflow. It is unlikely this would be followed to completion, as problems would be addressed at the point of identification.

If the pump is faulty or has a depleted battery, then an urgent replacement may be indicated. This is technically fairly straightforward although there are certain nuances and it is prudent to perform this in hours with the support of either a company rep or clinician experienced in the procedure. Furthermore, the drug delivery settings will need to be transferred over on the new pump. It is the authors' practice to monitor patients for 24 – 48 hours following pump revision prior to discharge.

Deep Brain Stimulation (DBS) Emergencies

A 65-year-old woman, with a 7-year history of idiopathic Parkinson's disease, underwent an uneventful elective DBS procedure with electrodes inserted to bilateral subthalamic nucleus targets to aid management of intrusive on–off motor fluctuations. Three weeks post-operatively she reports progressive erythema over her battery site wound on the anterior chest well. She is advised to attend a ward-attender clinic for prompt review. She is apyrexial and inflammatory markers are unremarkable. Clinically, a localised superficial surgical site infection is suspected. There is no evidence of dehiscence or discharge and no subcutaneous collection is palpable. She is admitted for further management.

DBS Core Knowledge

Deep brain stimulation is a stereotactic procedure that allows targeted circuit-based neuromodulation. It is a standard of care in Parkinson's disease, essential tremor and dystonia (including in paediatric patients) and underactive investigation for other conditions linked to pathological circuitry, in particular neuropsychiatric disorders and epilepsy. Contemporary DBS systems, adapted from the cardiac field, consist of an intracranial electrode, an extension wire and a pulse generator, and have evolved slowly over the past 20 years. There are several manufacturers with differentiated devices as well as considerable variation in operative practice (7).

There are several means by which a patient with DBS in situ might require on call neurosurgical input, which will be considered in turn. Acute and intraoperative complications per se will not be covered as it is expected these would be managed by the operating team.

Immediate Post-operative Complications, for example Extra-axial, Intra-cerebral Haematoma, Seizures etc.

The same principles apply here to any post-operative neurosurgical patient with a newly reported concern, that is, clinical assessment +/− an emergent CT head. A few points are however noteworthy. First, stimulation is not typically turned on for several weeks post-operatively, so any acute deficits will not represent

a stimulation side effect. Second, should the patient require a return to theatre, then monopolar diathermy should not be used with DBS in situ. Third, chronic Parkinsonian patients can exhibit a dramatic difference in their on and off medication state, so it is worth clarifying if they received a dose of L-dopa intraoperatively if they are noted to be akinetic post-op. Conversely, transient increases in dyskinesia are not infrequently seen following subthalamic nucleus (STN) DBS.

Both haemorrhagic complications and seizures are rare and would not typically entail the removal of hardware. Seizures would be managed like any other post-operative fit, and if recurrent, an anti-epileptic agent such as Levetiracetam initiated.

Wound Problems, for example Infections and Erosions

Again, the principles here are as for any neurosurgical patient with an implant in situ, with the proviso that removal of DBS hardware and interruption of stimulation are not without considerable potential morbidity. The most common area for problems to occur is over the implantable pulse generator (IPG) (8), which is typically sited over the pectoralis muscle. However, any part of the apparatus can be affected from intracranial electrodes to extension leads and IPG (see Figure 5 – diagram of a typical set-up). It is better to treat impending erosions early with a wound revision prior to the implant breaking through the skin as the latter almost certainly means the hardware will need to be removed with commensurate morbidity.

