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Original Article

Safety of the transventricular approach to deep brain stimulation: A retrospective review

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ABSTRACT

Background: Anatomically, deep brain stimulation (DBS) targets such as the ventral intermediate and subthalamic nucleus are positioned such that the long axis of the nucleus is often most accessible through a transventricular trajectory. We hypothesize that using this trajectory does not place patients at increased risk of neurologic complications.

Methods: A series of 206 patients at a single institution between 2000 and 2017 were reviewed. All patients had a confirmed transventricular trajectory and their clinical course was reviewed to assess neurologic complication rates in the postoperative period.

Results: The average length of hospital stay was 2.4 days. The most common neurologic complication was altered mental status in 1.2% of cases (four patients). This was followed by seizure in 0.6% of cases (two patients). No patients had ischemic stroke or postoperative hemiparesis. There were two mortalities in this series, one with lobar hemorrhage contralateral from the surgical site and one with a thalamic hemorrhage. There was only one confirmed intraventricular hemorrhage postoperatively; however, this was clinically asymptomatic.

Conclusion: Although the total incidence of intraventricular or intracerebral hemorrhage cannot be reliably assessed from this data set, the low incidence of neurologic complications challenges the notion that DBS electrode trajectories that transgress the ventricle significantly increase the risk of complications.

Keywords: Deep brain stimulation, Functional, Movement disorders, Parkinson's disease, Transventricular, Tremor

INTRODUCTION

Deep brain stimulation (DBS) for the treatment of diseases such as Parkinson's, dystonia, and essential tremor has increased in popularity since its introduction in the early nineties. Conventionally, care has been taken to avoid electrode trajectories that traverse the lateral ventricle due to the risk of neurologic complications such as intraventricular hemorrhage, seizure, postoperative confusion, and reduced accuracy of electrode placement.[3,5-8,10,12,16,17] In some circumstances, cerebral atrophy or age-related ventricular dilation precludes avoiding the ventricle, especially in more midline structures such as the subthalamic nucleus (STN) or ventral intermediate (VIM) nucleus of the thalamus.[5] Anatomically, common DBS targets such as the globus pallidus pars interna (GPi) and STN are positioned such that the long axis of the nucleus is often most accessible through a transventricular trajectory due to its orientation in the coronal plane. Historically, the localization of the STN was dependent on ventricular landmarks such

as the anterior commissure (AC), posterior commissure (PC), and the AC-PC line.[2] At our institution, trajectories are planned targeting the long axis of the nucleus regardless of whether or not the trajectory involves passing through the lateral ventricle. This study aims to challenge the notion that transventricular trajectories significantly increase the risk of morbidity. We report our institutional experience with transventricular electrode placement and its associated complications.

METHODS

Patient selection and variables assessed

This was a retrospective analysis of 206 patients who underwent DBS for movement disorders between 2000 and 2017 at a single institution. A total of 206 patients underwent 326 DBS procedures [Table 1]. Patient was included if transventricular trajectory was planned and had confirmed lead placement on magnetic resonance imaging (MRI) or computed tomography (CT), whether it was immediately postoperative imaging or in follow-up. Not all patients received postoperative imaging to confirm lead placement. Charts were reviewed to identify demographics, diagnosis of a movement disorder confirmed by a movement disorder specialist, length of hospital stay, and any neurologic complications. Surgical factors assessed included DBS target, intraoperative complications, and any neurologic complications during the immediate postoperative period. This was defined as the time between surgery and time of discharge from the hospital. At our institution, after the cranial portion of the surgery is complete, patients are then anesthetized to have the impulse generator(s) implanted on the same day. Thus, instances of altered mental status (AMS) occurring within the first 12 h of surgery were not counted as neurologic complications as it cannot be determined if the AMS was an anesthetic effect or a direct result of surgery. Common medical complications such as postoperative fever, urinary retention, or cardiac events were not included under our definition of neurologic complications and, therefore, not reported in this study.

Table 1: Number of patients by indication, number of total surgeries, and surgical targets by indication.

