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# Deep Brain Stimulation Surgery Programs in Canada

Environmental Scan

**Authors:** Camille Santos, Kendra Brett, Danielle MacDougall, Melissa Walter, Jennifer Horton

Contributor: Michelle Clark

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Questions or requests for information about this report can be directed to **Requests@CADTH.ca**.

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## Abbreviations

| | |
|---|---|
| **DBS** | deep brain stimulation |
| **GPi** | globus pallidus interna |
| **NICE** | National Institute for Health and Care Excellence |
| **OCD** | obsessive compulsive disorder |
| **PD** | Parkinson disease |
| **PTSD** | posttraumatic stress disorder |
| **STN** | subthalamic nucleus |

## Key Messages

- Deep brain stimulation involves the surgical insertion of electrodes to stimulate targeted areas of the brain. It is recommended to help control movement-related symptoms of Parkinson disease with certain indications and contraindications to consider.
- This rapid Environmental Scan describes the landscape of deep brain stimulation surgery across Canada and identifies conditions other than Parkinson disease that can benefit from the therapy. It also provides an overview of cost-effectiveness studies on deep brain stimulation for Parkinson disease.
- Emerging indications for deep brain stimulation include refractory obsessive-compulsive disorder, refractory epilepsy, treatment-resistant Tourette syndrome, certain types of pain, refractory major depressive disorder, tardive dyskinesia, and essential tremor.
- In Canada, there are deep brain stimulation surgery programs in Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, Quebec, and Saskatchewan. The number of qualified neurosurgeons for deep brain stimulation surgery ranges from 1 to 5 (at least) across jurisdictions.
- Overall, deep brain stimulation is considered cost-effective for people living with advanced Parkinson disease. The risk of developing Parkinson disease increases with age, with onset typically occurring in late adulthood. The number of people eligible for deep brain stimulation in Canada is expected to increase with the aging population and emerging indications. Information related to existing surgery programs can help support capacity planning for deep brain stimulation surgery in Canada.

## Context

Parkinson disease (PD) is a progressive adult-onset neurodegenerative disease that negatively impacts an individual's quality of life and function.[1,2] It is characterized by motor-related features, including resting tremor, slowness of movements (bradykinesia), stiffness (rigidity), and postural instability, as a result of a dopamine deficiency from the basal ganglia.[2,3] However, PD can also manifest in nonmotor features, such as cognitive dysfunction, hallucinations, sleep disturbances, and fatigue.[2]

In 2016, 6.1 million people globally were living with PD and it caused 3.2 million disability-adjusted life-years.[4] The mortality rate in 2019 was estimated to be 5.67 per 100,000 population worldwide.[5] In Canada, the prevalence of parkinsonism, which is inclusive of PD, is 0.43% of adults age 40 years and older, with a mortality rate of 3,153 per 100,000.[6] However, the proportion of the reported prevalence specific to people living with PD is unclear. Statistics Canada reported that approximately 55,000 adult living in Canada in 2015 were diagnosed with PD but cases are expected to grow with the aging population.[6,7]

There is no cure for PD, but treatment is available to help control symptoms. Dopaminergic therapy, most often levodopa, is the first line of treatment.[8,9] Long-term use of levodopa can lead to medication-induced dyskinesia (involuntary movements),[10] and as PD progresses, individuals can experience increased motor complications.[11] Deep brain stimulation (DBS) therapy is a treatment option available to individuals living

with advanced PD. It involves stereotactic brain surgery to implant electrodes that are connected to a neurostimulator and deliver electrical stimulation.[12] Movement-related specialists, such as neurologists and neurosurgeons, determine an individual's eligibility for DBS therapy before insertion.[13,14] Clinics specialized in DBS make the necessary adjustments to the neurostimulator after insertion.[15,16] In PD, DBS delivers stimulation to targeted areas within the basal ganglia, such as the subthalamic nucleus (STN) and the globus pallidus interna (GPi).[17] DBS can also be used for other movement-related disorders and is being investigated for other indications, such as posttraumatic stress disorder (PTSD), alcohol use disorder, obsessive-compulsive disorder (OCD), and major depressive disorder.[18] Innovations for related devices are also emerging, such as adaptive DBS, which can adjust stimulation based on fluctuations of biomarkers.[12]

As the prevalence of PD increases and indications for DBS expand, there is a need for information on capacity and the demand for DBS surgery programs across Canada. The key objectives of this rapid Environmental Scan are to:

1. describe the landscape of DBS surgery across Canada (this includes the number of neurosurgeons qualified to perform DBS surgery, the volume of surgeries, and information on professional associations that provide support to neurosurgeons conducting DBS surgery)
2. describe the cost-effectiveness of DBS therapy for people living with PD (this includes a narrative summary of economic evaluations)
3. describe populations that may benefit from DBS therapy (this includes guidelines regarding the use of DBS for people living with PD or with other conditions, and the prevalence of each condition in Canada when available).

Previous CADTH work on DBS includes 2 Rapid Response reports (summary with critical appraisal)[8,19] and a Horizon Scan.[12]

## Research Questions

1. What is the landscape of DBS surgery programs in Canada?
    a) Which jurisdictions have the capacity to perform DBS surgery?
    b) How many neurosurgeons are qualified to perform DBS surgery?
    c) How many people living in Canada are eligible for DBS surgery?
    d) What is the volume of DBS surgeries performed across Canada?
    e) Are there professional associations in Canada that provide support to neurosurgeons qualified to perform DBS?
    f) How many surgeries are required for neurosurgeons to maintain competency?
2. What is the cost-effectiveness of DBS for people living with PD?
3. What are the guidelines regarding the use of DBS for PD and other conditions?
    a) What is the recommended number of surgeries required for neurosurgeons to maintain competency?

# Methods

We provided a narrative summary of the DBS programs in Canada based on information from a limited search and a review of the grey literature, including public-facing websites (e.g., program websites, clinician bios, and news articles) to address question 1. Additionally, we performed a literature search to identify economic evaluations and guidelines to address question 2 and question 3, respectively, and a narrative synthesis of relevant findings was provided.

## Literature Search

Information specialists conducted literature searches on key resources including MEDLINE, CADTH, the National Institute for Health and Care Excellence (NICE), relevant websites from CADTH's Grey Matters: A Practical Tool For Searching Health-Related Grey Literature, as well as a focused internet search. The search approach was customized to retrieve a limited set of results, balancing comprehensiveness with relevancy. The search strategy comprised both controlled vocabulary, such as the National Library of Medicine's MeSH (Medical Subject Headings), and keywords. Search concepts were developed based on the elements of the research questions and selection criteria. A search for published guidelines was completed on May 3, 2023. The main search concepts were deep brain stimulation and Parkinson disease. CADTH-developed search filters were applied to limit retrieval to guidelines. Results were limited to English-language documents published since January 01, 2013. A supplemental search on the concept deep brain stimulation was completed on May 09, 2023. For this search CADTH-developed search filters were applied to limit retrieval to economic studies. Results were limited to English-language documents published since January 1, 2018. Additionally, focused internet searches were conducted between May 2 and May 8, 2023, to retrieve data on the prevalence of conditions that might be treated with DBS, including PD, dystonia, essential tremor, multiple sclerosis tremor, spasmodic dysphonia, epilepsy, treatment-resistant depression, obsessive-compulsive disorder, neuropathic pain, Tourette syndrome, and tardive dyskinesia. Focused internet searches for DBS programs in Canada were also conducted between May 2 and May 3, 2023.

### Screening and Study Selection

One researcher was involved with screening the grey literature for relevance to address objective 1. For this objective, information on the landscape of DBS surgery across Canada was sought, including available surgery programs, the number of qualified neurosurgeons, surgery volumes, professional associations providing support to neurosurgeons, and the number of surgeries required for neurosurgeons to maintain competency. One researcher was involved with screening the literature for economic evaluations to address objective 2. Two researchers were involved with the screening of the literature for relevant guidelines to address objective 3, including guidelines with recommendations on the number of surgeries required for neurosurgeons to maintain competency. Refer to the criteria listed in Table 1 as those used for information gathering and literature selection.

