Neuromodulation – what do anaesthetists, surgeons, and emergency physicians need to know?

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▶ **Citation:** Reining M, Gonnert FA, Stroh C, Kretzschmar M: Neuromodulation – what do anaesthetists, surgeons, and emergency physicians need to know? Anästh Intensivmed 2021;62:486–494.
DOI: 10.19224/ai2021.486

Summary

Neuromodulation covers established methods of invasive pain management. A distinction is made between pharmacological processes ("drug delivery systems") and electrical stimulation processes ("neurostimulation"). Patients with corresponding implants may present to non-specialized health care facilities. This article describes the peculiarities of preclinical emergency care, clinical diagnostics, and perioperative care for this special group of patients.

Emergency medical services (EMS) should take the implant ID card and any patient control devices or chargers with them to the hospital if they become aware of the implant. Neurostimulators must be switched off for ECG examinations and ECG monitoring. While X-ray diagnostics are possible without restrictions, there are considerable restrictions on the MRI approval of the implants.

Catheters and electrodes must be conserved perioperatively; precise knowledge of the location is a prerequisite. Regional anaesthesia close to the spinal cord is often possible, but subject to restrictions. Despite having an implant for pain therapy, patients require adequate postoperative analgesia.

Additionally, there are specific emergency situations related to the implants. In terms of patients harboring drug delivery systems, opiate overdose or opiate withdrawal should be considered – both of which can present with atypical symptoms. With neurostimulators, it is sufficient to switch off the stimulation and arrange for elective follow-up. Presenting the patient to the implanting center is only necessary if there are specific indications that the implant was causative, otherwise the nearest suitable hospital should be approached.

Introduction

The term „neuromodulation" covers various non-destructive methods for altering the transmission of pain stimuli in the central and peripheral nervous system [1]. A distinction is made between pharmacological processes (pump systems for the application of drugs directly into the cerebrospinal fluid) and electrical stimulation processes („neurostimulation"). Knowledge of both procedures is essential in emergency medicine and perioperative care for these patients.

There are no data available on the prevalence of such systems in the German population. In 2019, 1,090 intrathecal drug delivery systems (IDDS) and 1,954 implantable pulse generators (IPG) for neurostimulation near the spinal cord were implanted in Germany [2]. Based on our experience with system lifespan, a current estimation infers at least 8,000 patients with an IDDS and 10,000 patients with a neurostimulator in Germany. In recent years, the number of implanting centers has increased, and the various neuromodulation methods are being tested for new indications. For example, there is currently discussion over whether early spinal cord stimu-

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Financial support
None

Authorship statement
The manuscript was drafted by M. Reining based on an idea by Prof. M. Kretzschmar. Prof. Kretzschmar, PD Gonnert, and Prof. Stroh made significant scientific contributions through numerous corrections and literature recommendations.

Conflict of interest statement
Mr. Reining and Prof. Kretzschmar were involved in studies conducted by Abbott Laboratories as co-investigator and principal investigator in the past 2 years. PD Gonnert and Prof. Stroh declare no conflicts of interest.

Ethical responsibility
This paper contains no studies on humans or animals conducted by the authors.

Keywords
Drug Delivery Systems – Implantable Neurostimulators – Patient Safety – Perioperative Care – Emergency Medicine

lation in traumatic paraplegia leads to a better motor outcome [3]. In visceral surgery, sacral stimulation is now an established method for treating faecal incontinence [4]. Hence, the numbers can be expected to continually increase. The larger implanting centers regularly have a supra-regional catchment area, so that every physician may be confronted with these patients.

In our daily practice, numerous telephone inquiries from clinicians across all specialties are evidence of the need for more information about patients with neuromodulation procedures. Only two English language review articles and one case report reference the perioperative handling of these patients or their implants [5–7]. The recommendations given are shaped by differing approvals and legal systems in the Anglo-American region. Therefore, this review article is based mainly on the centre's many years of experience and proven therapeutic standards.