Indication	No. of Patients	Total surgeries	STN	GPI	VIM
Parkinson's	156	246	223	9	14
Tremor	47	77	0	0	77
Dystonia	2	2	0	2	0
Tourette	1	1	0	0	0
Total	206	326	223	11	91

GPI: Globus pallidus pars interna, STN: Subthalamic nucleus, VIM: Ventral intermediate

Operative technique

All patients were placed in a Leksell frame on the day of surgery with a local anesthetic (1% lidocaine with epinephrine + 0.25%–0.5% bupivacaine) and CT stereotactic images were obtained. The intended target and trajectory were identified and planned using StealthStation Navigation™ (Medtronic) with an emphasis on avoiding sulci and any obvious vasculature. A medial approach with an angle of 2–10° in the coronal plane was favored in most cases, regardless of whether or not the trajectory would pass through the lateral ventricles. Transventricular trajectories for VIM and STN placement are shown in Figures 1 and 2.

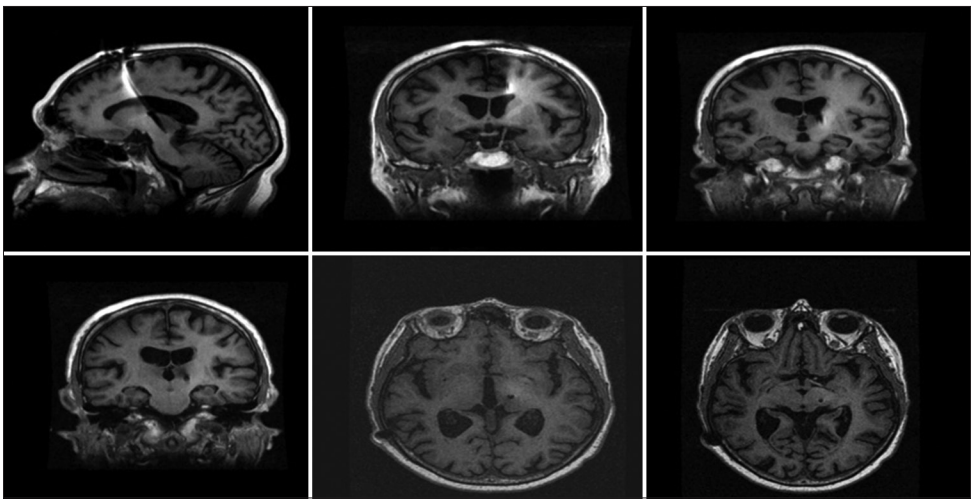

Figure 1: Ventral intermediate (VIM) trajectory. T1 magnetic resonance imaging showing trajectory of the left VIM electrode. Top left – sagittal view of electrode at target, top middle – coronal view of electrode entering left lateral ventricle, top right – coronal view of electrode exiting left lateral ventricle, bottom right – axial view of electrode at target.

The vast majority of procedures were performed without sedation to allow for intraoperative stimulation testing. Patients were placed in a chaise lounge position and 14 mm precoronal burr holes were drilled based on the planned trajectory. The dura was coagulated, incised, and a microstimulator was introduced. The burr holes were packed with GelFoam® (Pfizer) to minimize loss of CSF. Microelectrode recording was performed in STN or GPi lead placements. Once adequate electrodeposition was obtained, permanent electrodes were inserted, and patients were retested to ensure favorable positioning before closing. Intraoperative testing was assisted by neurologists and neurology physician assistants present in the operating room. Following implantation of the DBS electrodes, the stereotactic frame was removed, and the patients were immediately anesthetized and prepped for implantation of the impulse generator or connection to an existing generator. In rare cases, some patients were deemed too unstable to continue.

RESULTS

Patient population

Over a 17-year period (2000–2017), 206 patients (137 males and 69 females) were included with 326 confirmed transventricular electrodes. The average age was 64 years old. The indications for implantation were Parkinson's disease (156 patients, 246 electrodes), essential tremor (47 patients, 77 electrodes), dystonia (2 patients, patients), and Tourette syndrome (1 patient, 1 electrode) [Table 1]. In Parkinson's, the most common target was the STN (223) followed VIM (14) and then GPi (9). The targets in essential tremor were VIM in all 77 cases. The GPi was targeted in both dystonia cases. The globus pallidus externus was targeted in our only case of Tourette syndrome.