Staphylococcus aureus is the most common infective pathogen, for example (9) and local microbiological input should be sought where this is suspected. Units that perform DBS should have an antibiotic protocol. Anything more significant than a localised superficial surgical site infection (SSI) has a high chance of requiring removal of at least some of the hardware. Typically, even presumed superficial infections are managed more aggressively than other SSIs in the hope of arresting infection spread. For instance, it is often the authors' practice to manage a suspected superficial wound infection with seven days intravenous antibiotics followed by two further weeks of oral therapy. Following antibiotic cessation, the patient is then reviewed frequently and any clinical or biological evidence of relapse will normally be managed with surgical explantation of the affected part, for example IPG and/or extension leads. Typically the intracranial leads will be retained as long as they are a reasonable distance from the site of infection. Very occasionally an allergic reaction to metallic hardware masquerading as infection can be seen. There is variation in practice regarding re-implantation following an infection, although

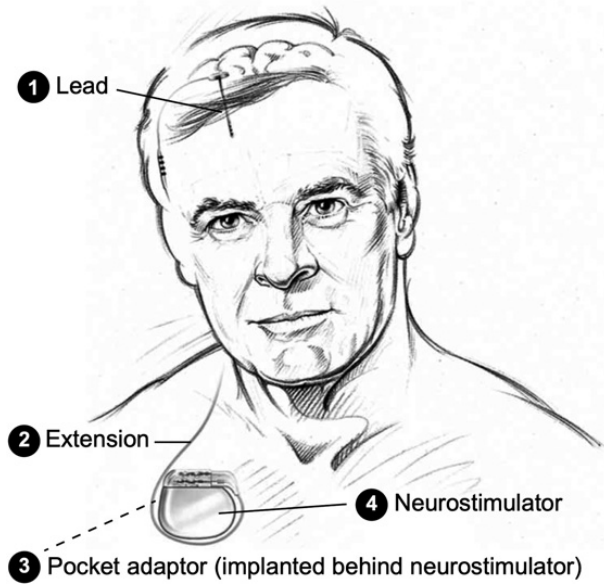


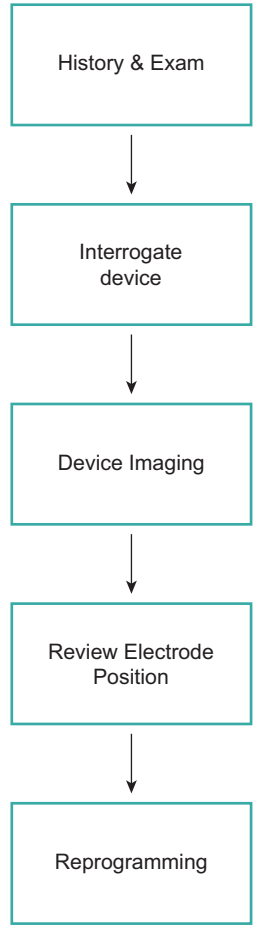
Figure 5 Diagram of implanted DBS system, illustrating intracranial leads, retro-auricular extension leads and infra-clavicular IPG. Depending on the specific apparatus, a pocket adaptor may sometimes be required. (With permission from Medtronic Inc.)

many centres will wait six months. It would be very unusual to re-implant any earlier than three months.

Intracranial infections, including brain abscesses, can occur, albeit rarely. These may be visualised on a contrast-enhanced CT scan but MRI can also be obtained with modern DBS systems subject to certain conditions (see 'Investigations with a Neuromodulation Device In Situ' section on MRI with implants in situ). Typically, this will be seen in the context of infection of the extracranial portion of the electrode combined with new neurological manifestations and imaging showing oedema around the electrodes. Differential diagnoses include idiopathic delayed-onset edema (IDE; an area of oedema restricted to the peri-electrode region), a rare probable immune-mediated foreign body response which appears self-limiting and can often be managed conservatively with steroids perhaps expediting recovery (10). Also rarely described are aseptic intraparenchymal cysts, with a possible related immune or inflammatory aetiology. However, in both cases intracranial infection should be excluded in the first instance with clinical, biochemical and imaging evaluation.

Implant/Hardware Malfunction and Loss of Efficacy

As with intrathecal drug delivery systems, patients may present with symptoms attributable to loss of device efficacy. The time course is relevant here as stimulation tolerance is described over time, and the underlying disease process, for example Parkinson's disease also continues to progress. It often takes the skillset of an experienced neurologist to distinguish disease symptoms from those attributable to stimulation. Nevertheless, particularly with an acute change, device malfunction and battery depletion should be excluded. A history of trauma or exposure to strong magnetic fields should be sought. Device interrogation entails checking impedances and current drain at each of the DBS contacts with the appropriate programmer. Algorithm 2 outlines one possible troubleshooting approach to DBS loss of efficacy.