### Table 1: Components for Literature Screening and Information Gathering

| Criteria | Description |
|---|---|
| **Population** | People eligible for DBS |
| **Intervention** | DBS |
| **Settings** | Facilities with the capacity to perform DBS surgery |
| **Type of information** | • Landscape of DBS surgery programs across Canada, including:<br>  ◦ DBS surgery programs<br>  ◦ number of neurosurgeons qualified to perform DBS surgery<br>  ◦ surgery volumes<br>  ◦ professional associations supporting neurosurgeons qualified for DBS surgery<br>  ◦ number of surgeries required for neurosurgeons to maintain competency<br>• Economic evaluations regarding the use of DBS for PD and other conditions<br>• Guidelines regarding the use of DBS for PD and other conditions, including:<br>  ◦ recommendations on the number of surgeries required for neurosurgeons to maintain competency |

DBS = deep brain stimulation; PD = Parkinson disease.

# Findings

## Objective 1: Landscape of DBS Surgery Across Canada

### Jurisdictions With Programs and Available Wait Times

Information about DBS surgery programs across Canada was gathered from grey literature, including public-facing websites, and may not reflect all programs available in Canada. Based on the programs identified, DBS surgery in Canada is performed in Alberta,[20,21] British Columbia,[15] Manitoba,[14] Nova Scotia,[22] Ontario,[13,23-25] Quebec,[26-29] and Saskatchewan.[16] People living in Prince Edward Island, Newfoundland and Labrador, and New Brunswick who need DBS surgery typically travel to Nova Scotia for the procedure.[30] Additionally, we did not identify facilities in the territories that perform DBS surgery. Refer to Table 2 for a summary of the information we identified on DBS surgery programs and their associated wait times. It is important to note that we may not have identified all DBS surgical programs in Canada.

All 7 jurisdictions with DBS programs identified provide DBS for movement-related disorders,[13,15,16,20,31,32] such as PD, essential tremor, and dystonia. British Columbia and Manitoba also provide DBS for pain (e.g., chronic pain). The Psychiatric Neuromodulation Clinic in Quebec performs DBS therapy for people with severe refractory OCD,[27] and British Columbia provides DBS surgery to individuals with depression.[15]

In Alberta, 2 programs were identified, the Parkinson and Movement Disorder Program (in Edmonton) and the Movement Disorder Clinic (in Calgary), with a total of 3 qualified neurosurgeons in 2021.[14,20,21] In 2018, it was reported that the wait time for DBS surgery in Alberta was 6 to 12 months.[33] The Deep Brain Stimulation Clinic in Vancouver[15] is the only DBS surgery program in British Columbia and there is at least 1 qualified neurosurgeon in the province.[33] There are 2 wait-lists for DBS surgery in British Columbia: the

first is to determine an individual's eligibility for DBS and the second is for the surgery.[33] In 2021, the wait time, inclusive of both wait-lists, was reported to be up to 4 years.[33,34] In 2019, British Columbia announced its plans to expand the program by recruiting additional neurosurgeons for insertion surgery and less specialized surgeries for battery replacements, in addition to increasing available operating room time for procedures, to meet surgical targets.[35] Based on the information we identified, a second neurosurgeon for implantation surgery for DBS in British Columbia had yet to be hired as of 2021.[34]

According to an assessment of DBS access in 2016, Saskatchewan and Nova Scotia were able to perform DBS with no annual budgetary restrictions, whereas other jurisdictions reported having a cap on annual funding available for DBS surgeries.[30] The Functional Neurosurgery Program in Saskatoon, Saskatchewan, has 3 qualified neurosurgeons,[16] with virtually no wait-list as of 2021.[34] The same assessment of DBS access reported that Saskatchewan has the highest ratio of qualified DBS neurosurgeons in Canada (1 per 0.37 million population).[30] In Nova Scotia, the neuromodulation program at Dalhousie University in Halifax conducts DBS surgery.[22] Consult and surgery wait times for brain procedures in Nova Scotia as of early 2023 are 168 days and 85 days, respectively.[36] However, the reported wait times are inclusive of other brain-related procedures, such as enterocolostomy, cerebrospinal fluid reservoir insertion, and tumour excision.[36]

In Ontario, 4 facilities were identified that may perform DBS surgery: the Ottawa Hospital,[23] Kingston Health Science Centre,[24] the Deep Brain Stimulation Clinic located at the Toronto Western Hospital,[13] and the Movement Disorder Centre at Western University (London).[25] We identified at least 5 neurosurgeons who are qualified to perform DBS surgery in Ontario from news articles and clinician bios via program websites.[13,23,24] The Harquail Centre for Neuromodulation at the Sunnybrook Hospital in Toronto is investigating the use of DBS for people with PTSD, alcohol use disorder, OCD, and major depressive disorder.[18] Additionally, the first cases of children receiving DBS therapy had surgery done in Ontario. The first child to receive DBS in Canada had their procedure done in 2018 at SickKids to help with treatment-resistant epilepsy.[37] Additionally, a child with autism spectrum disorder was provided DBS in 2021 to help prevent self-harm.[38] In Quebec, we found 4 programs that may perform DBS surgery: The neurosurgery department at Centre intégré universitaire de santé et de services sociaux de l'Estrie – Centre hospitalier universitaire de Sherbrooke,[26] the Psychiatric Neuromodulation Clinic at Centre Hospitalier de l'Université de Montréal (CHUM),[27] the CHU de Québec – Université Laval,[28] and the Montreal Neurologic Hospital and Institute.[29] In 2016, there were 4 qualified neurosurgeons in Quebec.[30] According to the assessment of DBS access in Canada, a significant portion of Quebec's funding for DBS is used for device replacement versus new implants.[30] The functional and neuromodulation program was the only program we identified for Manitoba.[14] We did not identify information related to wait times for Manitoba, Ontario, or Quebec.

### Number of DBS Surgeries

We did not identify the number of people living in Canada eligible for DBS. However, we identified a retrospective study published in 2018 that evaluated access to surgery for implantation of neural stimulators for DBS.[30] In 2015 to 2016, 722 implantation surgeries were performed in Canada.[30] No people living in the territories received DBS surgery during this period.[30] The authors of the study also calculated the jurisdictional age-adjusted rates of residents receiving DBS surgery to compare to the national average.

Results of this analysis found that Saskatchewan's rate of DBS was significantly higher than the national average, whereas Quebec and Newfoundland and Labrador were significantly below the national average.[30] Refer to Table 2 for information on DBS surgery volumes in 2015 to 2016 per jurisdiction as reported by this study.

From 2012 to July 2018, a total of 180 DBS surgeries, with 74 specifically for PD, were performed in British Columbia.[33] The average annual volume of DBS surgeries in British Columbia is 33.4, with 14.4 specifically for PD, with an annual growth of 0.20 between 2012 and 2018.[33]

We did not identify information regarding the number of surgeries neurosurgeons are required to perform to maintain their competency.

### Professional Associations

We identified 1 professional association, the Canadian Neurosurgical Society, which represents neurologists and neurosurgeons in Canada.[39] The organization's mission is "to enhance the care of patients with diseases of the nervous system through education, advocacy, and improved methods of diagnosis, treatment and rehabilitation."[39] The Canadian Neurosurgical Society provides opportunities for continuing education and networking to encourage collaboration for learning and training.[39]