Basics of Neurostimulation

Indications for neurostimulation are diseases with predominantly neuropathic pain, such as Failed-Back-Surgery-Syndrome, phantom pain, or polyneuropathies. Even with sympathetically maintained pain (complex regional pain syndrome, CRPS I and II), neurostimulation is a promising approach after the failure of multimodal conservative therapy. In ischaemic pain (coronary heart disease and peripheral arterial disease), spinal cord stimulation can significantly improve blood flow and pain relief when options for causal intervention are exhausted. However, the exact mode of action is still unknown [8]. Additionally, some headache disorders, in particular migraines and cluster headaches, can be positively influenced by neurostimulation [9].

Basically, every neurostimulator consists of one or more electrodes (usually called leads) and a pulse generator. The IPG is often implanted subcutaneously in the gluteal or abdominal region, but an infraclavicular position is also possible. Extensions may also be implanted depending on the location of the leads and IPG.

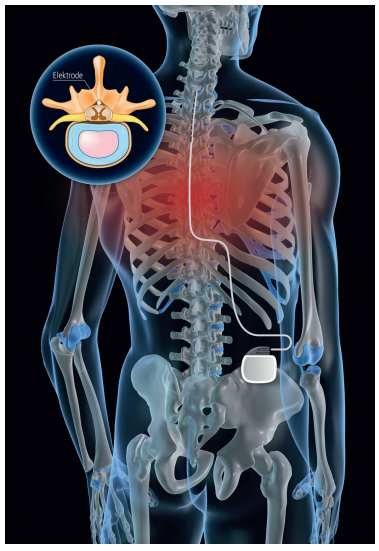
The leads are available in different shapes (percutaneous leads, paddle leads) and lengths, and also differ in the number of contacts (mostly 8, but also 4 or 16). Depending on the location of the leads, a distinction is made between spinal cord stimulation (SCS) as the most common method (see Figure 1), stimulation of the spinal ganglion (dorsal root ganglion stimulation, DRG-S), peripheral nerve stimulation (PNS), peripheral nerve field stimulation (PNFS), motor cortex stimulation, and deep brain stimulation [10]. This classification is not only relevant for the specialist but also for those covering other specialities. For example, the anaesthetist can use this knowledge to determine the possibility of regional anaesthesia.

A trial period with a temporary catheter or a mostly temporary lead is considered standard for most neuromodulation methods. This trial can be performed in part under domestic conditions. In these cases, the patients are put on leave or discharged with the externalized trial lead connected to an external pulse generator. After a few days, they return to evaluate the test result and have the temporary leads removed. Clear evidence of effectiveness in the trial period is an indication for permanent implantation; implantation of an SCS system without a trial period is possible only for coronary heart disease and peripheral arterial disease, where the prospect of success is excellent.

Different modes of stimulation differ in the way in which the current is delivered. Some modes of stimulation should be experienced by the patient as a weak tingling sensation. In other modes, a soft tingling sensation already indicates overstimulation, which can cause increased pain. Patients are regularly informed as to the degree of stimulation sensations they should be experiencing.

Two types of IPG are available: low-maintenance, battery-operated IPGs, and rechargeable IPGs. Recharging the battery occurs through intact skin by means of induction, similar to modern smartphones. Most patients engage well with

Figure 1



Schematic representation of an SCS system.

the recharging process. Recently, another induction system with a receiving unit integrated into the lead has also been introduced. With this system the transmitter and control unit must be constantly worn attached to a belt over the implanted receiver unit.

All patients with a neurostimulator receive an implant ID card, a patient control unit, and a manual. Additionally, detailed training regarding the operation of their neurostimulator is provided immediately after implantation. Unfortunately, the devices differ from manufacturer to manufacturer, so generalized instructions cannot be provided. The display on the devices is freely programmable and does not provide objective information on stimulation intensity or location. **When questions or problems arise, do not hesitate to call the implanting centre or the manufacturer's hotline.**

My emergency patient has a neurostimulator – what now?

