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Perioperative Anaesthesia Considerations for Dystonia Patients with DBS: Brief Review and a Suggested Protocol

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Abstract

Dystonia is the commonest neurological movement disorder that is basically treated by anticholinergics, GABAergic medications and deep brain stimulation (DBS). This is a narrative review of anaesthetic management of dystonic patients with DBS, performed using PubMed (www.ncbi.nlm.nih.gov/PubMed/), and the keywords Dystonia, Deep brain stimulation (DBS), dystonia, acute dystonic reactions) ADR, Electrosurgery, MRI, medical cannabis. Prevention of both acute dystonic reactions ADR and electromagnetic interference EMI is the cornerstone of such management. Almost all anaesthetics are reported to cause ADR, but total intravenous protocol and remifentanil remains to be the choice, however we suggest sequential TIVA is safer and less stressful. All antiemetics are incriminated in causing ADR, however medical cannabis is suggested to offer an advantage as it could decrease muscle tension as well minimising the likelihood of causing ADR. DBS systems, while offering excellent range of options regarding different frequencies of stimulation and rechargeable batteries, still lack either neurostimulator's circuit monitor of induced current or brain temperature monitor, which results in the absence of prompt safeguarding against untoward brain damage. Besides, a protocol that clearly indicates duties of all responsible disciplines and possibly describes safest anaesthetic technique, is added.

Keywords: Dystonia; Deep brain stimulation; Medical cannabis; Brain Temperature monitoring; Electromagnetic monitoring; Medical cannabis

Introduction

Dystonia is a neurological movement disorder characterised by co-contraction of agonist and antagonist muscles that leads to either repetitive twisting movements or abnormal posturing. It is a large-scale dysfunction of, not only cortico-basal ganglia-thalamo-cortical pathways as traditionally thought, but also the cortico-ponto-cerebello-thalamo-cortical loop as well [1]. Mainly, imbalance between basal ganglia inhibitory neurotransmitters Dopaminergic-Gabergic and excitatory Cholinergic ones, is the mechanism of such dysfunction reducing, what we might call, basal ganglia Inhibitory/Excitatory ratio, (BG I/E ratio). Though,

indirect evidence has suggested that serotonin [5-hydroxytryptamine (5HT)] is involved too, through Dorsal Raphe Nuclei (DRN) serotonergic neuronal projections into deep cerebellar nuclei, especially in stress induced dystonia [2]. Treatment includes [3]; local muscle injection of Botulinum toxin, increasing BG I/E ratio through anticholinergic, GABAergic benzodiazepines and dopaminergic Levodopa. Surgery where adjustable and Bilateral Deep Brain Stimulators (DBS) has increasingly substituted ablative procedures such as local muscle denervation and/or pallidotomy. This narrative review, searching for dystonia with DBS anesthesia, will endeavor to assimilate the present knowledge regarding; anesthetic management of dystonic patients with DBS, perioperative complications, raising questions about EMI and finally suggesting a protocol. DBS is widely used for the treatment of dystonia and other medically refractory movement disorders and few neurological and psychiatric condition. DBS for dystonia is a four-contact stimulating electrode stereotactically implanted in globes palladium internal GPi bilaterally and connected via a subcutaneous wire to an Implantable Pulse Generator (IPG), a neurostimulator that is placed subcutaneously underneath the collarbone. IPG delivers stimulation to the electrodes at a high frequency (typically 130–180 Hz) suppressing over activity in the pallidum [4], releasing inhibitory dopamine and GABA increasing I/E ratio, hence creating a DBS-GPi milieu that would decrease needs for medications [5]. Physician's programmer controls the system wirelessly to adjust the parameters of stimulation, maximising symptom relief and minimising side effects. Patient's programmer allows the patient to perform checking programmer battery and turning the IPG on or off. DBS acts via several, nonexclusive mechanisms including local and network-wide electrical and neurochemical effects of stimulation, modulation of oscillatory activity, synaptic plasticity, and, potentially, neuroprotection and neurogenesis [6,7]. In dystonia, DBS can induce an early improvement in phasic dystonic movements, while tonic symptoms require months of DBS treatment to become fully realised [8]. The time course of DBS-induced symptoms relief is interestingly mirrored by its reappearance time course on interrupting DBS [9]. Clinical DBS protocols will cause Joule heating with concomitant increased metabolic activity, raising temperature of surrounding tissue by up to 0.8 ◦C depending on stimulation/tissue parameters [10]. Stable DBS-GPi milieu, through maintaining DBS, disallowing drop of I/E ratio, and preventing electromagnetic interference EMI, is crucially central to safe anaesthesia and surgery for dystonia patient with DBS. Electrosurgery constitutes major concern of EMI affecting DBS. EMI, generally, can cause direct damage to the IPG, suppressing, accelerating, or stopping its output, especially if applied in direct vicinity of IPG. Alternatively, induced current can pass through the IPG along the conducting wires, leading to heat generation at DBS electrodes and brain tissue damage. Even when the IPG is turned off, the metallic case and leads remain conductive, allowing current to pass through. There are two case reports of serious brain injuries secondary to heat generation at the DBS electrodes after use of diathermy for dental treatment [11,12]. The manufacturer subsequently issued a product advisory [13] to caution against the use of all forms of, shortwave, microwave, and therapeutic ultrasound diathermy treatment in patients with a IPG. Earlier review [14] found little DBS-specific intraoperative management information with more emphasis on references to experience with other implantable stimulator devices, mainly cardiac pacemakers. Similarities between all these stimulators could permit such reference, nevertheless heating dissipation at pacemaker electrodes is much faster that in brain or nerve tissues which might disqualify such reference. However, in a more recent review [15], evidence-based anaesthetic management is still not crystal clear. Bipolar mode [16] with minimum power settings and short intermittent bursts, has been shown to be safer for use in patients with turned-off IPGs. If necessary, unipolar mode could be used only with lowest possible