## Table 2: Identified DBS Surgery Programs Across Canada

| Province and prevalence | Criteria | Description |
|---|---|---|
| **Alberta**<br>Prevalence = 0.42% | Program(s) identified | • Parkinson and Movement Disorder Program (University of Alberta)<br>• Movement Disorders Program (University of Calgary)<br>Types of DBS performed: pallidal, pallidotomy and pallidal, STN, and thalamic |
| | Conditions eligible for DBS | PD, dystonia, tremor |
| | Number of neurosurgeon(s) | 3 as of 2021[a,b] |
| | Volume of surgeries performed | 75 in 2015 to 2016[c] |
| | Wait time | 6 to 12 months in 2018[d] |
| **British Columbia**<br>Prevalence = 0.44% | Program(s) identified | Deep Brain Stimulation Clinic (Vancouver General Hospital and University of British Columbia Hospital)<br>Types of DBS performed: thalamic, GPi, STN |
| | Conditions eligible for DBS | PD, tremors, spasmodic dysphonia, pain, depression, epilepsy |
| | Number of neurosurgeon(s) | 1 as of 2021[d] |
| | Volume of surgeries performed | 80 in 2015 to 2016[c] and 13 in 2017 to 2018[d]<br>Average annual volume of surgeries is 33.4 (14.4 for PD)[d] |
| | Wait time | There are 2 wait-lists with a total wait time of up to 4 years in 2021. The first wait-list is for the specialist to determine an individual's eligibility and the second is for the surgery.[d] |

| Province and prevalence | Criteria | Description |
|---|---|---|
| **Manitoba**<br>Prevalence = 0.49% | Program(s) identified | Functional and Neuromodulation of Neurosurgery (University of Manitoba) |
| | Conditions eligible for DBS | PD, essential tremor, other movement-related conditions, chronic pain |
| | Number of neurosurgeon(s) | NA |
| | Volume of surgeries performed | 13 in 2015 to 2016[c] |
| | Wait time | NA |
| **Nova Scotia**<br>Prevalence = 0.34% | Program(s) identified | Neuromodulation Program – Division of Neurosurgery (Dalhousie University) |
| | Conditions eligible for DBS | PD, essential tremor, dystonia, and other neurologic disorders |
| | Number of neurosurgeon(s) | NA |
| | Volume of surgeries performed | 22 in 2015 to 2016[c] |
| | Wait time | Average of 168 days for a consult and 85 days for surgery. The wait times are inclusive of various procedures (e.g., entricolostomy, DBS, biopsy, CSF reservoir insertion, and excision of a tumour).[e] |
| **Ontario**<br>Prevalence = 0.47% | Program(s) identified | • Movement Disorders Clinic and Deep Brain Stimulation Clinic (University Health Network)<br>• The Ottawa Hospital<br>• Kingston Health Science Centre<br>• Movement Disorders Centre (Western University)<br>• Harquail Centre for Neuromodulation (research only) |
| | Conditions eligible for DBS | PD, dystonia, tremor, other involuntary movements |
| | Number of neurosurgeon(s) | 5 at minimum[f,g,h] |
| | Volume of surgeries performed | 347 in 2015 to 2016[c] |
| | Wait time | NA |
| **Quebec**<br>Prevalence = 0.40% | Program(s) identified | • Deep Brain Stimulation Program (McGill University Health Centre)<br>• Psychiatric Neuromodulation Clinic (Centre hospitalier de l'Université de Montréal)<br>• The neurosurgery department (Centre Intégré Universitaire de Santé et de Services Sociaux de l'Estrie – Centre Hospitalier Universitaire de Sherbrooke)<br>• CHU de Québec – Université Laval |
| | Conditions eligible for DBS | PD, severe refractory obsessive-compulsive disorder |
| | Number of neurosurgeon(s) | 4 in 2016[c] |
| | Volume of surgeries performed | 75 in 2015 to 2016; a significantly lower DBS rate than the national average[c] |
| | Wait time | NA |

| Province and prevalence | Criteria | Description |
|---|---|---|
| **Saskatchewan**<br>Prevalence = 0.40% | Program(s) identified | Functional Neurosurgery (University of Saskatchewan) |
| | Conditions eligible for DBS | PD, essential tremor, dystonia |
| | Number of neurosurgeon(s) | 3 reported in 2021;[i] highest ratio of neurosurgeons implanting DBS in the provincial population (1 per 0.37 million in Canada) in 2015 to 2016[c] |
| | Volume of surgeries performed | 79 in 2015 to 2016; significantly higher DBS rate than the national average in 2015 to 2016[c] |
| | Wait time | No wait time[i] |

CSF = cerebrospinal fluid; DBS = deep brain stimulation; GPi = globus pallidus interna; NA = not available; PD = Parkinson Disease; STN = subthalamic nucleus.

Notes: This table includes parkinsonism prevalence (inclusive of PD) between 2019 and 2020 as reported by the Canadian Chronic Disease Surveillance System (CCDSS).[6] Prevalence of parkinsonism not included in the table:[6] Newfoundland and Labrador = 0.29%; Prince Edward Island = 0.35%; New Brunswick = 0.37%; Nunavut = 0.27%.

[a]Data sourced from the Parkinson and Movement Disorders Program website.[20]

[b]Data sourced from the Movement Disorders Program website.[21]

[c]Data sourced from a Canadian assessment of DBS.[30]

[d]Data sourced from a health technology review from British Columbia.[33]

[e]Data sourced from wait times provided by the province of Nova Scotia.[36]

[f]Data sourced from a DBS clinic website.[13]

[g]Data sourced from a news release from The Ottawa Hospital.[23]

[h]Data sourced from a web page dedicated to faculty and staff at the department of surgery.[24]

[i]Data sourced from Parkinson Society British Columbia.[34]

## Objective 2: Cost-Effectiveness of DBS for PD

We identified 2 cost-effectiveness studies and 3 systematic reviews of economic evaluations that examined the cost-effectiveness of DBS for people living with PD.[40-42] All of the relevant studies in 2 of the systematic reviews were captured in another more recent and more comprehensive systematic review, and were excluded to avoid overlap. Refer to Appendix 1 for economic evaluations of DBS for people living with conditions other than PD.

In general, the economic evaluations and the systematic review found that DBS may be cost-effective for people living with advanced PD.[40-42] One economic evaluation conducted in the context of China's health care system compared DBS to best medical therapy on a 15-year time horizon.[40] The other economic evaluation compared STN DBS to medication for a 10-year follow-up in Taiwan.[42] The systematic review identified economic evaluations in the US, Italy, Germany, Spain, the UK, China, and Japan that compared the cost-effectiveness of DBS to best medical therapy using oral formulations.[41]

## Objective 3: Summary of Guidelines for DBS

### DBS Guidelines for PD

We identified 10 guidelines regarding the use of DBS for individuals living with PD.[43-52] One guideline supports the use of DBS for carefully selected individuals living with PD and with consideration of symptoms known to respond to the therapy.[48] Among the identified guidelines related to PD, DBS is recommended to help control dyskinesia,[43,44,52] motor fluctuations,[43,44,51,52] and tremor for individuals living with PD.[43,45] However,

the guidelines indicate that the following considerations within the context of an individual's clinical history should be assessed before moving forward with DBS:

- severity of and duration of PD[43,45]
- age[45,51,52]
- response to presurgery therapy and/or medication (e.g., levodopa)[45,46,48,49]
- cognitive function[48,51,52]
- type of DBS therapy (i.e., thalamic, STN, GPi).[43,45,46,52]

Some guidelines suggest DBS as a potential therapy for excessive daytime sleepiness[47] and pain in dystonia[50] for individuals living with PD. However, the authors indicated that more research on the effectiveness of DBS as therapy for these symptoms is required.[47,50]

Refer to Table 3 for a detailed summary of recommendations for the use of DBS in PD. Refer to Table 4 for a detailed summary of recommendations for DBS for other conditions, as well as the prevalence of the condition in Canada (when available).

## Table 3: Summary of Recommendations for DBS for PD

| Guideline development group and year | Summary of recommendations | Methodology[a] |
|---|---|---|
| **European Academy of Neurology/Movement Disorder Society,[43] 2022** | "Offer STN-DBS to people with advanced PD if fluctuations are not satisfactorily controlled with medication or if tremor cannot be controlled with medications." (15 voters; 100% consensus) | Evidence-based |
| | "Consider offering STN-DBS people with early PD and early fluctuations." (15 voters; 100% consensus) | |
| | "Do not offer DBS to people with early PD without fluctuations." (16 voters; 100% consensus) | |
| | "Both STN-DBS and GPi-DBS are effective to treat symptoms of advanced PD with fluctuations, but dopaminergic medications can be more reduced with STN-DBS." (16 voters; 100% consensus) | |
| Movement Disorders Scientific Department of the Brazilian Academy of Neurology,[44] 2021 | "DBS is an effective therapeutic option for controlling disabling motor fluctuations and dyskinesia." (Level A) | Evidence-based |
| Parkinson Canada,[45] 2019 | "With the current evidence, it is not possible to decide if the STN or GPi is the preferred target for DBS for people with PD, or whether 1 form of surgery is more effective than the other." (Source: NICE;[b] Grade: D) | Evidence-based |
| | "Thalamic DBS may be considered as an option in people with PD who predominately have severe disabling tremor." (Source: NICE;[b] Grade: D) | |
| | "Preoperative response to levodopa should be considered as a factor predictive of outcome after DBS of the STN." (Source: AAN;[c] Grade: B) | |

