INSTRUCTIONS FOR USE

This Medical Policy provides assistance in interpreting UnitedHealthcare benefit plans. When deciding coverage, the member specific benefit plan document must be referenced. The terms of the member specific benefit plan document [e.g., Certificate of Coverage (COC), Schedule of Benefits (SOB), and/or Summary Plan Description (SPD)] may differ greatly from the standard benefit plan upon which this Medical Policy is based. In the event of a conflict, the member specific benefit plan document supersedes this Medical Policy. All reviewers must first identify member eligibility, any federal or state regulatory requirements, and the member specific benefit plan coverage prior to use of this Medical Policy. Other Policies and Coverage Determination Guidelines may apply. UnitedHealthcare reserves the right, in its sole discretion, to modify its Policies and Guidelines as necessary. This Medical Policy is provided for informational purposes. It does not constitute medical advice.

UnitedHealthcare may also use tools developed by third parties, such as the MCG™ Care Guidelines, to assist us in administering health benefits. The MCG™ Care Guidelines are intended to be used in connection with the independent professional medical judgment of a qualified health care provider and do not constitute the practice of medicine or medical advice.

BENEFIT CONSIDERATIONS

Before using this policy, please check the member specific benefit plan document and any federal or state mandates, if applicable.

In certain benefit documents (for example, the 2001 Certificate of Coverage), HUDs require Institutional Review Board (IRB) oversight and are considered to be investigational and not covered. In other benefit documents (for example, the 2007 Certificate of Coverage and subsequent versions), HUDs are not considered to be investigational and are covered when used for proven indications. Please consult the member specific benefit plan document for details.

Essential Health Benefits for Individual and Small Group

For plan years beginning on or after January 1, 2014, the Affordable Care Act of 2010 (ACA) requires fully insured non-grandfathered individual and small group plans (inside and outside of Exchanges) to provide coverage for ten categories of Essential Health Benefits ("EHBs"). Large group plans (both self-funded and fully insured), and small group ASO plans, are not subject to the requirement to offer coverage for EHBs. However, if such plans choose to provide coverage for benefits which are deemed EHBs, the ACA requires all dollar limits on those benefits to be removed on all Grandfathered and Non-Grandfathered plans. The determination of which benefits constitute EHBs is made on a state by state basis. As such, when using this policy, it is important to refer to the member specific benefit plan document to determine benefit coverage.
COVERAGE RATIONALE

Deep Brain Stimulation
Deep brain stimulation (excluding directional deep brain stimulation) is proven and medically necessary for treating the following:

- Idiopathic Parkinson's disease when used according to U.S. Food and Drug Administration (FDA) labeled indications, contraindications, warnings and precautions.
- Essential tremor when used according to U.S. Food and Drug Administration (FDA) labeled indications, contraindications, warnings and precautions.
- Primary dystonia (occurs apart from any other identifiable illness) including generalized and/or segmental dystonia, hemidystonia and cervical dystonia (torticollis) when used according to the U.S. Food and Drug Administration (FDA) labeled indications, contraindications, warnings and precautions.

Deep brain stimulation is unproven and not medically necessary for treating secondary Parkinsonism (result of head trauma, metabolic conditions, toxicity, drugs, or other medical disorders). Well-designed studies demonstrating the efficacy of deep brain stimulation for treating secondary Parkinsonism are not available. Clinical trials are needed to demonstrate the benefit of deep brain stimulation for this patient population.

Deep brain stimulation is unproven and not medically necessary for treating secondary dystonia (occurs with illness, after trauma or following exposure to certain medications or toxins). There is inadequate evidence of the safety and efficacy of deep brain stimulation for treating secondary dystonia. Questions remain with regard to patient selection criteria and long-term benefits and safety compared with standard treatments. Formal comparisons, with large randomized controlled or comparative trials of pallidotomy, thalamotomy, and deep brain stimulation, are required before conclusions can be drawn regarding the use of deep brain stimulation for patients with secondary dystonia.