voltage and power settings with ground plate as far from IPG and leads as possible. MRI is considered safe under specified conditions after being an absolute contraindication due to electromagnetic interactions that could potentially result in patient morbidity as hemiplegia and new onset dystonic development. The safety concerns with MRI include excessive heating at the electrode tips, that results in bleeding, due to compounding of the current produced by the gradient and RF magnetic fields within the DBS system **[17,18]**, magnetic field interactions, image artifacts and distortion, and functional disruption of the DBS system. MRI specific guidelines in patients with implanted DBS devices vary according to the manufacturer, are well rehearsed by MRI people. Some neurostimulators are likely MR compatible, as suggested by studies showing the safe use of MRI under specified conditions, mainly head scans, 1.5 Tesla and < 0.1 W/Kg specific absorption rate SAR, in patients with an implanted DBS system. With advances in DBS technology, some centres now routinely insert DBS devices under intraoperative MRI guidance **[19]**. Neurostimulators should be turned off during imaging, which, in some patients, can lead to recurring symptoms that interfere with adequate image acquisition, hence anaesthesia standby could be called for and management might vary from reassurance, sedation to general anaesthetics. Electroconvulsive Therapy (ECT) application might similarly cause heat at the DBS electrodes, functional disruption of the DBS system and lead to displacement of electrodes from induced seizure activity **[20]**. Turning IPG off, placement of the ECT electrodes as far away as possible from the DBS electrodes, and seizure relaxant-induced control might prove safe, besides improving DBS itself might decrease the need for such harsh technique. Though DBS is now a widely accepted therapy, we still lack a definitive understanding of its mechanism of action. DBS manufacturing is growing out of its primary stage where only, continuous stimulation similar to asynchronous ventricular pacing, was produced. Current DBS systems have smaller IPGs, offer rechargeable IPG options, and are capable of providing variable frequencies and strengths of stimulation **[21].** Fundamental questions remain about heating effects especially secondary to EMI coupling with DBS, even when IPG is off **[22-26].** There is now increasing interest in the development of smart DBS producing novel electrophysiological and neurotransmitter microsensor systems, forming the basis of closed-loop DBS system with feedback-guided neuromodulation to optimize both electrode placement and therapeutic efficacy. Also bidirectional DBS leads **[27],** and computer-guided programming of DBS **[28],** are still in early development. Deep brain stimulation is now a standard of care for dystonic patients. Thus, for safe management, it is imperative for the anesthesiologist to be aware of DBS parameters, practicing precautions for safe use of electrosurgical equipment, turning off the IPG intraoperatively and checking the device postoperatively. We suppose that integrating monitoring of local temperature and/or induced currents into IPG, could be next addition to guarantee safety through early intervention before developing irreversible brain damage as well as covering the gap of evidence-based recommendations. Besides, Bluetooth mechanism could guarantee reverse pairing between electrosurgical unit and IPG, (if one is on, the other is off), to minimise the off time. Should all these be viable options, then continuous intraoperative monitoring of DBS welfare would diagnose any adverse induced current and/or heating early enough and help to get much-needed evidence-based recommendations regarding DBS or other neurostimulators.