| Guideline development group and year | Summary of recommendations | Methodology[a] |
|---|---|---|
| | "Age and duration of PD may be considered as factors predictive of outcome after DBS of the STN. Younger patients with shorter disease durations may possibly have improvement greater than that of older patients with longer disease durations." (Source: AAN;[c] Grade: C) | |
| Congress of Neurologic Surgeons,[46] 2018 | "Given that bilateral STN DBS is at least as effective as bilateral GPi DBS in treating motor symptoms of PD (as measured by improvements in UPDRS-III scores), consideration can be given to the selection of either target in patients undergoing surgery to treat motor symptoms." (Level I) | Evidence-Based |
| | "When the main goal of surgery is reduction of dopaminergic medications in a patient with PD, then bilateral STN DBS should be performed instead of GPi DBS." (Level I) | |
| Liu et al.,[47] 2018 | "Cognitive-behavioral therapy, light treatment, repetitive transcranial magnetic stimulation, and DBS might improve excessive daytime sleepiness of PD patients." | Consensus-based |
| Anderson et al.,[48] 2017 | "DBS is a safe and effective treatment for carefully selected patients with PD" (section 4). | Unclear |
| | "Patients should be carefully selected for symptoms that are known to respond to DBS" (section 6). | |
| | "Patients should undergo neuropsychological testing, and the presence of significant cognitive impairment is usually a contraindication to DBS" (section 7.3). | |
| | Guidance on dopamine challenge testing for assessment (section 7.2), approaches on selecting appropriate targets (sections 8 and 9), and follow-up and programming of therapy (sections 11 and 12) were also provided. | |
| NICE,[49] 2017 | "Do not offer deep brain stimulation to people with Parkinson's disease whose symptoms are adequately controlled by best medical therapy." | Evidence-based |
| | "Consider deep brain stimulation for people with advanced Parkinson's disease whose symptoms are not adequately controlled by best medical therapy." | |
| Italian Consensus Conference on Pain,[50] 2016 | "Neuromodulation techniques and DBS have been used to treat pain in dystonia, but further studies are needed on this topic." (Strength of recommendation: D) | Evidence-based |
| Odin et al.,[51] 2015 | "For patients aged <70 years with motor fluctuations or dyskinesias who are otherwise healthy, any of the device-aided therapies [levodopa/carbidopa intestinal gel infusions, subcutaneous apomorphine, or DBS] may be considered." | Consensus-based |
| | "For patients aged >70 years, DBS surgery should be considered second-line among the device-aided therapies (although patients can be operated on in the presence of a normal MRI and preserved cognitive function)." | |

| Guideline development group and year | Summary of recommendations | Methodology[a] |
|---|---|---|
| | "For patients aged >70 years with mildly or moderately impaired cognition (or other contraindications to DBS), levodopa/carbidopa intestinal gel infusions or subcutaneous apomorphine may be considered with cessation or reduction in oral therapy (note that rapid cessation of dopamine agonists may lead to withdrawal symptoms)." | |
| EFNS and the MDS-ES,[52] 2013 | "DBS of the STM or the GPi is effective against motor fluctuations and dyskinesia (Level A), but because of risk for adverse events, the procedure is only recommended for patients below the age of 70 without major psychiatric or cognitive problems." | Evidence-based |
| | Deep brain stimulation is recommended for patients with persistent and significant tremor. | |

AAN = American Academy of Neurology; DBS = deep brain stimulation; EFNS = European Federation of Neurologic Sciences; GPi = globus pallidus interna; MDS-ES = Movement Disorder Society – European Section; NICE = National Institute for Health and Clinical Excellence; PD = Parkinson disease; STN = subthalamic nucleus; UPDRS-III = Unified Parkinson Disease Rating Scale part III.

[a]Guidance documents were classified as evidence-based (i.e., recommendations were informed using a systematic search of the literature), consensus-based (i.e., recommendations were informed by expert opinion, with or without consideration for evidence collected using nonsystematic methods), or as having an unclear (i.e., not reported in detail) methodology.

[b]Sourced from NICE CG35 recommendations (2006).[53]

[c]Sourced from AAN evidence-based recommendations (2006).[54]

### DBS Guidelines for Other Conditions

Guidelines for the use of DBS in 9 conditions other than PD were identified: 4 for OCD, 3 for epilepsy, 3 for refractory tremor, 3 for Tourette syndrome, 3 for dystonia, 1 for tardive dyskinesia, 1 for major depressive disorder, 1 for neuropathic pain, and 1 for other types of pain. These identified guidelines suggest that indications for DBS are expanding beyond PD. The following considerations should be assessed before moving forward with DBS for the treatment of these conditions:

- type of DBS[55-60]
- response to prior treatment (e.g., refractory cases)[55,56,58,61-68]
- quantity and/or quality of evidence[56,57,59,60,69]
- age[60,63,66]
- clinical versus experimental context[61,64,70]
- expertise and experience of clinicians available[57,58,70]
- other indications and/or contraindications specific to the condition.[57,63-65]

Refer to Table 4 for a detailed summary of recommendations for DBS for other conditions and the prevalence of the condition in Canada (when available).

## Table 4: Summary of Recommendations for DBS for Other Conditions

| Condition and prevalence in Canada | Guideline development group and year | Recommendation | Methodology[a] |
|---|---|---|---|
| **OCD (refractory)** Prevalence = 0.93% in | World Federation Societies of Biologic Psychiatry,[62] 2023 | DBS should be restricted to carefully selected patients with treatment-refractory OCD (weak | Evidence-based |

| Condition and prevalence in Canada | Guideline development group and year | Recommendation | Methodology[a] |
|---|---|---|---|
| people aged 15 or older in 2018[71] | | recommendation based on a strong level of evidence). | |
| | Congress of Neurologic Surgeons,[55] 2021 | "It is recommended that clinicians utilize bilateral STN nucleus DBS over best medical management for the treatment of patients with medically refractory OCD" (based on evidence 1 or more well-designed RCT or an overview such trials). | Evidence-based |
| | | "Clinicians may use bilateral nucleus accumbens or bed nucleus of stria terminalis DBS for the treatment of patients with medically refractory OCD" (based on evidence from 1 or more well-designed comparative clinical studies or other comparable studies). | |
| | NICE,[70] 2021 | "Evidence on the safety and efficacy of deep brain stimulation for chronic, severe, treatment-resistant obsessive-compulsive disorder (OCD) in adults is inadequate in quality and quantity. Therefore, this procedure should only be used in the context of research" (p. 2). | Evidence-based |
| | | "Patient selection should be done by a multidisciplinary team experienced in managing OCD. It should include experts in psychiatry, neuropsychiatry, clinical psychology, neurology, neurosurgery and deep brain stimulation" (p. 2). | |
| | | "The procedure should only be done in centres with expertise in deep brain stimulation and experience in managing OCD" (p. 2). | |
| | | "Further research should primarily be randomised controlled trials. It should clearly define the area of the brain that should be targeted in this procedure. It should also describe details of patient selection, comorbidities, and use of adjunctive therapies. Outcomes should include reduction in OCD symptoms, improvement in quality of life and any neuropsychiatric and cognitive effects" (p. 2). | |
| | ASSN and CNS,[56] 2014 | There is evidence for the use of bilateral subthalamic nucleus DBS for the treatment of medically refractory OCD (based on evidence from 1 high-quality study). | Evidence-based |
| | | There is evidence for the use of bilateral nucleus accumbens DBS for the treatment of medically refractory OCD (based on 1 well-designed observational study). | |