Complications

The total complication rate in our study was 5.6%, with higher complication rates for patients with Parkinson's (6.1%) versus essential tremor (2.6%), dystonia (0%), or Tourette's (0%) [Table 2]. Only four patients demonstrated postoperative AMS (1.2%). Two patients demonstrated suspected seizure activity (0.6%); however, seizures were never confirmed nor did either develop chronic epilepsy. One patient suffered a postoperative subdural hematoma requiring emergent craniotomy. Two mortalities were noted with intracerebral hemorrhage originating in the thalamus in one patient and a spontaneous lobar intracerebral hemorrhage originating in the contralateral hemisphere in another patient. This was determined to be from a Valsalva maneuver while using the restroom. No patients demonstrated postoperative hemiparesis or ischemic stroke. In patients with postoperative imaging, one patient had confirmed intraventricular hemorrhage, but this was clinically asymptomatic. Four patients were found to have intraparenchymal hemorrhage. This includes the two previously mentioned mortalities, one subdural hematoma and additionally one small sulcal bleed associated with suspected seizure activity, though never confirmed. Of these four patients, none had hemorrhages that can be directly associated to the electrodes passing through the ventricle. Our total complications found in this study are listed below [Table 3]. Average length of stay was 2.4 days. All patients were discharged home in stable condition except for the two mortalities and one patient with SDH who was eventually transferred to a rehab facility.

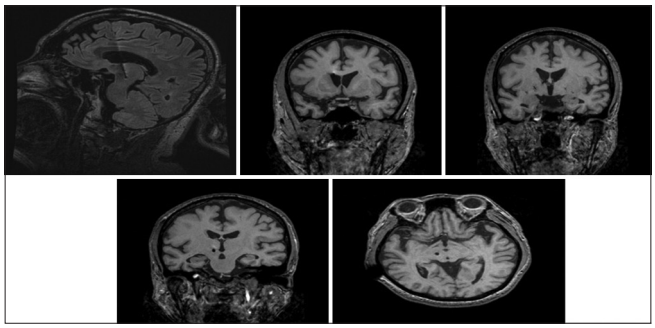

Figure 2: Subthalamic nucleus (STN) trajectory. T1 magnetic resonance imaging showing trajectory of the right STN electrode. Top left – sagittal view of electrode at target, top middle – coronal view with electrode entering right lateral ventricle, top right – electrode exiting ventricle, bottom middle – axial view of electrode at target.

Table 2: Complication rates per surgical indication.

Surgical Indication	Total surgeries	Adverse effects	Complication rate (%)
Parkinson's	246	15	6.1
Tremor	77	2	2.6
Dystonia	2	0	0
Tourette	1	0	0
Total	326	17	5.2

Table 3: Individual complication rates associated with each diagnosis.

Complications	Parkinson's	Tremor	Dystonia	Rate (%)
Altered mental status	4	0	0	1.2
Seizure	2	0	0	0.6
Delirium	1	0	0	0.3
Lethargy	1	0	0	0.3
ICH	3	1	0	1.2
Nausea	0	1	0	0.3
Aphasia	1	0	0	0.3
Hyponatremia	1	0	0	0.3
Death	2	0	0	0.6
Total	15	2	0	5.2

ICH: Intracerebral hemorrhage

DISCUSSION

In our series, we report comparable or lower complication rates utilizing a transventricular trajectory for DBS. Our frequency of intracerebral hemorrhage (ICH) (1.2%) is lower than the average rate of 3% reported in literature; however, ranges of 1.2–3.6% have been reported.[13,14] Postoperative confusion/AMS (1.2%) was the most common complication in our patients and is lower than 5% reported by Kenney *et al.*, in 2007.[8] Again, it is important to reiterate that at our institution, the patient is anesthetized after lead placement to proceed directly to battery implantation or connection to an existing battery. For this reason, we only included patients that had persistent AMS beyond 12 h postoperatively to rule out AMS that was simply due to the effects of anesthesia. In patients who experienced postoperative confusion/AMS, three had electrodes placed in the STN and one underwent second side electrode placement in the GPi. Transient confusion has been reported in 15–30% of patients after STN deep brain stimulator placement.[12] It has been reported that placement of electrodes in the STN without ventricular involvement increases risk of postoperative confusion.[1,7,10] Thus, it is unclear if postoperative confusion is related to transgression of the ventricle or due to lead placement in the STN. In addition, it has been reported that larger lateral ventricular width is associated with a higher incidence of postoperative confusion as well as complicated recovery.[4]