Deep brain stimulation is unproven and not medically necessary for treating conditions other than those listed as proven. This includes but is not limited to the following diagnoses:

- Depression
- Obsessive-compulsive disorder (OCD)
- Epilepsy
- Tourette syndrome
- Cluster headache
- Impulsive or violent behavior
- Chronic pain
- Trigeminal neuralgia
- Movement disorders caused by multiple sclerosis (MS)
- Phantom limb pain
- Stroke pain

Due to limited studies, small sample sizes, weak study designs and heterogenous patient characteristics, there is insufficient data to conclude that deep brain stimulation is safe and/or effective for treating these indications.

Directional deep brain stimulation that enables specific steering of current towards targeted lesions (e.g., Infinity™ DBS System) is unproven and not medically necessary for treating any condition including Parkinson's disease, dystonia, or tremor.
There is limited evidence comparing directional deep brain stimulation with traditional deep brain stimulation methods of stimulation. Long-term follow-up of large cohorts are needed to determine the effectiveness and long-term results of directional deep brain stimulation.

Responsive Cortical Stimulation
Responsive cortical stimulation (e.g., NeuroPace® RNS® System) is proven and medically necessary for treating partial onset seizures in patients who meet ALL of the following criteria:

- 18 years of age or older; and
- Partial onset seizures with all of the following:
  - Undergone diagnostic testing that localized no more than two epileptogenic foci, and
  - Seizures are refractory to therapeutic dosing of two or more antiepileptic medications, and
  - Currently experiencing an average of three or more disabling seizures (e.g., motor, partial seizures, complex partial seizures and/or secondarily generalized seizures) per month over the most recent three months (with no month with fewer than two seizures)
Responsive cortical stimulation is unproven and not medically necessary for treating conditions in patients who do not meet the above criteria.

DEFINITIONS

Generalized Epilepsy: Seizures engaging networks across both cerebral hemispheres.

Partial Epilepsy: Seizures originating within networks limited to one cerebral hemisphere.

APPLICABLE CODES

The following list(s) of procedure and/or diagnosis codes is provided for reference purposes only and may not be all inclusive. Listing of a code in this policy does not imply that the service described by the code is a covered or non-covered health service. Benefit coverage for health services is determined by the member specific benefit plan document and applicable laws that may require coverage for a specific service. The inclusion of a code does not imply any right to reimbursement or guarantee claim payment. Other Policies and Coverage Determination Guidelines may apply.

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<thead>
<tr>
<th>CPT Code</th>
<th>Description</th>
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<tr>
<td>61850</td>
<td>Twist drill or burr hole(s) for implantation of neurostimulator electrodes, cortical</td>
</tr>
<tr>
<td>61860</td>
<td>Craniectomy or craniotomy for implantation of neurostimulator electrodes, cerebral, cortical</td>
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<td>61863</td>
<td>Twist drill, burr hole, craniotomy, or craniectomy with stereotactic implantation of neurostimulator electrode array in subcortical site (e.g., thalamus, globus pallidus, subthalamic nucleus, periventricular, periaqueductal gray), without use of intraoperative microelectrode recording; first array</td>
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<tr>
<td>61864</td>
<td>Twist drill, burr hole, craniotomy, or craniectomy with stereotactic implantation of neurostimulator electrode array in subcortical site (e.g., thalamus, globus pallidus, subthalamic nucleus, periventricular, periaqueductal gray), without use of intraoperative microelectrode recording; each additional array (List separately in addition to primary procedure)</td>
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<td>61867</td>
<td>Twist drill, burr hole, craniotomy, or craniectomy with stereotactic implantation of neurostimulator electrode array in subcortical site (e.g., thalamus, globus pallidus, subthalamic nucleus, periventricular, periaqueductal gray), with use of intraoperative microelectrode recording; first array</td>
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<td>61868</td>
<td>Twist drill, burr hole, craniotomy, or craniectomy with stereotactic implantation of neurostimulator electrode array in subcortical site (e.g., thalamus, globus pallidus, subthalamic nucleus, periventricular, periaqueductal gray), with use of intraoperative microelectrode recording; each additional array (List separately in addition to primary procedure)</td>
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<td>61885</td>
<td>Insertion or replacement of cranial neurostimulator pulse generator or receiver, direct or inductive coupling; with connection to a single electrode array</td>
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<tr>
<td>61886</td>
<td>Insertion or replacement of cranial neurostimulator pulse generator or receiver, direct or inductive coupling; with connection to 2 or more electrode arrays</td>
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<td>L8680</td>
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<td>L8682</td>
<td>Implantable neurostimulator radiofrequency receiver</td>
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<td>L8683</td>
<td>Radiofrequency transmitter (external) for use with implantable neurostimulator radiofrequency receiver</td>
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**DESCRIPTION OF SERVICES**