Case vignette 1: Mr. Z. (62 years old) presents about two months after the implantation of an SCS system for reprogramming due to pain intensifi-

cation. The indication for neurostimulation was a typical post-nucleotomy syndrome with L4 radiculopathy after L4/5 sequesterectomy; no neurological deficit was evidenced at the time of implantation. Upon entering the room, a limping gait pattern and evident relieving posture were noted. Mr. Z. reported that he was almost pain-free after the SCS implantation. Five days ago, he suffered from a sudden, massive increase of his previous pain. Additionally, he reported a new feeling of numbness in the L4 dermatome on the left and a marked reduction in strength of the left leg. Normal bladder and rectum functions were reported. In addition to a reduction in strength of the hip flexors and knee extensors, massive lumbar tapping pain was notable during the examination.

In general, every emergency patient with a neurostimulator should be treated in the same way as a patient with the same symptoms without a neurostimulator. It is not necessary to consult a pain therapist in most cases, as this will delay further treatment. If possible, EMS should take the implant ID card, the patient control unit, and – if available – the charger to hospital together with the patient. In most cases, the transport destination will not be the implanting centre but the nearest suitable hospital, which can contact specialists at the implanting centre if necessary. If the neurostimulator is the cause of the emergency, the decision to primarily transport the patient to the implanting centre versus to a local hospital for emergency diagnosis and stabilisation with later secondary transfer must be assessed based on patient condition and tactical considerations (availability of the implanting centre, distance, ambulance cover during prolonged absence).

Emergencies caused by the neurostimulator itself are rare. The only time-critical crisis is an infection of the implant, which can occur years after implantation. The diagnosis is made clinically (reddening, swelling, pain, later skin perforation in the implant area); laboratory diagnostics (leucocytes, CRP) often show normal values. Efforts should be made to transport the patient to the implanting centre for surgery immediately.

As reported in case 1, patients often present with pain exacerbation. During history taking, the duration, localisation, and nature of the pain upon presentation and prior to implantation should be determined. Particular attention should be paid to new sensorimotor deficits during the clinical examination. If the same pain is only gradually worsened, presentation to the treating pain centre for system checkup and further treatment on the next working day is usually sufficient. A new pathology is very likely to be the cause of the complaints in the case of acute pain, changes in the pain characteristics or localisation, as well as new sensorimotor deficits; therefore, a diagnosis must be sought as with any other patient with the same complaints. Irritation of the spinal cord or spinal ganglia due to dislocated electrodes must be considered in the differential diagnosis.

If the patient shows up because of violent power surges or other unpleasant sensations, the system should be switched off with the patient control unit. If the sensations persist after switching off the stimulation, the neurostimulator cannot be the cause, and further diagnostics are required in accordance with the symptoms. If the sensations stop when the stimulator is switched off, or the stimulation cannot be restarted, an elective procedure can be organised in the treating pain center for system checkup on the next working day.

Diagnostic procedures with a neurostimulator

All currently available neurostimulators have either no or only limited approval for MRI examinations [11,12]. Due to the many different types of implants, no general statements can be inferred. Information on the MRI approval and implant preparation can be found in the MRI information tab, which is usually available for download on the manufacturer's homepage.