Algorithm 2 One possible troubleshooting approach to DBS loss of efficacy.

With lead fracture, the patient may describe intermittent symptoms which occur during movements or in certain postures. The most common reported site of fracture is the cervical area, involving the extension wires (11). Investigation comprises device interrogation as above and plain X-rays (although these may not always show breakages). A lead fracture will produce abnormally high device impedances, unless a partial breakage has resulted in a 'short circuit' of wires within the lead, in which case they will be abnormally low. Normal impedances should attest to lead integrity. A CT head can be fused with a previous MRI to exclude intracranial lead migration, which is unusual.

Some patients are known to consciously or subconsciously manipulate their IPG in its pocket resulting in twisting and potential dislodgment of implanted electrodes with consequent loss of function. This is so-called 'Twiddler's Syndrome' (see Figure 6) first described in the contest of cardiac pacemakers (12) and should be managed expeditiously so as to prevent displacement of the intracranial electrodes.

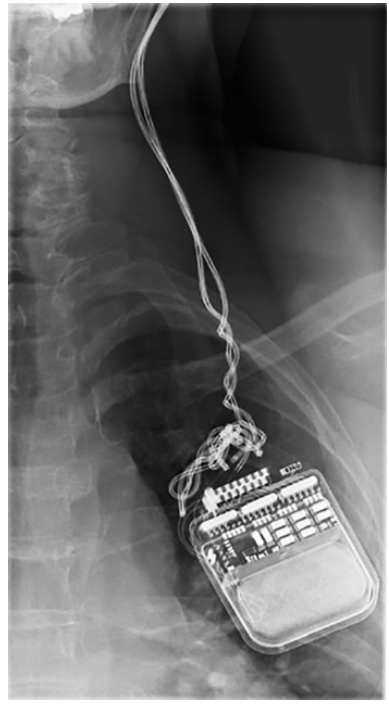


Figure 6 Radiograph depicting Twiddler's syndrome (image courtesy of Prof Patric Blomstedt, used with permission).

The history clarifies any precipitating factors (e.g. trauma, intercurrent illness etc.). Interrogation with clinician programmer confirms the device is indeed switched on, battery life remains and the electrical impedances are within normal limits. If these are newly deranged, hardware damage is possible. X-rays can assess for any lead fracture or disconnection. Cranial lead migration is unusual and most easily assessed with a CT head scan either compared to previous imaging or fused to the patient's DBS planning MRI to review electrode position. If all the above are unrevealing, then device reprogramming would ordinarily be attempted to try and re-establish efficacy. This can be challenging and requires specialist input.

Patients may present complaining of straining extension cables with associated discomfort, but this is not an emergency and can be referred to the clinic of the operating surgeon.

DBS Withdrawal Symptoms

Symptom rebound following abrupt DBS interruption may include both motor and non-motor manifestations, the latter may include suicidal ideation and depression (see next). The more benefit the patient derived from stimulation, the more marked withdrawal features may be. Long-term DBS and advanced PD are probable risk factors. Symptoms may include acute dyskinetic Parkinsonian or dystonic crises and deaths have been reported (13, 14). These can be difficult to manage and prompt recognition and involvement of an experienced neurologist are essential.

Stimulation Side Effects and Suicide

It is noteworthy that stimulation of the limbic components of deep brain basal ganglia structures may result in acute depression. Patients with suicide attempts and/or ideation should be admitted for multi/interdisciplinary care, including neuropsychiatric input, and/or medication/stimulation adjustment(s) (14). A meta-analysis found that approximately 52% of cases with suicidal ideation and/or attempts were reported to commit suicide following DBS (15). These patients are accordingly high risk and should be treated as such – not left to general liaison psychiatry management.