**Deep Brain Stimulation**

Deep brain stimulation (DBS) delivers electrical pulses to select areas of the brain (e.g., the internal globus pallidus interna (GPI), subthalamic nucleus (STN) or ventral intermediate nucleus (VIM) of the thalamus) via surgically implanted electrodes. The mechanism of action is not completely understood, but the goal of DBS is to interrupt the pathways responsible for the abnormal movements associated with movement disorders such as Parkinson’s disease and essential tremor. The exact location of electrodes depends on the type of disorder being treated, and unlike standard surgical ablation, which causes permanent destruction of the targeted area, DBS is reversible and adjustable. The DBS device consists of an implantable pulse generator (IPG) or neurostimulator, an implantable lead with electrodes and a connecting wire. The neurostimulator is approximately the size of a stop watch and is similar to a cardiac pacemaker. Subcutaneous extension wires connect the lead(s) to the neurostimulator which is implanted near the clavicle or, in the case of younger primary dystonia patients, in the abdomen. Conventional deep brain stimulation systems deliver stimulation using cylindrical electrodes or Ring Mode (omnidirectional) stimulation, which stimulate neurons around the entire circumference of the lead. Directional deep brain stimulation uses a directional lead designed to steer electrical current to relevant areas of the brain while avoiding areas that may cause side effects. Several independent electrode contacts can be programmed, creating a more customized therapy.

When used according to U.S. Food and Drug Administration (FDA) indications, deep brain stimulation is used to treat selected individuals with Parkinson’s disease, essential tremor, and primary dystonia. Most forms of Parkinson’s disease are idiopathic (having no specific known cause). In secondary Parkinsonism, the symptoms are a result of head trauma, metabolic conditions, toxicity, drugs, or other medical disorders. Primary dystonia occurs on its own, apart from any illness. Secondary dystonia can occur with illness, after trauma or following exposure to certain medications or toxins. Types of dystonia include:

- Generalized – Affects multiple areas of the body
- Focal – Affects one specific area of the body, such as the neck (cervical dystonia or torticollis), eyelid (blepharospasm) or hand (writer’s cramp)
- Segmental – Affects two or more adjacent parts of the body
- Multifocal – Affects two nonadjacent parts of the body
- Hemidystonia – Affects one side of the body
- Cervical dystonia or torticollis

Deep brain stimulation has been proposed to treat other disorders including, but not limited to the following:

- Depression
- Obsessive-compulsive disorder (OCD)
- Epilepsy
- Tourette syndrome
- Cluster headache
- Impulsive or violent behavior
- Chronic pain
- Trigeminal neuralgia
- Movement disorders caused by multiple sclerosis (MS)
- Phantom limb pain
- Stroke pain
**Responsive Cortical Stimulation**

The RNS® System (NeuroPace, Inc.) is intended to detect abnormal electrical brain signals that precede seizures and deliver electrical stimulation in response to try to normalize electrical brain activity and prevent seizures. The device includes a neurostimulator that is placed in the skull and leads that are placed in the seizure-originating areas of the brain. The system's intended benefits include seizure prevention, fewer adverse events than other neurostimulation methods, and data transmission by patients from home to clinicians.

**CLINICAL EVIDENCE**

**Deep Brain Stimulation**

**Parkinson's Disease and Essential Tremor**

Evidence from available published studies indicates that deep brain stimulation (DBS) provides clinically and statistically significant improvements in patients with Parkinson's disease (PD) and essential tremor (ET).