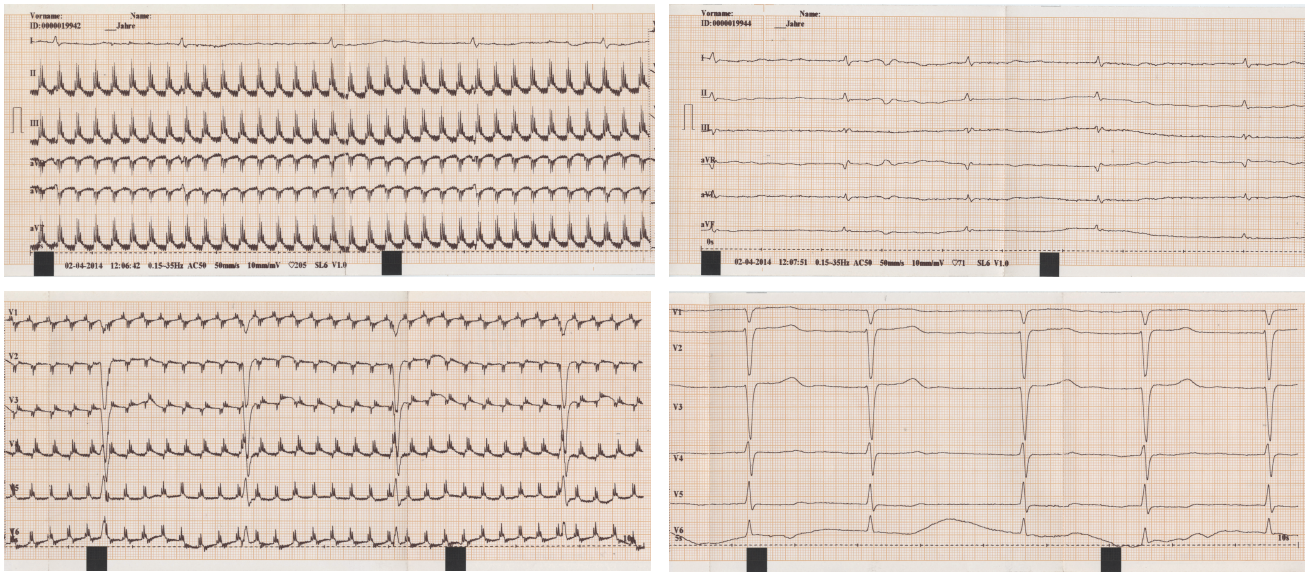
Performing an MRI scan is also conceivable outside the approval after an individual risk-benefit assessment, considering approved alternatives, and obtaining informed consent [13]. Theoretically, possible complications are induction of currents with resulting burns in the course of the electrodes and damage to the electronics of the IPG [14]. In the literature, there are only four studies with mostly outdated implants [13,15–17] and some case reports with and without complications.

In emergencies, the non-specialist should choose alternative imaging methods (computed tomography, X-ray, sonography) wherever possible. Any MRI diagnostics should only be carried out in close consultation with the implanting facility and, if necessary, with the assistance of a therapy specialist from the manufacturer to prepare the implant in accordance with the specifications of the respective manufacturer. The MRI examination should only be performed on the awake, cooperative patient [13]. Termination criteria include a local sensation of heat or pain in the area of the system as well as electrifying sensations or motor reactions during the examination. After the MRI examination, a complete system check must be carried out again by the manufacturer or the implanting facility.

All X-ray examinations, including computed tomography, can be carried out as usual [6].

The neurostimulator generates a current that can significantly interfere with all electrophysiological examinations (e.g., ECG, electroneurography) (see Figure 2). Most IPGs have a magnetic switch for emergency shutdown in the absence of a control unit. The stimulation can be switched off and, depending on the programming, also switched on by swiping a strong magnet (e.g., pacemaker magnet) over the IPG once. The magnet is positioned about 10 cm next to the IPG and then moved over the IPG to the other side at a speed of 5–10 cm per second. However, it is not possible to reliably monitor the shutdown in this way.

Figure 2



On the left ECG with active Burst-Stimulation (peripheral leads above, chest wall leads below), on the right ECG for the same patient after stopping the stimulation.

Case vignette 1 (continued): A new pathology was suspected due to acute pain exacerbation with new neurological deficits. Following the national health care guideline for back pain [19], there are new cautionary warnings („red flags“) and new imaging is recommend. The implanted SCS system had limited MRI approval for examinations of the entire body, so the pain therapist and neurosurgeon jointly ordered an MRI examination of the lumbar spine. The pain therapist switched the SCS system into MRI mode, and the MRI was performed without complications. An extensive recurrent disc prolapse L4/5 was diagnosed. The neurosurgeons who were initially consulted recommended surgical decompression with subsequent PLIF L4/5. The patient was transferred to the spinal surgery department to prepare for surgery.

Perioperative care for patients with neurostimulators

In addition to the usual procedure, data on the neurostimulation should be attained during the pre-anaesthesia assessment [6]: Which implants does the patient have? Where is the IPG located? Where are the leads located? Where is the access to the spine? Where is the tip of the lead? This information can usually be found in the discharge letters and surgery reports on the implantation. If in doubt, an X-ray in 2 planes can be helpful.