| Condition and prevalence in Canada | Guideline development group and year | Recommendation | Methodology[a] |
|---|---|---|---|
| | | There is insufficient evidence to make a recommendation for unilateral DBS for the treatment of medically refractory OCD. | |
| **Epilepsy (refractory)** Prevalence = 0.65% in 2019 to 2020 (199,640 people).[72] | American Society and Joint Section of Stereotactic and Functional Neurosurgery,[57] 2022 | DBS is a safe and effective treatment for patients with medication-refractory epilepsy; indications and contraindications are provided (based on several RCTs and clinical trials). | Consensus-based |
| | NICE,[58] 2022 | "For anterior thalamic targets the evidence is limited in quantity and quality, therefore this procedure should only be used with special arrangements for clinical governance, consent, and audit or research" (p. 2). | Evidence-based |
| | | "For targets other than the anterior thalamus the evidence is inadequate in quantity and quality, therefore this procedure should only be used in the context of research" (p. 2). | |
| | | "Patient selection should be done by a multidisciplinary team experienced in managing epilepsy including a neurologist, neurophysiologist and neurosurgeon" (p. 2). | |
| | | "The procedure should only be done in neurosurgery centres that specialise in managing epilepsy" (p. 3). | |
| | Neuromodulation Committee for the Brazilian League of Epilepsy and the Scientific Department of Epilepsy of the Brazilian Academy of Neurology,[63] 2016 | DBS may be considered for patients of any age with refractory epilepsy, if they meet specific criteria. | Consensus-based |
| **Tourette syndrome (treatment resistant)** Prevalence = 0.89 per 1,000 males and 0.44 per 1,000 females in 2010 to 2011.[73] | European Society for the Study of Tourette Syndrome,[74] 2022 | Consider DBS as an experimental therapeutic option for carefully selected patients with treatment-resistant Tourette syndrome. | Evidence-based |
| | American Academy of Neurology,[64] 2019 | "Physicians must use a multidisciplinary evaluation to establish when the benefits of treatment outweigh the risks of prescribing DBS for medication-resistant motor and phonic tics" (strong recommendation). | Evidence-based |
| | | "Physicians may consider DBS for severe, self-injurious tics, such as severe cervical tics that result in spinal injury" (weak recommendation). | |

| Condition and prevalence in Canada | Guideline development group and year | Recommendation | Methodology[a] |
|---|---|---|---|
| | Tourette Syndrome Association,[65] 2015 | Requirements for DBS treatment for Tourette syndrome include:<br>• severe tic disorder with functional impairments<br>• failed conventional therapy, including treatment from 3 pharmacological classes, and cognitive behavioural therapy. | Consensus-based |
| **Dystonia**<br>Prevalence = 50,000[75] | NICE,[66] 2019 | "If adults with cerebral palsy continue to have severe and painful dystonia, despite having enteral anti-dystonic drug treatment or botulinum toxin type A treatment, consider referring them to a specialised centre with experience in providing deep brain stimulation" (p. 23). | Evidence-based |
| | American Academy of Neurology,[59] 2018 | There is insufficient evidence for the use of globus pallidus interna DBS for tardive dystonia. | Evidence-based |
| | British Neurotoxin Network,[67] 2016 | In patients with poor response to botulinum toxin treatment, consider DBS (in conjunction with referral to expert centre). | Unclear |
| **Tardive dyskinesia**<br>**Prevalence = NA** | American Academy of Neurology,[59]2018 | Globus pallidus interna DBS is possibly effective in the treatment of tardive dyskinesia (weak recommendation based on limited moderate-quality evidence). | Evidence-based |
| **Major depressive disorder (refractory)**<br>Prevalence = 21.7% in 2014 (treatment-resistant depression)[76] | Canadian Network for Mood and Anxiety Treatments,[61] 2016 | DBS is an investigational treatment for patients with treatment-refractory major depressive disorder (based on evidence from small-sample RCTs or observational studies). | Evidence-based |
| **Pain (neuropathic)**<br>**Prevalence = NA** | European Academy of Neurology,[69] 2016 | The recommendation for DBS in neuropathic pain is inconclusive due to very low-quality evidence and uncertainty in DBS effects.<br>It is recommended that more research is needed on DBS for neuropathic pain. | Evidence-based |
| **Pain (chronic facial, cluster headaches, some central pain syndromes) (refractory)**<br>**Prevalence = NA** | International Neuromodulation Society,[68] 2014 | "In lieu of the success of both DBS and motor cortex stimulation in treating facial pain, cluster headache, and some central pain syndromes, their use is recommended in refractory cases" (p. 4) (based on evidence from clinical opinions or observations, descriptive studies, or expert committee reports; moderate strength consensus panel recommendation [> 75% agreement within the panel]). | Evidence-based |
| | | "Motor cortex stimulation should be considered before DBS when reasonable, and both therapies be considered after both extracranial stimulation and high cervical stimulation have been ruled out as options" (p. 4) (based on evidence from clinical opinions or observations, descriptive | |

| Condition and prevalence in Canada | Guideline development group and year | Recommendation | Methodology[a] |
|---|---|---|---|
| | | studies, or expert committee reports; moderate strength consensus panel recommendation [> 75% agreement within the panel]). | |
| **Essential tremor (refractory)**<br>Prevalence = approximately 3% of people in Canada[77] | Italian Movement Disorders Association,[60] 2013 | "In patients with medically refractory limb essential tremor, unilateral thalamic-DBS is effective for treating contralateral limb tremor" (p. 13) (strong recommendation based on a low quality of evidence). | Evidence-based |
| | | "Placement of the second lead is associated with mild midline (head and voice) tremor improvement but, due to lack of controlled studies and serious adverse events with bilateral stimulation, bilateral thalamic-DBS should not be used" (p. 13) (strong recommendation based on a low quality of evidence). | |
| | | "STN nucleus-DBS could be a target for long-term treatment of essential tremor even if there is very low quality of evidence to support this treatment" (p. 13) (weak recommendation based on a very low quality of evidence). | |
| | | "For patients above the age of 70 years, ventralis intermedius nucleus seems to be a preferable target" (p. 13) (weak recommendation based on a very low quality of evidence). | |

ASSN = American Society for Stereotactic and Functional Neurosurgery; CNS = Congress of Neurologic Surgeons; DBS = deep brain stimulation; NICE = National Institute for Health and Care Excellence; OCD = obsessive-compulsive disorder; RCT = randomized controlled trial; STN = subthalamic nucleus.

[a]Guidance documents were classified as evidence-based (i.e., recommendations were informed using a systematic search of the literature), consensus-based (i.e., recommendations were informed by expert opinion, with or without consideration for evidence collected using nonsystematic methods), or as having an unclear (i.e., not reported in detail) methodology.

### Guidelines for Neurosurgeons to Maintain Competency

We did not identify guidelines regarding the number of DBS surgeries recommended for neurosurgeons to maintain competency.

## Limitations

There are limitations to note for this rapid Environmental Scan. The information gathered on programs providing DBS surgery is limited to public, online sources identified from grey literature. Due to time constraints, provinces and territories were not consulted to provide information regarding the availability of DBS surgery within their jurisdictions; therefore, we may not have captured the full breadth of programs and resources (including number of neurosurgeons) for DBS surgery across Canada. This rapid Environmental Scan focused on identifying programs that had the capacity to perform DBS surgery in Canada. Programs focused only on providing preservices and postservices, although critical to DBS, were outside the scope of this report. Furthermore, the data on surgery volumes across Canada were from 2015 to 2016, with more

recent data for British Columbia (from 2017 to 2018). Thus, the data are outdated and likely not reflective of current surgery volumes in Canada. The data on surgery volumes from 2015 to 2016 was also limited to surgeries for implanting neural electrodes and excluded surgeries for battery replacements.

We did not perform critical appraisal of the guidelines and cost-effectiveness studies included in this rapid Environmental Scan. The quality of the guidelines and its development, as well as the economic evaluations included, is unclear. Some guidelines were developed in other countries, and all the economic evaluations were done within the context of other health care systems. These limitations should be considered in the interpretation of the findings and application of DBS for PD and other conditions.

## Conclusions

This report provides an overview of the DBS surgery landscape in Canada, in addition to identifying populations that may benefit from DBS.

A total of 722 DBS insertion surgeries were conducted in 2015 to 2016. Based on publicly available information, jurisdictions in Canada with the capacity to perform DBS surgeries include Alberta, British Columbia, Manitoba, Nova Scotia, Ontario, Quebec, and Saskatchewan. DBS is primarily used to help control movement-related disorders, including PD, in Canada. Some jurisdictions provide DBS for pain, depression, or OCD. The number of neurosurgeons qualified for DBS surgery in Canada ranges from 1 to 5 (at least) across jurisdictions based on incomplete data gathered from public sources. While outside the scope of this report, virtual postsurgery care is available for people to receive adjustments to their DBS devices remotely. Virtual postsurgery care can benefit people who otherwise would have had to travel to access these services, including people living in remote or rural areas or in jurisdictions without facilities specialized in DBS therapy.