Headache was commonly reported though this is an expected finding and no patients in our study had severe headache documented beyond postoperative day 2. Seizures are an uncommon finding after DBS with a reported rate of 1.2% by Kenney *et al.* and 4.3% reported by Pouratian *et al.*, in 2011.[8,10] Pouratian noted a statistical association with traversing the ventricle and seizure; however, our series did not corroborate this association with only 0.6% of our patients experiencing only mild suspected seizure activity which was focal, transient, and unable to be confirmed with EEG. In fact, we saw a significantly lower rate of seizure in our patient population. Given that seizure has previously been associated with electrodes near a sulcus, it is possible that our seizure rate is lower because less cortical tissue and parenchyma are in contact with the electrode. Intraventricular hemorrhage was documented in only one patient; however, the patient was clinically asymptomatic. A total of four patients with postoperative imaging demonstrated intraparenchymal or subdural hemorrhage; however, the imaging was obtained based on clinical judgment. None of these hemorrhages could be directly attributed to the electrode puncturing the ventricle. We were unable to accurately determine the incidence of intraventricular hemorrhage (IVH) in our series because confirmation of lead placement was obtained primarily from preoperative imaging for the second side surgery or when head CT was obtained for unrelated reasons after discharge. It can be inferred that even if our rate of IVH is significantly higher, it is clinically insignificant as patients did not require further intervention or longer hospital stay. It is also reasonable to assume that any other intracranial hemorrhages that may have occurred are also clinically insignificant as our patients' postoperative course did not prompt any further imaging or investigation.

Risks of transventricular trajectory

The previous authors report an increased risk of complications such as IVH with transgressing the ventricle such as confusion and increased length of stay.[7] There is one report of transient confusion and ophthalmoplegia associated with IVH.[11] Several papers have documented intraventricular hemorrhage following transventricular lead placement; however, no significant neurologic morbidity or mortality was reported as a direct result.[1-3] Hypertension is a major risk factor that is associated postoperative ICH in DBS placement with one study reporting the risk of hemorrhage 2.5 times higher than that of normotensive patients regardless of trajectory.[5,15] This makes the consequence of traversing the ventricle unclear.

Elias *et al.* identified 15 intracerebral adverse events of 113 transventricular lead placements though none of these complications were directly associated to ventricular punctures. They also found 5% rate of IVH, but this was clinically asymptomatic.[5] Fenoy *et al.* reported complications of DBS in their series of 728 patients, in which they found asymptomatic intraventricular hemorrhage in 3.4%, symptomatic ICH in 1.1%, ischemic infarction in 0.4%, and hemiparesis and/or decreased consciousness in 1.7%. They also reported an increased 2.4% increased risk of postoperative confusion after STN electrode placement.[6] Terao *et al.* reported 2/59 (3.4%) patients with IVH after lead placement which were asymptomatic. It is unclear from their report how many electrodes penetrated the ventricle.[12] Traversing the ventricle has been associated with increased length of stay and transient postoperative confusion.[7,12] Zrinzo *et al.* showed that traversing the ventricle decreased the accuracy of lead placement but that the error was not clinically significant.[10] To the best of our knowledge, only one study that purposely took a transventricular trajectory through an MRI-guided tube system for electrode placement in midline structures such as the pedunculopontine and periaqueductal gray matter. In this study, no incidence of lead misplacement or hemorrhage was seen in the 13 patients included in their study.[9]

Limitations

A major limitation of our study is the fact that not all patients receive immediate postoperative imaging to detect any potential intracranial hemorrhage. This limits the uniformity of our data analysis; however, we do not believe that this had any bearing on patient outcome or management as those patients who exhibited signs of neurologic dysfunction received appropriate imaging. Another limitation of our study exists with respect to accuracy of actual electrode placement compared to the intended target. Preoperative target plans were not routinely saved on the navigation software nor were immediate postoperative scans obtained for comparison in most cases. The previous authors have reported drift from the intended target due to loss of CSF or deflection of electrodes off ependymal lining of the ventricle although this was not found to be clinically significant.[6] All patients in this series showed adequate response to surgery intraoperatively, indicating that the intended target was sufficiently in contact with the implanted electrodes.

CONCLUSION

Our results challenge the notion that transventricular lead placement puts patients at a significantly higher risk for neurologic complications, particularly with respect to clinically significant intraventricular hemorrhage, postoperative confusion, or seizures. We found no clinically significant neurologic complications associated with a transventricular approach. Although the incidence of intraventricular hemorrhage is underreported in this study due to lack of routine postoperative imaging, it can be inferred that if intraventricular hemorrhage was present, it was not clinically relevant. Therefore, we believe that using a transventricular trajectory is safe and offers an optimal trajectory to maximize electrode placement in medial structures such as the STN or VIM. Prospective studies are recommended to help confirm these findings.

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Conflicts of interest

There are no conflicts of interest.

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