Non-Dystonic Anesthesia

Dystonia is often exacerbated by stress [29-31], anesthesia, hyperglycaemia, hypothermia and specific medications, besides putting DBS off. Preanesthetic neuropsychological assessment [32] could ease preoperative stress [33] and anxiety; preparing patient and carer for such traumatic event, guaranteeing their informed cooperation and decreasing likelihood of acute dystonic reaction ADR. Preoperative assessment clinic would focus on dystonia picture, optimising medications, co-morbidities and DBS specifications. The patient or carer should be, informed about potential EMI in theatre and able to demonstrate how to turn IPG on or off. DBS is inserted in specialised centres and its specifications and limitations should be clearly disseminated in patient's record and easily available for all professional teams, preferably with a protocol for anaesthesia. DBS-trained physician attendance might sound ideal but, in reality, is a degree of redundancy, unachievable in majority of hospitals and may only lead to unnecessary delay or cancellation of surgery. The anaesthetist would take control of patient's programmer; checking IPG battery and turning it on or off. Non-dystonic anaesthesia maintains high basal ganglia I/E ratio through careful selection of drugs that will not precipitate ADR, ensures normothermia and normoglycemia, brings DBS-GPi milieu safely to preoperative level on recovery and finally manages any developed ADR which is a drug induced dystonic sustained or intermittent contractions of face, tongue, jaw, eyes, neck and very rarely the larynx. It occurs more commonly in young male dystonic or any other movement disorders or patients who have recently received antipsychotic medications, and less commonly other patients. It is often rapid and reversible, may happen overtly on induction or recovery where it could compromise patient airway and safety, or covertly under anaesthesia where it could be transient. Almost all drugs used in anaesthetics are reported to cause such ADR [34]. Unfortunately, antiemetics [35,36], as well as ketamine [37] are definite prime mover under anaesthesia, besides first and second generation antipsychotics. Their ADRs usually presents disturbingly postoperative and may be prolonged. Other anaesthetic drugs are probable causer as shown in case reports including propofol [38], midazolam [39], diazepam, etomidate, thiopental, sevoflurane, fentanyl, remifentanil, gabapentin. The preferred anaesthetic agents are dexmedetomidine [40], remifentanil and propofol [41] which are even used for sedation and general anaesthesia during DBS insertion [42]. However, clonidine and dexmedetomidine are not reported, yet, to cause it, however clonidine is a recognized treatment for children dystonia [43]. ADR could be immediate or delayed, transient or prolonged and easily treated or resistant [44,45], on induction, ADR could be managed by deepening anaesthesia and relaxants, however ADR on recovery is disturbing to patient, anaesthesia and recovery staff, delaying discharge or even causing unplanned admission. Antiemetics remain to be the most offensive postoperatively as most of them are reported for ADR including ondansetron that is a serotonin 5-HT3 receptor antagonist [46,47], however its dystonic symptoms are caused by blockade of D2 dopamine receptors within the extra-pyramidal system resulting in slow movements, stiffness and tremor. Search of an antiemetic that is antidystonic as well is warranted. Cannabis plant contain predominantly the psychotropic Δ9-Tetrahydrocannabinol (Δ9-THC) and the non-psychoactive ingredient Cannabidiol (CBD) with ability to act as analgesics, antiemetics, anti-inflammatory agents and antiseizure compounds with lack of well-controlled, double blind, randomized clinical trials. Is it time to conduct well controlled study that could allow medical canabis fill in this antiemetic gap perioperatively [48-50]. Otherwise or meanwhile, we resort to no routine antiemetic prophylaxis, carful patient positioning, careful preoxygenation, modified rapid sequence induction, TIVA, hydration, avoiding reversal of neuromuscular blockade with neostigmine [51], and fine-tuning of

surgical details. Then and only then, dexamethasone could be chosen for treatment, or as last resort Ondansetron with careful observation. Opioid analgesics continue to pose ADR threat, and other analgesia modalities should be maximally used, while fentanyl or morphine pose as the least probable. Treatment centres on discontinuation of the offending agent and balancing I/E ratio. Anticholinergics; Diphenhydramine and benztropine are conventionally used, but in anaesthesia or recovery setting, probably familiar drugs could be used as; dexmedetomidine, clonidine [52], midazolam, diazepam and appropriately drug-specific antidotes like flumazenil [53], naloxone [54], while maintaining patent airway, oxygenation and safe patient positioning. Premedication allays anxiety and proactively affects I/E ratio favourably, where clonidine could lend itself. Co-induction by midazolam and propofol could be fast, balanced and with little probability of a transient ADR, that can be managed by muscle relaxant. Recovery is bringing back preoperative DBS-Dystonia baseline and immediate management of ADR. With full-definite and well-documented reversal of neuromuscular blocking agent, any involuntary movement could be taken as ADR which is caused by drugs or non-functioning DBS. Maintain airway, oxygenation and safe positioning, make sure IPG is on and working, then use the first line of treatment or the conventional one as stated earlier. Delayed recovery has got extra specific cause as brain damage by heating, where MRI and communication with DBS specialist should be initiated. On the other side, capable patient of checking lifespan of the IPG, programmer battery and turning the IPG on or off, is a proof of successful anaesthesia and recovery.