Based on the results of a literature search of guidelines, DBS is recommended to help control the movement-related symptoms of PD. However, certain indications and contraindications should be considered before DBS therapy. Furthermore, DBS may be considered for people with refractory OCD, refractory epilepsy, treatment-resistant Tourette syndrome, pain, major depressive disorder, tardive dyskinesia, and essential tremor. The results of economic evaluations of DBS for PD suggests that DBS is cost-effective. However, none of the cost-effectiveness analyses were conducted in the context of the health care system in Canada and their applicability is unclear. Critical appraisal of the guidelines and economic evaluations is outside the scope of this report.

The findings of this rapid Environmental Scan can help guide decision-makers across Canada when implementing or expanding DBS programs by providing insight into established programs across the country. The information provided on these programs, including the number of qualified neurosurgeons and surgery volumes, was informed by publicly available information, some of which may be outdated, without consultation with program representatives. Therefore, it only provides a snapshot of an evolving landscape.

Given the aging population in Canada, and the growing evidence base for additional indications for DBS, the number of people eligible for DBS is expected to increase. It is crucial that capacity to perform surgery

is monitored and assessed to ensure adequate access to DBS. Future investigations could aim to provide a more comprehensive survey of programs across Canada with up-to-date information on program characteristics.

## References


1. Zhao N, Yang Y, Zhang L, et al. Quality of life in Parkinson's disease: A systematic review and meta-analysis of comparative studies. *CNS Neurosci Ther.* 2021;27(3):270-279. PubMed
2. Chou KL. Clinical manifestations of Parkinson disease. In: Post TW, ed. *UpToDate.* Waltham (MA): UpToDate; 2023 Mar 15: http://www.uptodate.com. Accessed 2023 May 04.
3. Jankovic J. Epidemiology, pathogenesis, and genetics of Parkinson disease. In: Post TW, ed. *UpToDate.* Waltham (MA): UpToDate; 2023 Apr 24: http://www.uptodate.com. Accessed 2023 May 04.
4. Global, regional, and national burden of Parkinson's disease, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol.* 2018;17(11):939-953. PubMed
5. Lampropoulos IC, Malli F, Sinani O, Gourgoulianis KI, Xiromerisiou G. Worldwide trends in mortality related to Parkinson's disease in the period of 1994-2019: Analysis of vital registration data from the WHO Mortality Database. *Front Neurol.* 2022;13:956440. PubMed
6. Government of Canada. Parkinsonism. Canadian Chronic Disease Surveillance System (CCDSS) 2023; https://health-infobase.canada.ca/ccdss/data-tool/Index. Accessed 2023 May 5.
7. Wong SL, Gilmour H, Ramage-Morin PL. Parkinson's disease: Prevalence, diagnosis and impact 2015. *(Health Reports).* Ottawa (ON): Statistics Canada; 2014: https://www150.statcan.gc.ca/n1/pub/82-003-x/2014011/article/14112-eng.htm. Accessed 2023 May 5.
8. Smith A, Farrah K. Deep Brain Stimulation and Levodopa-Carbidopa Intestinal Gel as Interventions for Advanced Parkinson Disease: A Review of the Qualitative Patient Perspectives and Experiences Literature. *(CADTH Rapid response report: summary with critical appraisal).* Ottawa (ON): CADTH; 2017: https://www.cadth.ca/sites/default/files/pdf/htis/2018/RC0914%20PPE%20for%20PD%20final.pdf. Accessed 2023 May 3.
9. Spindler MA, Tarsy D. Initial pharmacologic treatment of Parkinson disease. In: Post TW, ed. UpToDate. Waltham (MA): UpToDate; 2023 Feb 17: http://www.uptodate.com. Accessed 2023 May 04.
10. Pandey S, Srivanitchapoom P. Levodopa-induced Dyskinesia: Clinical Features, Pathophysiology, and Medical Management. *Ann Indian Acad Neurol.* 2017;20(3):190-198. PubMed
11. Groiss SJ, Wojtecki L, Südmeyer M, Schnitzler A. Deep brain stimulation in Parkinson's disease. *Ther Adv Neurol Disord.* 2009;2(6):20-28. PubMed
12. Peprah K, Horton J. Adaptive Deep Brain Stimulation for the Treatment of Parkinson Disease and Essential Tremor. *Can J Health Technol.* 2021;1(12). https://www.cadth.ca/sites/default/files/hs-eh/EN0036%20DBS%20with%20Brainsense%20v.7.0-meta.pdf. Accessed 2023 May 5. PubMed
13. University Health Network. Deep Brain Stimulation (DBS) Clinic. [2023]; https://www.uhn.ca/Krembil/Clinics/Deep_Brain_Stimulation_Clinic. Accessed 2023 May 03.
14. University of Manitoba Section of Neurosurgery. Functional and Neuromodulation. 2023; https://manitobaneurosurgery.com/programs-services/functional-neuromodulation. Accessed 2023 May 5.
15. Vancouver Coastal Health. Deep Brain Stimulation Clinic. 2023; https://www.vch.ca/en/service/deep-brain-stimulation-clinic#find-it-near-you. Accessed 2023 May 03.
16. University of Saskatchewan College of Medicine. Functional Neurosurgery - Deep Brain Stimulation. [2023]; https://medicine.usask.ca/department/clinical/surgery-divisions/neurosurgery-pages/functional.php. Accessed 2023 May 3.
17. Negida A, Elminawy M, El Ashal G, Essam A, Eysa A, Abd Elalem Aziz M. Subthalamic and Pallidal Deep Brain Stimulation for Parkinson's Disease. *Cureus.* 2018;10(2):e2232. PubMed
18. Sunnybrook Health Sciences Centre. Deep brain stimulation. 2023; https://sunnybrook.ca/content/?page=deep-brain-stimulation. Accessed 2023 May 3.