Is regional anaesthesia (close to the spinal cord) possible? To answer this question, exact knowledge of the location of all components of the neurostimulation system is essential. **Under no circumstances should a puncture be made in the course of the leads.** With SCS systems, spinal anaesthesia is often possible below the access for the leads [20]; a lateral Taylor approach may be required. An epidural catheter can be placed 1–2 segments above the tip of the lead. With DRG-S systems, an epidural relief loop is usually placed cranially over 2–3 segments; a puncture is often possible two segments above the cranial end of the loop or below the access, although the individual lead course must be taken into consideration [6].

The following additional risks must be considered when carefully weighing up the risks and benefits of regional anaesthesia:

- If the electrode is damaged or dislodged, the stimulation will lose effectiveness, and revision surgery will be required.
- The risk of infection is significantly increased if foreign material is present. In the case of an epidural abscess, explantation of the neurostimulator is essential.

The patient should bring his patient control unit into the operating room. Before initiating anaesthesia, the neurostimulator should be switched to surgery mode to avoid possible ECG artifacts, if possible. Alternatively, it should be switched off. The stimulation can be restarted after transfer back to the normal ward.

Only the bipolar technique may be used for high-frequency surgery [21]. In this specific patient population, several defective IPGs have been reported after using the monopolar technique. The surgeon should protect the leads during surgery, but damage cannot be avoided with absolute certainty. If the lead(s) are damaged, this must be correctly documented in the surgical report, and the patient must be informed. Repairs may be performed during the same session in implanting centres, so the pain therapist should be consulted. Before discharge, contact should be made with the treating neuromodulation center for an appointment to plan further action.

Postoperatively, despite the neurostimulator, patients generally require treatment of typical postoperative pain in accordance with the department's standard algorithms. If opiate therapy is already in place, higher doses are often needed temporarily. The neurostimulator does not affect wound pain.

Case vignette 1 (continued): First, the assessing anaesthetist asked the pain therapist to detail any considerations with regard to the planned surgery. Together it was determined that the neurostimulator should immediately be switched into surgery mode. A reminder was posted to the surgical team for bipolar current usage only. The responsible neurosurgeon asked for details of the implanted system and the exact cable route. The relief loop borders the surgical area cranially. He was asked only to use bipolar current and to protect the lead. Surgery was uncomplicated, and postoperative pain was treated in accordance with the appropriate standard using a non-opioid analgesic and a WHO level 3 opioid. After being transferred from the recovery room, the SCS system was reactivated the next day. The patient was discharged home almost pain free a few days later with a non-opioid analgesic (wound pain!).

Basics of pharmacological neuromodulation

Pharmacological neuromodulation takes place through the continuous application of drugs into the cerebrospinal fluid. In most cases, a catheter is placed intrathecally via lumbar access with the tip in the area of the middle thoracic spine (often T7), but the catheter tip can also be positioned in the cerebellomedullary cistern or the ventricular system. The catheter is connected to an implanted drug delivery system (IDDS) (see Figure 3), which is usually implanted epifascially in the abdominal area [10]. In highly palliative and decreased life expectancy situations, the spinal catheter can also be connected to a port system. Treatment is then via an external drug pump. In these cases, the port chamber – in contrast to intravenous port systems – is placed in the area of the lower thoracic aperture.