Conclusion

The anesthesiologist plays major role to ensure a safe operating environment and non-dystonic anaesthesia. Pertinent issues include; identifying dystonia state, disallowing and treating ADR, proper DBS managing, preventing EMI, minimising DBS-off time while using bipolar electrosurgery and postoperative checking and communicating with DBS specialist. Definitely, it is a long way to go for developing DBS and managing dystonic patients through evidence-based guidelines. Monitoring of electromagnetic waves in theatre is probably due, not only for safe management of patients with or even without electrical stimulators, but also as a prelude to awareness and safe living among all EM waves producing and/or receiving gadgets. Probably, EMWs in-depth knowledge added to physics for anaesthetists' curriculum could be needed.

Suggested Protocol

Anaesthetic Management of Dystonia Patient with DBS

Clinical picture

- Dystonia; dystonic picture, post DBS improvement, any airway or unsafe positioning dystonia.
- DBS; history, specifications, limitations, records of anaesthesia for insertion, communication with neurologist or DBS-specialist.
- Co-morbidities.
- Surgery; site, extent, necessary Electrosurgery.

Stress reduction

- Preanesthetic neuropsychological assessment to prepare patient and carer for such traumatic event.
- Preanaesthetic assessment.
- Patient and/or carer is informed about electrocautery and precautions against electromagnetic interference, EMI.
- Patient is allowed to demonstrate checking implantable pulse generator IPG battery and turning it on and off. Record allowed IPG-off time and effects.
- Record interference with ECG and compare while IPG is off.
- Anaesthetic plan is discussed with patient and/or carer with the potential of interference and acute dystonic reaction, and necessity of postoperative IPG check.
- Schedule patient first case to allow for any possible delay in recovery.
- Premedication, clonidine.

Anaesthetic management

- Continue all anti-dystonic medications without interruptions.
- GA or regional; preferably awake if possible, US-guided or Nerve stimulator-guided are all
- allowed.
- Standard monitor, with added temperature, blood sugar and BIS. Any interference is noted and checked versus IPG off.
- Sequential total intravenous anaesthesia; Propofol first for sleeping, followed by rocuronium and then remifentanil.
- Balanced analgesia intraoperatively, with morphine at the end.
- Rocuronium is preferred as its reversal is easily and surely managed, with liberal use of sugammadex on recovery, as neostigmine may increase PONV.
- Maintain normothermia and normoglycemia.
- Avoid prophylactic antiemetics, ensure carful mask ventilation, head poisoning and surgical techniques. As medical cannabis needs further controlled studies, ondansetron and dexamethasone could be used to treat PONV.
- Record use of Electrosurgery, bipolar or unipolar, DBS-off total duration.

Recovery: early diagnosis of ADR

- Sugamadex reversal is essential so that partial paralysis is not confused with ADR.
- Close observe for ADR; monitoring, upper airway and diaphragmatic maintenance, any involuntary muscle contraction, administered drugs mainly antiemetic.

Diagnose and treat rapidly

- Anticholinergic benztropine 1-2 mg, iv. Response appears within 5 minutes and dystonic reaction disappears within15 minutes. No response; repeat after 10 minutes. No response; reconsider diagnosis is probably wrong.
- Antihistamine and anticholinergic Diphenhydramine 1-2 mg/kg.
- Others worth trying; dexmedetomidine, clonidine, midazolam, diazepam or physostigmine, and causative drug-specific antidote like flumazinil, naloxone.

Differential diagnosis includes

- Tetanus and strychnine poisoning.
- Hyperventilation, carpopedal spasm.
- Hypocalcaemia and hypomagnesaemia.
- Primary neurological causes such as Wilson's disease.

Summary

Communicate early with neurologist and DBS centre. Anaesthesia department logbook; Dystonia and DBS Technique of anaesthesia, all medications used, Electrosurgery bipolar or unipolar, DBS-off time, and smooth, dystonic or delayed recovery that could be communicated to patient DBS centre closing the circle and hoping for national register with yearly review.

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