19. Lachance C, Spry C, MacDougall D. Deep Brain Stimulation for Parkinson's Disease: A Review of Clinical Effectiveness, Cost-Effectiveness, and Guidelines. *(CADTH Rapid response report: summary with critical appraisal).* Ottawa (ON): CADTH; 2018: https://www.cadth.ca/deep-brain-stimulation-parkinsons-disease-review-clinical-effectiveness-cost-effectiveness-and. Accessed 2023 May 11.
20. University of Alberta. Parkinson and Movement Disorders Program. 2023; https://www.ualberta.ca/department-of-medicine/movement-disorders/index.html. Accessed 2023 May 03.
21. University of Calgary Department of Clinical Neurosciences. Movement disorders program - our team. 2023; https://cumming.ucalgary.ca/departments/dcns/programs/dcns-programs-movement-disorders/dcns-movement-disorders-our-team. Accessed 2023 May 03.
22. Nova Scotia Health. QEII Health Sciences Centre first location in Canada to use Brainlab Elements automated virtual surgical planning tool for deep brain stimulation. 2022; https://www.nshealth.ca/news/qeii-health-sciences-centre-first-location-canada-use-brainlab-elementsr-automated-virtual. Accessed 2023 May 3.
23. The Ottawa Hospital. Deep-brain stimulation brings a family doctor with Parkinson's back from "the abyss". [2015]; https://www.ottawahospital.on.ca/en/uncategorized/deep-brain-stimulation-brings-a-family-doctor-with-parkinsons-back-from-the-abyss/. Accessed 2023 May 03.
24. Queen's University School of Medicine Department of Surgery. Faculty & Staff. [2017]; https://surgery.queensu.ca/administration/faculty-staff. Accessed 2023 May 03.
25. Western University Movement Disorders Centre. Personnel. 2023; https://www.uwo.ca/physpharm/jog/personnel/index.html. Accessed 2023 May 3.
26. Gilbert M. Deep brain neurostimulator implant. Sherbrooke (QC): Centre intégré universitaire de santé et de services sociaux de l'Estrie – Centre hospitalier universitaire de Sherbrooke (CIUSSS de l'Estrie - CHUS); 2020: https://www.santeestrie.qc.ca/clients/SanteEstrie/soins-services/Specialises/Examens-tests/Neuromodulation/Deep_brain_neurostimulator_implant.pdf. Accessed 2025 May 3.
27. Centre hospitalier de l'Université de Montréal (CHUM). Clinique de neuromodulation psychiatrique - Stimulation intracérébrale (SIC/DBS) [Psychiatric Neuromodulation Clinic - intracerebral stimulation (SIC/DBS]. 2023; https://www.chumontreal.qc.ca/cliniques/clinique-de-neuromodulation-psychiatrique/traitements/sic. Accessed 2023 May 5.
28. CHU de Québec–Université Laval. Stimulation cérébrale profonde pour la maladie de Parkinson [Deep brain stimulation for Parkinson Disease]. 2022; https://www.chudequebec.ca/patient/maladies,-soins-et-services/traitements-et-examens/traitements/stimulation-cerebrale-profonde-maladie-de-parkinso.aspx#. Accessed 2023 May 15.
29. McGill University Health Centre. A major force in Parkinson's disease research and treatment. 2016; https://muhc.ca/newsroom/news/neuro-%E2%80%93-major-force-parkinson%E2%80%99s-disease-research-and-treatment. Accessed 2023 May 5.
30. Honey CM, Malhotra AK, Tamber MS, Prud'homme M, Mendez I, Honey CR. Canadian Assessment of Deep Brain Stimulation Access: The Canada Study. *Can J Neurol Sci.* 2018;45(5):553-558. PubMed
31. Postuma R, Anang J. Parkinson's Disease: An introductory guide. Montreal (QC): McGill University Health Centre; 2018: https://muhcpatienteducation.ca/DATA/GUIDE/313_en~v~parkinson-s-disease-pdf-.pdf. Accessed 2023 May 3.
32. Patient & Family Guide: Deep brain stimuation. Halifax (NS): Nova Scotia Health Authority; 2021: https://www.nshealth.ca/sites/nshealth.ca/files/patientinformation/0060.pdf. Accessed 2023 May 5.
33. Conte T, Wong WK, Bayat S, et al. Deep brain stimulation or duodopa for advanced Parkinson disease in British Columbia: Health Technology Assessment Report. Vancouver (BC): BC Health Technology Review Office; 2017: https://www2.gov.bc.ca/assets/gov/health/about-bc-s-health-care-system/heath-care-partners/health-authorities/bc-health-technology-assessments/deep-brain-stimulation.pdf. Accessed 2023 May 03.
34. Parkinson Society British Columbia. Deep Brain Stimulation. 2021; https://www.parkinson.bc.ca/about-us/advocacy/deep-brain-stimulation/. Accessed 2023 May 08.
35. BC Gov News. Action plan to provide faster care for people with Parkinson's. 2019; https://news.gov.bc.ca/releases/2019HLTH0029-000159. Accessed 2023 May 3.

36. Nova Scotia Wait Time Information. Brain Surgery (Adult). 2023; https://waittimes.novascotia.ca/procedure/brain-surgery-adult. Accessed 2023 May 03.
37. Gerster J. First-Canadian child receives deep brain stimulation for drug resistant epilepsy. Global News https://globalnews.ca/news/4754413/drug-resistant-epilepsy-sickkids-surgery/. Accessed 2023 May 15.
38. Favaro A. Canadian girl with autism in world-first test on how brain stimulation could stop severe self-harm. CTV News 2022; https://www.ctvnews.ca/health/canadian-girl-with-autism-in-world-first-test-on-how-brain-stimulation-could-stop-severe-self-harm-1.5954087. Accessed 2023 May 15.
39. Canadian Neurological Sciences Federation. Benefits of membership - CNSF. [2020]; https://www.cnsf.org/about-cnsf/membership/benefits-of-cnsf-membership/. Accessed 2023 May 5.
40. Guo X, Feng C, Pu J, et al. Deep Brain Stimulation for Advanced Parkinson Disease in Developing Countries: A Cost-Effectiveness Study From China. *Neurosurgery.* 2023;92(4):812-819. PubMed
41. Smilowska K, van Wamelen DJ, Pietrzykowski T, et al. Cost-Effectiveness of Device-Aided Therapies in Parkinson's Disease: A Structured Review. *J Parkinsons Dis.* 2021;11(2):475-489. PubMed
42. Fann JC, Chang KC, Yen AM, et al. Cost-Effectiveness Analysis of Deep Brain Stimulation for Parkinson Disease in Taiwan. *World Neurosurg.* 2020;138:e459-e468. PubMed
43. Deuschl G, Antonini A, Costa J, et al. European Academy of Neurology/Movement Disorder Society - European Section guideline on the treatment of Parkinson's disease: I. Invasive therapies. *Eur J Neurol.* 2022;29(9):2580-2595. PubMed
44. Saba RA, Maia DP, Cardoso FEC, et al. Guidelines for Parkinson's disease treatment: consensus from the Movement Disorders Scientific Department of the Brazilian Academy of Neurology - motor symptoms. *Arq Neuropsiquiatr.* 2022;80(3):316-329. PubMed
45. Grimes D, Fitzpatrick M, Gordon J, et al. Canadian guideline for Parkinson disease. *CMAJ.* 2019;191(36):E989-E1004. PubMed
46. Rughani A, Schwalb JM, Sidiropoulos C, et al. Congress of Neurological Surgeons Systematic Review and Evidence-Based Guideline on Subthalamic Nucleus and Globus Pallidus Internus Deep Brain Stimulation for the Treatment of Patients With Parkinson's Disease: Executive Summary. *Neurosurgery.* 2018;82(6):753-756. PubMed
47. Liu CF, Wang T, Zhan SQ, et al. Management Recommendations on Sleep Disturbance of Patients with Parkinson's Disease. *Chin Med J (Engl).* 2018;131(24):2976-2985. PubMed
48. Anderson DG, Van Coller R, Carr J. South African guideline on deep brain stimulation for Parkinson's disease. *S Afr Med J.* 2017;107(10):1027-1032. PubMed
49. National Institute for Health and Care Excellence. Parkinson's disease in adults. (NICE guideline NG71) 2017; https://www.nice.org.uk/guidance/ng71. Accessed 2023 May 04.
50. Bartolo M, Chio A, Ferrari S, et al. Assessing and treating pain in movement disorders, amyotrophic lateral sclerosis, severe acquired brain injury, disorders of consciousness, dementia, oncology and neuroinfectivology. Evidence and recommendations from the Italian Consensus Conference on Pain in Neurorehabilitation. *Eur J Phys Rehabil Med.* 2016;52(6):841-854. PubMed
51. Odin P, Ray Chaudhuri K, Slevin JT, et al. Collective physician perspectives on non-oral medication approaches for the management of clinically relevant unresolved issues in Parkinson's disease: Consensus from an international survey and discussion program. *Parkinsonism Relat Disord.* 2015;21(10):1133-1144. PubMed
52. Ferreira JJ, Katzenschlager R, Bloem BR, et al. Summary of the recommendations of the EFNS/MDS-ES review on therapeutic management of Parkinson's disease. *Eur J Neurol.* 2013;20(1):5-15. PubMed
53. National Collaborating Centre for Chronic Conditions. Parkinson's Disease: National Clinical Guideline for Diagnosis and Management in Primary and Secondary Care. (National Institute for Health and Clinical Excellence: Guidance). London (GB): Royal College of Physicians (UK); 2006: https://pubmed.ncbi.nlm.nih.gov/21089238/. Accessed 2023 May 5.
54. Pahwa R, Factor SA, Lyons KE, et al. Practice Parameter: treatment of Parkinson disease with motor fluctuations and dyskinesia (an evidence-based review): report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology.* 2006;66(7):983-995. PubMed

55. Staudt MD, Pouratian N, Miller JP, et al. Congress of Neurological Surgeons Systematic Review and Evidence-Based Guidelines for Deep Brain Stimulations for Obsessive-Compulsive Disorder: Update of the 2014 Guidelines. *Neurosurgery.* 2021;88(4):710-712. PubMed

56. Hamani C, Pilitsis J, Rughani AI, et al. Deep brain stimulation for obsessive-compulsive disorder: systematic review and evidence-based guideline sponsored by the American Society for Stereotactic and Functional Neurosurgery and the Congress of Neurological Surgeons (CNS) and endorsed by the CNS and American Association of Neurological Surgeons. *Neurosurgery.* 2014;75(4):327-333; quiz 333. PubMed

57. Gummadavelli A, Englot DJ, Schwalb JM, et al. ASSFN Position Statement on Deep Brain Stimulation for Medication-Refractory Epilepsy. *Neurosurgery.* 2022;90(5):636-641. PubMed

58. National Institute for Health and Care Excellence. Deep brain stimulation for refractory epilepsy in adults. *(Interventional procedures guidance IPG678)* 2020; https://www.nice.org.uk/guidance/ipg678. Accessed 2023 May 08.