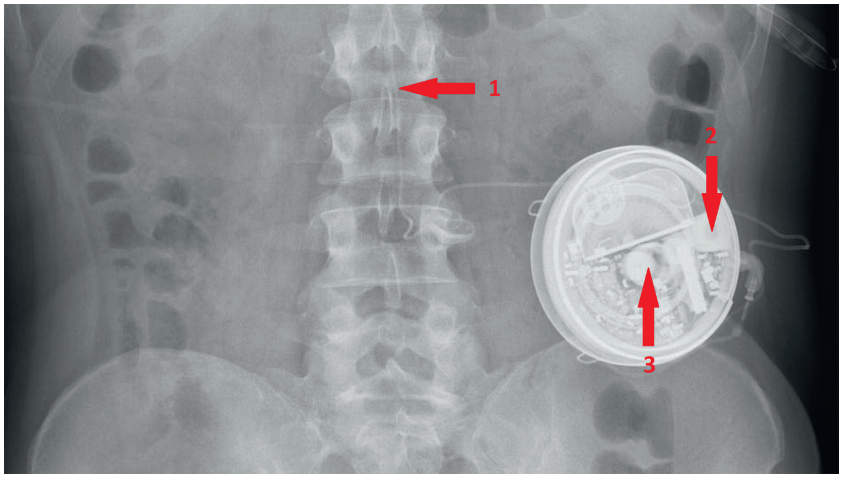
Indications for testing intrathecal drug administration using a temporary catheter and external pump (in some centers also with a port system or single shot) include both treatment of spasticity and intolerable side effects from sufficiently dosed systemic opiate therapy. Well-localized tumour pain from bone metastases can be an excellent indication for intrathecal therapy, for example. Successful testing is the main indication for the implantation of a permanent IDDS system [22].

Technically, a distinction is made between gas pressure pumps and motor-driven pumps. In the case of gas pressure pumps, when the drug is filled, a gas (mostly n-butane) is compressed, and the resulting pressure presses the drug into the catheter system via the control mechanism. Gas pressure pumps are available with a constant flow rate; regulation is exclusively via a capillary. Programmable gas pressure pumps also have a valve mechanism that regulates the opening time of the capillary.

Motor-driven pumps are always programmable. The flow rate can be varied during the day; the devices optionally incorporate a bolus function, which can be triggered by the patient within the limits of the doctor's specifications, and are therefore particularly suitable for oncological patients. The limiting factor is the battery capacity. Both gas pressure pumps and motor-driven pumps are available with different volumes.

Approved drugs include morphine sulfate and baclofen, and occasionally for some pump models ziconotide and NaCl 0.9 %. Nonetheless, hydromorphone, sufentanil, clonidine, ropivacaine 1 %,

Figure 3



X-ray of an IDDS system (MedStream®, Codman & Shurtleff, Inc., Raynham, MA, USA).
1: Spinal catheter; **2:** Bolus port of the pump; **3:** Refill port of the pump.

and bupivacaine 4 % are also often used off-label.

Immediately after implantation, patients receive a pump ID card in which all relevant data on pump fillings (date, medication, current daily dose, next refill date) can be found. Refilling is regularly organised by the implanting centres before discharge and is required every 4–13 weeks depending on the size of the pump, contents, and dosage. **All pumps may only be refilled by a specialist using specifically suited canulae!**

Emergency IDDS patient – what to do?

Case vignette 2: Ms. A. (72 years) presents to the emergency department outside of regular working hours with a prescription for hospital treatment because of general deterioration of her condition. Two weeks earlier, the resident radiologist carried out an MRI examination of the knee joint, and shortly afterward, the patient presented to her family doctor for nausea, vomiting, and diarrhoea. She was admitted to a nearby hospital for suspected gastroenteritis. Her general condition worsened further under infusion therapy; she also experienced severe back pain and has been immobile since being admitted to hospital. After seven days, she was discharged home with an unchanged poor general condition following unsuccessful treatment. For a few days, she also suffered left-sided chest pain. She also currently reports visual disturbances and a general reduction in strength. The family doctor admitted her to our hospital because she could no longer take her oral medication due to persistent nausea. Numerous previous illnesses are known (myocardial infarction with stent implantation four years earlier, hypertension, type II diabetes mellitus, stage III kidney failure). Two years earlier, a programmable IDDS system was implanted due to failed back syndrome, and provided satisfactory pain relief.

Emergency patients with an IDDS system should be treated in the same way as patients with the same symptoms without a pump. The pain therapist should be consulted if there is a reasonable suspicion that ongoing therapy is the cause of the symptoms. The emergency physician should also consider this aspect when choosing the transport destination, and the pump ID card should always be taken to the hospital.