In a meta-analysis of randomized controlled trials (RCTs), Perestelo-Perez et al. (2014) described the efficacy of DBS in improving motor signs, functionality and quality of life of PD patients. Six RCTs (n = 1,184) that compared DBS plus medication versus medication alone were included in the analysis. The results showed that DBS significantly improves patients' symptoms, functionality and quality of life. Effects sizes are intense for the reduction of motor signs and improvement of functionality in the off-medication phase, in addition to the reduction of the required medication dose and its associated complications. Moderate effects were observed in the case of motor signs and time in good functionality in the on-medication phase, in addition to the quality of life. Although the number of RCTs obtained is small, the total sample size is relatively large, confirming the efficacy of DBS in the control of motor signs and improvement of patients' functionality and quality of life.

Liu et al. (2014) performed a meta-analysis that compared the efficacy of DBS in the globus pallidus internus (GPI) and the subthalamic nucleus (STN) regions for patients with advanced Parkinson disease (PD). Six eligible trials containing a total of 563 patients were included in the analysis. The Unified Parkinson's Disease Rating Scale Section II (UPDRS Section II - activities of daily living) scores for patients on medication improved equally in both DBS groups (p = 0.97). STN DBS allowed medication dosages to be reduced more than GPI DBS. Psychiatric symptoms, measured by Beck Depression Inventory, 2nd edition scores, showed greater improvement from baseline after GPI DBS than after STN DBS. The authors concluded that GPI and STN DBS improve motor function and activities of daily living for PD patients. Differences in therapeutic efficacy for PD were not observed between the 2 procedures. STN DBS allowed greater reduction in medication for patients, whereas GPI DBS provided greater relief from psychiatric symptoms. According to the authors, an understanding of other symptomatic aspects of targeting each region and long-term observations on therapeutic effects are needed.

To assess the current state of knowledge on essential tremor (ET) therapy and make recommendations based on the analysis of evidence, Zappia et al. (2013) reviewed the literature regarding pharmacologic and surgical therapies, providing a quality assessment of the studies and the strength of recommendations for each treatment. A systematic literature review was performed to identify all the studies conducted on patients with ET. Based on the results of the review, thalamic deep-brain stimulation was recommended for refractory ET.

**Professional Societies**

**American Academy of Neurology (AAN)**

In a practice parameter for the treatment of Parkinson's disease (PD), the AAN recommends the following:

- DBS of the subthalamic nucleus (STN) may be considered as a treatment option in PD patients to improve motor function and to reduce motor fluctuations, dyskinesia, and medication usage (Level C - possibly effective, ineffective, or harmful for the given condition in the specified population). Patients need to be counseled regarding the risks and benefits of this procedure. There is insufficient evidence to make any recommendations about the effectiveness of DBS of the GPI or ventralis intermedius (VIM) nucleus of the thalamus in reducing motor complications or medication usage, or in improving motor function in PD patients (Level U - data inadequate or conflicting given current knowledge, treatment is unproven).
- Preoperative response to levodopa should be considered as a factor predictive of outcome after DBS of the STN (Level B - probably effective, ineffective, or harmful for the given condition in the specified population). 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 (Level C). There is insufficient evidence to make any recommendations about factors predictive of improvement after DBS of the GPI or VIM nucleus of the thalamus in PD patients (Level U) (Pahwa, 2006).

In a practice parameter for essential tremor therapies, the AAN recommends the following:

- DBS of the VIM thalamic nucleus may be used to treat medically refractory limb tremor in essential tremor (Level C - possibly effective, ineffective, or harmful for the given condition in the specified population).
• There is insufficient evidence to make recommendations regarding the use of thalamic DBS for head or voice tremor (Level U - data inadequate or conflicting given current knowledge, treatment is unproven).

• DBS has fewer adverse events than thalamotomy (Level B - probably effective, ineffective, or harmful for the given condition in the specified population). However, the decision to use either procedure depends on each patients circumstances and risk for intraoperative complications compared to feasibility of stimulator monitoring and adjustments (Zesiewicz, 2005).