Other stimulation-related side effects will vary depending on the electrode location but may commonly include dysarthria, imbalance, tonic muscle contractions, paraesthesiae and visual disturbances. These can typically be managed with an urgent outpatient review for re-programming.

Trigeminal Neuralgia Emergencies

A 71-year-old lady presents to your hospital A&E out of hours. She has a history of typical trigeminal neuralgia for which she takes Oxcarbazepine and Gabapentin, with a percutaneous glycerol rhizotomy also performed two years earlier. She now complains of an excruciating acute exacerbation such that she is unable to eat or drink. She is admitted for analgesia and intravenous hydration.

Trigeminal Neuralgia Core Knowledge

Most patients with established trigeminal neuralgia will be managed medically with titration of carbamazepine and similar medications. Suitable candidates who are either refractory to medical management or with intolerable side effects can be offered microvascular decompression (if anaesthetically suitable and with neurovascular compression on imaging) or percutaneous procedures, that is, glycerol, balloon or radiofrequency rhizotomy.

Patients are liable to present to the on call services with uncontrollable exacerbations of pain, or pain that is sufficiently severe to impair eating and drinking. They are then likely to require admission for rescue therapy and intravenous re-hydration.

Intravenous phenytoin via infusion is supported by some evidence and is often effective in this setting. In a recent series of 65 patients, around 90% obtained immediate pain relief. Dosing strategies varied between 10–20 mg/kg over 30–60 minutes, with 10 mg/kg over 60 minutes recommended in the first instance (16). In one author's unit dosing is typically as per status epilepticus. Important considerations are that cardiac monitoring is required (ECG and blood pressure) during IV administration, so the patient will need to be admitted to an appropriate ward. A pre-administration ECG should also be obtained to exclude second- or third-degree heart block, which are contraindications. The related fosphenytoin (at, for example, 15 mg/kg) is an alternative which may be better tolerated (17). Other alternative medicines described in the literature include subcutaneous sumatriptan and intravenous lidocaine (18). It should be noted that the aim of the rescue treatment is to provide a period of symptomatic remission, for example 24 hours to enable a neurology review and rapid oral agent titration or a more definitive procedure such as percutaneous rhizotomy.

Spinal Cord Stimulator Emergencies

A 34-year-old woman with a percutaneously implanted spinal cord stimulator in situ for Persistent Spinal Pain Syndrome Type 2 (formerly known as Failed Back Surgery Syndrome) is referred to the hospital following a routine General Practitioner appointment. During an unrelated examination the GP noted

a glimmer of metal in her gluteal region, suggesting IPG erosion. The patient was reluctant to attend, as the device is continuing to be highly effective for her, but ultimately agreed to admission for assessment.

Spinal Cord Stimulation Core Knowledge

In addition to DBS, the other main class of implanted neuromodulation devices encountered in clinical practice is spinal cord stimulators (SCS). Nowadays most SCS are inserted percutaneously, often by pain physicians or anaesthetists. Although complications requiring surgical intervention are rare, this does mean that the primary operator may not be in a position to manage them should they arise (19). Recognised complications potentially requiring emergent surgical intervention include epidural haematoma, intra-spinal abscess manifesting with neurological deficit and deep surgical site infection. Lead migration or fracture is likely to be encountered more commonly but does not present an emergency per se (20), although acute loss of efficacy may cause significant distress and should be managed promptly. It is worth noting that dorsal root ganglion (DRG) stimulation wires are especially fragile and prone to such complications.

It may become necessary to explant an SCS system on an urgent basis, most likely for infection or percutaneous erosion, so some familiarity with the typical apparatus is required (see Figure 7).