With any opiate therapy, regardless of the route of application, opiate overdose and opiate withdrawal must always be considered. An overdose is often heralded by nausea and vomiting, followed by the typical symptoms of miosis, impaired consciousness, and respiratory depression [23]. With intrathecal opiate therapy, opiate withdrawal is rather untypical and unspecific: in addition to an intensification of the known pain, gastrointestinal symptoms suggestive of gastroenteritis are usually the first sign. Vegetative derailment is often less pronounced than with oral or intravenous opiates, but in the older patient population, it can manifest as myocardial infarction [24].

The leading causes for opiate withdrawal are:

- The pump was stopped (refill, MRI, …) and not restarted
- Discontinued additional oral opiate medication
- Appointment for refill forgotten or calculated incorrectly
- Mistakes during refilling of the pump
- Catheter problems (dislocation, leakage)
- Pump defects.

If a malfunction of the implanted system is suspected, the system should be checked at the implanting centre as soon as possible. Programmable drug pumps usually have an alarm function. A beeping pump is always to be interpreted as indicating a manifest or impending short-term failure of the pump. When taking the patient's medical history and examining them, a targeted search for withdrawal symptoms should be carried out.

Withdrawal symptoms can be eliminated within a few minutes by oral or intravenous administration of an opiate. Conversion factors between intrathecal and oral morphine have been suggested to be between 1:12 and 1:300 depending on the conversion table or literature reference [25], but in our experience, these factors can hardly be used for calculating substitution doses in practice. Withdrawal symptoms can regularly be eliminated with unexpectedly low doses, but the increased pain is often difficult to control even with significantly higher doses. Therefore, we recommend an intravenous dose titration until withdrawal symptoms cease. If the desired effect does not set in even after 50–60 mg morphine equivalent or the onset of typical side effects of opiates, the diagnosis of opiate withdrawal should be critically examined.

If the patient with ongoing intrathecal therapy presents due to an intensification of the pain, a detailed history and examination will provide valuable information. A recommendation for approaching differential diagnoses can be found in Table 1.

The intrathecal treatment of spasticity deserves special attention: **both baclofen withdrawal and baclofen overdose are potentially life-threatening emergencies** [26]. All procedures that could endanger the system's function (e.g., MRI, regional anaesthesia near the spinal cord) should be avoided or left to an experienced specialist who is able to deal with the complications. While overdose is associated with refilling or reprogramming of the pump in almost all cases, withdrawal can occur at any time. Symptoms, differential diagnoses, and treatment recommendations are summarised in Table 2.

Another acute emergency is infection of the IDDS system, which often occurs years after the implantation. The diagnosis is made clinically. In our experience, in the case of pump pocket infections laboratory values are often inconspicuous. In contrast, they are significantly

Table 1
Differential diagnosis of increased pain during ongoing intrathecal therapy.

Symptoms	Causes	Recommendation
Gradual increase in known complaints, no new sensorimotor deficit	- Development of tolerance - Increase in (degenerative) changes causing pain	Elective presentation to the treating pain therapist
Acute increase in known symptoms, no new sensorimotor deficit, no withdrawal symptoms	- Increase in (degenerative) changes causing pain - New pathology possible - First symptom of device malfunction	- Inpatient monitoring (development of withdrawal symptoms?) - Diagnostics as required - Presentation to the treating pain therapist
Change in symptoms or new sensorimotor deficit	- New pathology likely	Diagnostics necessary
Acute increase of symptoms with withdrawal symptoms	Malfunction of the IDDS system	Opiate substitution Presentation to the implanting centre as soon as possible

Table 2
Differential diagnosis and treatment of emergencies associated with intrathecal baclofen therapy according to [25].

	Baclofen withdrawal	Baclofen overdose
Symptoms	Spasticity ↑ Blood pressure ↓ Heart rate ↑ Blood heat ↑ Itching Seizures Hallucinations Impaired consciousness	Paralysis Blood pressure ↓ Delirium Seizures Impaired consciousness ranging to coma Respiratory depression
Risks	Rhabdomyolysis Disseminated intravascular coagulopathy (DIC) Multiple organ failure	Hypoxia
Differential diagnoses	Autonomic dysreflexia Malignant hyperthermia Neuroleptic malignant syndrome Serotonin syndrome Meningitis, sepsis	Sepsis Intracranial haemorrhage Hypoglycaemia Electrolyte imbalance
Treatment	Admission to the intensive care unit Oral baclofen substitution Restore intrathecal therapy as quickly as possible	Admission to the intensive care unit Check and, if necessary, refill the pump

increased in most cases of infections of the catheter system or meningitis. An urgent presentation to the implanting centre is required to decide on further therapy; the complete IDDS system must be explanted in most cases.