The AAN issued an update of the 2005 American Academy of Neurology practice parameter on the treatment of essential tremor (ET) in 2011. Conclusions and recommendations for deep brain stimulation (Level C, possibly effective) were unchanged from the previous guideline. The guideline indicated that there were no additional trials (published between 2004 and April 2010) rated better than Class IV that examined the efficacy and safety of deep brain stimulation (DBS) of the thalamus for the treatment of ET (Zesiewicz, 2011).

**Dystonia**

Evidence from available published controlled trials and case series indicates that deep brain stimulation provides improvement in movement symptoms in patients with primary dystonia (Volkmann et al. 2015; Sarubbo et al. 2012; Vidailhet et al. 2007; Houeto et al. 2007).

In a controlled multicentre trial, Volkmann et al. (2013) assessed the safety and efficacy of pallidal neurostimulation in patients with primary generalized or segmental dystonia who were prospectively followed up for 5 years. Forty patients were randomly assigned to either sham neurostimulation or neurostimulation of the internal globus pallidus for a period of 3 months and thereafter all patients completed 6 months of active neurostimulation. A total of 38 patients agreed to be followed up annually after the activation of neurostimulation, including assessments of dystonia severity, pain, disability, and quality of life. An intention-to-treat analysis including all patients from the parent trial showed significant improvements in dystonia severity at 3 years and 5 years compared with baseline. The improvement from 6 months to 3 years was significant and sustained at the 5-year follow-up. The authors concluded that 3 years and 5 years after surgery, pallidal neurostimulation continues to be an effective and relatively safe treatment option for patients with severe idiopathic dystonia. This long-term observation provides further evidence in favor of pallidal neurostimulation as a first-line treatment for patients with medically intractable, segmental, or generalized dystonia.

Andrews et al. (2010) analyzed combined published results of individual patient outcomes following DBS for all types of dystonia. Data was available in 157 studies for 466 patients with all forms of dystonia. The subclassification of these patients included 344 with primary forms of dystonia, 10 with myoclonus dystonia, 19 with heredodegenerative dystonias and 93 who had DBS for secondary dystonia. Patients with primary forms of dystonia, myoclonus dystonia, subtypes of heredodegenerative dystonia and tardive dystonia have a greater than 50% mean improvement in dystonia severity following DBS. Among patients with primary generalized dystonia, multiple regression analysis showed that a shorter duration of symptoms, a lower baseline severity score and DYT1 positive status were all independently associated with a significantly higher percentage improvement from surgery. Patients with other forms of heredodegenerative and secondary dystonia have variable responses, making prediction of response in future patients difficult.

Koy et al. (2013) performed a meta-analysis and analyzed the published literature regarding deep brain stimulation and secondary dystonia to evaluate the effect on cerebral palsy, a common cause of secondary dystonia. Twenty articles that included 68 patients with cerebral palsy undergoing deep brain stimulation assessed by the Burke-Fahn-Marsden Dystonia Rating Scale were identified. Most articles were case reports reflecting great variability in the score and duration of follow-up. The mean Burke-Fahn-Marsden Dystonia Rating Scale movement score was 64.94 ± 25.40 preoperatively and dropped to 50.5 ± 26.77 postoperatively, with a mean improvement of 23.6% at a median follow-up of 12 months. There was a significant negative correlation between severity of dystonia and clinical outcome. The authors concluded that deep brain stimulation can be an effective treatment option for dyskinetic cerebral palsy. The authors stated that in view of the heterogeneous data, a prospective study with a large cohort of patients in a standardized setting with a multidisciplinary approach would be helpful in further evaluating the role of deep brain stimulation in cerebral palsy.