59. Bhidayasiri R, Jitkritsadakul O, Friedman JH, Fahn S. Updating the recommendations for treatment of tardive syndromes: A systematic review of new evidence and practical treatment algorithm. *J Neurol Sci.* 2018;389:67-75. PubMed

60. Zappia M, Albanese A, Bruno E, et al. Treatment of essential tremor: a systematic review of evidence and recommendations from the Italian Movement Disorders Association. *J Neurol.* 2013;260(3):714-740. PubMed

61. Milev RV, Giacobbe P, Kennedy SH, et al. Canadian Network for Mood and Anxiety Treatments (CANMAT) 2016 Clinical Guidelines for the Management of Adults with Major Depressive Disorder: Section 4. Neurostimulation Treatments. *Can J Psychiatry.* 2016;61(9):561-575. PubMed

62. Bandelow B, Allgulander C, Baldwin DS, et al. World Federation of Societies of Biological Psychiatry (WFSBP) guidelines for treatment of anxiety, obsessive-compulsive and posttraumatic stress disorders - Version 3. Part II: OCD and PTSD. *World J Biol Psychiatry.* 2023;24(2):118-134. PubMed

63. Terra VC, D'Andrea-Meira I, Amorim R, et al. Neuromodulation in refractory epilepsy: Brazilian specialists consensus. *Arq Neuropsiquiatr.* 2016;74(12):1031-1034. PubMed

64. Pringsheim T, Okun MS, Muller-Vahl K, et al. Practice guideline recommendations summary: Treatment of tics in people with Tourette syndrome and chronic tic disorders. *Neurology.* 2019;92(19):896-906. PubMed

65. Schrock LE, Mink JW, Woods DW, et al. Tourette syndrome deep brain stimulation: a review and updated recommendations. *Mov Disord.* 2015;30(4):448-471. PubMed

66. National Institute for Health and Care Excellence. Cerebral palsy in adults. *(NICE guideline NG119)* 2019; https://www.nice.org.uk/guidance/ng119. Accessed 2023 May 08.

67. Marion MH, Humberstone M, Grunewald R, Wimalaratna S. British Neurotoxin Network recommendations for managing cervical dystonia in patients with a poor response to botulinum toxin. *Pract Neurol.* 2016;16(4):288-295. PubMed

68. Deer TR, Mekhail N, Petersen E, et al. The appropriate use of neurostimulation: stimulation of the intracranial and extracranial space and head for chronic pain. Neuromodulation Appropriateness Consensus Committee. *Neuromodulation.* 2014;17(6):551-570; discussion 570. PubMed

69. Cruccu G, Garcia-Larrea L, Hansson P, et al. EAN guidelines on central neurostimulation therapy in chronic pain conditions. *Eur J Neurol.* 2016;23(10):1489-1499. PubMed

70. National Institute for Health and Care Excellence. Deep brain stimulation for chronic, severe, treatment-resistant obsessive-compulsive disorder in adults. *(Interventional procedures guidance IPG693)* 2021; https://www.nice.org.uk/guidance/ipg693. Accessed 2023 May 08.

71. Quality Standard: Obsessive Compulsive Disorder. Care in All Settings. Toronto (ON): Ontario Health; 2020: https://www.hqontario.ca/Portals/0/documents/evidence/quality-standards/qs-obsessive-compulsive-disorder-quality-standard-en.pdf. Accessed 2023 May 5.

72. Government of Canada. Epilepsy. Canadian Chronic Disease Surveillance System (CCDSS) 2023; https://health-infobase.canada.ca/ccdss/data-tool/. Accessed 2023 May 5.

73. Yang J, Hirsch L, Martino D, Jette N, Roberts J, Pringsheim T. The prevalence of diagnosed tourette syndrome in Canada: A national population-based study. *Mov Disord.* 2016;31(11):1658-1663. PubMed

74. Szejko N, Worbe Y, Hartmann A, et al. European clinical guidelines for Tourette syndrome and other tic disorders-version 2.0. Part IV: deep brain stimulation. *Eur Child Adolesc Psychiatry.* 2022;31(3):443-461. PubMed

75. Dystonia Canada. What is dystonia? 2016; https://www.dystoniacanada.org/sites/dystoniacanada.org/files/2016-10/DMRF_WhatIsDystonia.pdf. Accessed 2023 May 05.

76. Rizvi SJ, Grima E, Tan M, et al. Treatment-resistant depression in primary care across Canada. *Can J Psychiatry.* 2014;59(7):349-357. PubMed

77. Sunnybrook Research Institute Centre of Excellence in Focused Ultrasound. Essential tremor. 2023; https://sunnybrook.ca/research/content/?page=sri-centres-focused-ultrasound-tremor. Accessed 2023 May 5.

# Appendix 1: References of Potential Interest

## Economic Evaluations for Other Conditions

### *Epilepsy*

Ngan Kee N, Foster E, Marquina C, et al. Systematic Review of Cost-effectiveness Analysis for Surgical and Neurostimulation Treatments for Drug-Resistant Epilepsy in Adults. *Neurology*. 2023 05 02;100(18):e1866-e1877. PubMed

Chan HY, Wijnen BFM, Majoie M, Evers S, Hiligsmann M. Economic evaluation of deep brain stimulation compared with vagus nerve stimulation and usual care for patients with refractory epilepsy: A lifetime decision analytic model. *Epilepsia*. 2022 03;63(3):641-651. PubMed

### *Obsessive-Compulsive Disorder*

Strouphauer ER, Morris OJ, Soileau KJ, et al. Economic Analyses of Obsessive-Compulsive Disorder Interventions: A Systematic Review. *Pharmacoeconomics*. 2023 May;41(5):499-527. PubMed

### *Tourette Syndrome*

Dang TTH, Rowell D, Liddle J, Coyne T, Silburn P, Connelly LB. Economic evaluation of deep-brain stimulation for Tourette's syndrome: an initial exploration. *J Neurol*. 2019 Dec;266(12):2997-3008. PubMed

## Investigational Use of DBS

### *Obesity*

Mahajan UV, Ojukwu DI, Azagury DE, Safer DL, Cunningham T, Halpern CH. Can responsive deep brain stimulation be a cost-effective treatment for severe obesity? *Obesity (Silver Spring)*. 2022 02;30(2):338-346. PubMed

### *Cocaine Use Disorder*

Kuijper FM, Mahajan UV, Ku S, et al. Deep brain Stimulation Compared With Contingency Management for the Treatment of Cocaine Use Disorders: A Threshold and Cost-effectiveness Analysis. *Neuromodulation*. 2022 Feb;25(2):253-262. PubMed

### *Alcohol Use Disorder*

Maatoug R, Bihan K, Duriez P, et al. Non-invasive and invasive brain stimulation in alcohol use disorders: A critical review of selected human evidence and methodological considerations to guide future research. *Compr Psychiatry*. 2021 08;109:152257. PubMed

### *Pediatric Populations*

Yan H, Siegel L, Breitbart S, et al. The Child & Youth CompreHensIve Longitudinal Database for Deep brain Stimulation (CHILD-DBS). *Childs Nerv Syst*. 2021 02;37(2):607-615. PubMed

*DBS for Rural and Remote areas.*

Pinter D, Jardahazi E, Janszky J, Kovacs N. Potential clinical and economic benefits of remote deep brain stimulation programming. *Sci Rep*. 2022 10 19;12(1):17420. PubMed

## DBS During the COVID-19 Pandemic

Miocinovic S, Ostrem JL, Okun MS, et al. Recommendations for Deep Brain Stimulation Device Management During a Pandemic. *J Parkinsons Dis*. 2020;10(3):903-910. PubMed