Diagnostics with IDDS systems

All available IDDS systems are at least MRI conditional, and most systems are also approved for examinations throughout the whole body with 3 Tesla. Details may be found in the device manuals or obtained from manufacturers. There are significant erasures around the implanted pump itself, which should be considered when determining the indication [27]. Particular care should be taken when intrathecal baclofen therapy is ongoing. Patients with programmable pumps must visit the treating pain therapist immediately after the MRI to check the system function; this aspect should be considered when planning the appointment.

All X-ray diagnostics, including computed tomography, are possible without restrictions. While neurostimulators interfere with all electrophysiological studies, such problems are not to be expected with IDDS systems.

Case vignette 2 (continued): The on-call pain therapist was informed and arrived about 30 minutes later to address the untreated patient. He initiated an ECG and the usual laboratory diagnostics. The IDDS system was checked and it was determined that the pump had been off for 17 days. The last daily dose was 3.92 mg morphine. The pump was reactivated immediately with a reduced dose. After intravenous titration of 10 mg of morphine there was significant pain relief, the visual disturbances ceased within a few minutes, and strength was restored. Due to a troponin I of 131 pg/ml (max. value 5 days later 459 pg/ml), the patient was admitted to the chest pain unit. A coronary angiography was performed but provided no evidence of stenosis. The patient recovered quickly and, after 7 days, could be transferred to geriatric rehabilitation.

It was retrospectively determined that the treating pain therapist switched off the IDDS system for the MRI diagnostics. Apparently, reactivation of the pump was forgotten or failed after the MRI. All of the symptoms described are to be interpreted as opiate withdrawal syndrome.

Perioperative management with IDDS systems

The current intrathecal medication and the date of the next pump refill should be asked after during preoperative evaluation by the anaesthetist. Information on the exact model, the location of the pump, and the catheter (access to the spine and tip) can be found in the pump ID card, doctors' letters, and surgery reports on the implantation if necessary. Comprehensive documentation of these data preoperatively is recommended so that this information is available in the event of prolonged treatment on intensive care. Only some catheter systems provide X-ray contrast, so that X-rays are only deemed helpful if the course of the catheter is clearly visible. With IDDS systems, no special preparation of the implant is required before surgery [26].

In principle, regional anaesthesia is also possible with an implanted drug pump. For spinal anaesthesia, in most cases, the puncture can be performed below access to the spine. Depending on current medication and the position of the catheter tip, the specialist can also puncture the bolus port of the pump and inject via the catheter system. In epidural catheter analgesia, spinal access and the neighbouring segments should be omitted. When weighing the risks and benefits, the following risks must be considered: possible damage to the catheter system with resulting opiate withdrawal and revision surgery, and the increased risk of a spinal abscess or meningitis due to the presence of foreign material with resulting explantation of the entire system [26].

During surgery the catheter system must be protected under all circumstances! If the catheter is damaged, catheter revision should be carried out in the same session, if possible. If this is not possible, forward-looking substitution is mandatory until revision surgery is undertaken. These aspects must also be considered when establishing the surgical indication and gaining informed consent. Elective interventions along the course of the catheter should, if possible, be carried out in an implanting center.

Any acute pain is usually insufficiently relieved by intrathecal medication. Any change in dose is slow and sometimes takes several days to take effect. That is why almost all patients need oral or intravenous treatment of usual postoperative pain, based on the departmental standards. Sometimes significantly higher doses are required for for sufficient pain relief.

Acknowledgment

The authors would like to thank the German Federal Office for Statistics (Destatis) for providing extracts from the German Diagnosis Related Groups statistics free of charge.

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