In a systematic review, Mentzel et al. (2012) assessed the efficacy and safety, specifically the psychiatric side effects, of DBS in patients with medication-induced tardive dyskinesia and dystonia (TDD) (a form of secondary dystonia). Seventeen studies involving 50 patients with TDD who underwent DBS were included in the review. The mean improvement of TDD of the combined patients 3 to 76 months after implantation was 77.5% on the Burke-Fahn-Marsden Dystonia Rating Scale. Of the 50 patients, 1 experienced an exacerbation of depression, and 1 experienced an exacerbation of psychosis. The authors concluded that DBS seems to be effective and relatively safe for patients with treatment-resistant TDD; however, the results should be interpreted with caution, as most of the data are from case reports and small trials.
Kim et al. (2011) applied a multimodal method to maximize the treatment effects of deep brain stimulation in patients with secondary dystonia. Four patients underwent bilateral globus pallidus internus (GPI) deep brain stimulation (DBS) and six patients underwent bilateral GPI DBS plus unilateral thalamotomy for treatment of cerebral palsy (CP). Among the patients with secondary dystonia without CP, five were also treated by DBS. Patients with generalized secondary dystonia with cerebral palsy were classified into group I and patients with focal dystonia without CP into group II. The movement and disability scores of group I-A had improved by 32.0% and 14.3%, respectively, at the last follow-up compared with baseline. The movement and disability scores of group I-B had improved by 31.5% and 0.18% at the last follow-up compared with baseline, respectively. In comparison with patients in group I-A, patients in group I-B showed a significant improvement in movement scores for the contralateral arm. Group II patients showed a marked improvement in movement and disability scores of 77.7% and 80.0%, respectively. The authors concluded that DBS plus unilateral ventralis oralis thalamotomy for CP patients with fixed states in the upper extremities is useful not only to treat secondary dystonic movement but also to improve quality of life. The authors concluded that excellent clinical outcomes were achieved using DBS in group II patients with post-traumatic dystonia and tardive dyskinesia. However, the conclusions that can be drawn from this study are limited by the extremely small number of study participants. These findings require confirmation in a larger study.

The National Institute for Health and Care Excellence (NICE) issued a guidance stating that the current evidence supports the safety and efficacy of DBS as a treatment modality for dystonia. Dystonia may be treated conservatively or surgically. Conservative treatment only treats the symptoms, and surgical intervention (i.e., thalamotomy and pallidotomy) may not render long-term benefits. Patient selection and management should be managed by a multidisciplinary team specializing in the long-term care of patients with movement disorders (NICE, 2006).

**Professional Societies**

*European Federation of Neurological Societies*

The European Federation of Neurological Societies Guidelines on Diagnosis and Treatment of Primary Dystonias state that pallidal deep brain stimulation is considered a good option, particularly for primary generalized or cervical dystonia, after medication or botulinum toxin have failed. Deep brain stimulation is less effective in secondary dystonia (Albanese et al., 2011).

**Tourette Syndrome**

Baldermann et al. (2016) conducted a systematic literature review to evaluate the efficacy of deep brain stimulation (DBS) for severe cases of Tourette syndrome that failed to respond to standard therapies. In total, 57 studies were eligible, including 156 cases. Overall, DBS resulted in a significant improvement of 52.68% in the Yale Global Tic Severity Scale (YGTSS). Analysis of controlled studies significantly favored stimulation versus off stimulation with a standardized mean difference of 0.96. Disentangling different target points revealed significant YGTSS reductions after stimulation of the thalamus, the posteroverentralateral part and the anteromedial part of the globus pallidus internus, the anterior limb of the internal capsule and nucleus accumbens with no significant difference between these targets. A significant negative correlation of preoperative tic scores with the outcome of thalamic stimulation was found. Despite small patient numbers, the authors conclude that DBS for GTS is a valid option, particularly for primary generalized or cervical dystonia, after medication or botulinum toxin have failed. Deep brain stimulation is less effective in secondary dystonia (Kim et al.).