Typically, the epidural leads are anchored in the lumbar fascia and then connected to the IPG/battery. A proprietary screwdriver is often needed to disconnect the battery from leads. Removing the stimulator requires first dissecting out the anchors, then pulling out the epidural leads and finally removing the IPG. The most important point is to avoid transecting the wires leaving orphaned epidural leads in situ as these will then be very difficult to remove and would also preclude any future MRI imaging. Conventional monopolar diathermy should not damage the insulated wires, but should be avoided with an SCS system in situ (21) due to both the risk of thermal injury and potential damage to the apparatus. Bipolar diathermy can be used safely. Pulsed radiofrequency energy devices such as the Medtronic Plasmablade operate at a significantly lower temperature than conventional monopolar diathermy and are routinely used by one author for both DBS, VNS and occasional SCS revisions without complication. It should however be noted that, excepting DBS battery replacement, these uses are off-licence. Of the neuro-modulation systems, SCS are the most susceptible to thermal damage, so additional precautions, including a lower power setting and avoiding direct contact with the apparatus, are advised (22). Although more expensive, these devices are much less likely to damage wiring than sharp dissection making revisional surgery swifter and safer.

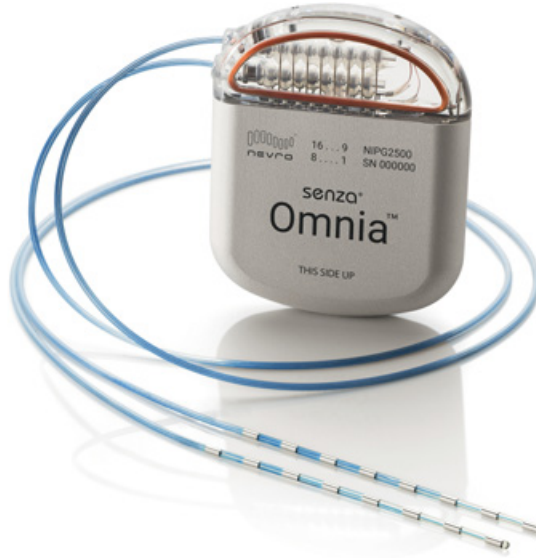


Figure 7 Illustration of percutaneously inserted spinal cord stimulation system demonstrating two epidural leads and IPG. (Image courtesy of Nevro Inc., used with permission.)

Investigations with a Neuromodulation Device In Situ

A 41-year-old man underwent a left L1 dorsal root ganglion stimulator for post-herniorrhaphy neuralgia. He now presents to A&E with a two-day history of lower back pain, right-sided sciatica, saddle anaesthesia and one episode of urinary incontinence precipitated by lifting up his son. Neurosurgical advice was sought on the most appropriate imaging modality to exclude acute cauda equina syndrome.

Core Knowledge

CT and MRI represent the mainstay of neurosurgical imaging and both present potential challenges for patients harbouring neuromodulation devices.

CT does not pose a problem per se but electrodes can create significant artefact which can make interpretation more difficult. It is noteworthy that metal artefact reduction image processing techniques do exist and these can be requested. Examples include Canon's single-energy metal artefact reduction technique (SEMAR), for example (23). Photon counting CT scanners are not yet widely available but provide the best available imaging (25). Alternatively, manually adjusting the CT windowing settings can often be helpful.

MR imaging can prove more challenging. The first step is to establish the specific implant the patient has and to then check its MRI conditionality status. This is likely to differ depending on which body part is being imaged and is often available on the manufacturer's website, or a company rep can be consulted. Differing MRI machine coils can also be relevant, so liaison with local radiology is necessary. Assuming conditionality, any specific absorption rate restrictions must then be noted. These can present significant challenges and often require specifically adapted scanning protocols developed with an MRI physicist, for example (24). Furthermore, before any imaging can take place, device impedances must be checked with the appropriate programmer/interrogator and some devices will need to be put into a specific mode. In the case of the Medtronic Synchromed II intrathecal pump, stalling following MRI is well described and requires programmer interrogation post scan. These hurdles will typically make out of hours imaging difficult to obtain and many non-neuroscience hospitals will not have neuromodulation device MRI scanning protocols, precluding local imaging. In the authors' experience, reticence is likely to be encountered from radiology departments unless clear standard operating procedures have been established which include the availability of staff trained to use relevant device programmers.

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Emergency Neurosurgery

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