In a randomized, double-blind, crossover trial, Kefalopoulou et al. (2015) recruited eligible patients (severe medically refractory Tourette's syndrome, age ≥20 years) from two clinics for tertiary movement disorders. Enrolled patients received surgery for globus pallidus internus (GPI) DBS and then were randomly assigned in a 1:1 ratio (computer-generated pairwise randomization according to order of enrollment) to receive either stimulation on-first or stimulation off-first for 3 months, followed by a switch to the opposite condition for a further 3 month period. Patients and rating clinicians were masked to treatment allocation; an unmasked clinician was responsible for programming the stimulation. Fifteen patients were enrolled in the study. Fourteen patients were randomly assigned and 13 completed assessments in both blinded periods (seven in the on-first group, six in the off-first group). Mean Yale Global Tic Severity Scale (YGTSS) total score in these 13 patients was 87.9 at baseline, 80.7 for the off-stimulation period, and 68.3 for the on-stimulation period. All 15 patients received stimulation in the open-label phase. Overall, three serious adverse events occurred (two infections in DBS hardware at 2 and 7 weeks postoperatively, and one episode of deep-brain-stimulation-induced hypomania during the blinded on-stimulation period); all three resolved with treatment. The authors concluded that GPI stimulation led to a significant improvement in tic severity, with an overall acceptable safety profile. According to the authors, future research should concentrate on identifying the most effective target for DBS to control both tics and associated comorbidities, and further clarify factors that predict individual patient response.
Piedad et al. (2012) evaluated which patients with Gilles de la Tourette syndrome (GTS) should be treated with DBS and what is the best target. To answer these questions, the authors conducted a systematic literature review of the published studies of DBS in GTS and critically evaluated the current evidence for both patient and target selection. The authors found that since 1999, up to 99 cases of DBS in GTS have been reported in the scientific literature, with varying selection criteria, stimulation targets, and assessment protocols. The vast majority of studies published to date are case reports or case series reporting successful outcomes in terms of both tic severity improvement and tolerability. The reviewed studies suggest that the best candidates are patients with significant functional impairment related to the tic symptoms, who did not respond to conventional pharmacological and behavioral interventions. The globus pallidus internus and thalamus appear to be the safest and most effective targets, especially for patients with "pure" GTS and patients with comorbid obsessive-compulsive symptoms, anxiety, and depression. The authors concluded that DBS is a promising treatment option for severe cases of GTS. According to the authors, there is a need to reach consensus on the definition of refractory treatment and to conduct larger double-blind randomized controlled studies on the most promising targets.

Saleh et al. (2012) analyzed 33 research articles reporting on DBS in patients with Gilles de la Tourette syndrome (GTS). The review included 88 patients with Tourette's syndrome who were treated since 1999 with DBS. The majority of patients received thalamic stimulation. Significantly fewer patients were treated with globus pallidus internus stimulation. Occasionally, the anterior limb of the internal capsule and the nucleus accumbens were implanted. The subthalamic nucleus was selected once. All targets were reported with positive results, but of variable extent. The majority of studies (n = 26) met only level 4 criteria (observational studies without control), while four studies met level 1 criteria (randomized control studies) and three studies met level 2 criteria (non-randomized controlled trials). This translates into level 1 evidence for 14 GTS patients, level 2 evidence for 38 patients, and level 4 evidence for 36 patients. The authors concluded that in light of the wide spectrum of associated behavioral co-morbidities in GTS, multiple networks modulation may result in the most efficacious treatment strategy. The optimal locations for DBS within the cortico-basal ganglia-thalamocortical circuits remain to be established. However, at the current stage, comparison between targets should be done with great caution. Significant differences between number of patients treated per target, methodological variability, and quality of reporting makes a meaningful comparison between targets difficult. According to the authors, randomized controlled trials with larger cohorts and standardization of procedures are needed.

Porta et al. (2012) assessed the long term (5-6 years) outcome of bilateral thalamic deep brain stimulation in 18 patients with severe and refractory Tourette syndrome. The aim of the research was the assessment of long-term outcome on tics, obsessional behaviors, anxiety, mood, and on the overall general health of the patients and their general satisfaction. At 5-6 year follow-up, there was a significant reduction in tic severity, and significant improvements in obsessive compulsive behaviors, anxiety and depressive symptoms. Patients, in general, required less medication for tics, co-morbid conditions and/or co-existent psychopathologies. The long-term outcome and satisfaction were not unanimous between patients and the medical team. According to the authors, at long-term follow-up, DBS was very successful in terms of a significant improvement in tics and also a significant reduction in the potentially disabling symptoms of obsessonality, anxiety and depression. However, compared with the more positive overall results at 2 years, these later results demonstrate long-term difficulties as follows: non-compliance, long-term complications, and the differences in the opinions between the medical, the surgical teams and the post-DBS patients as to their outcome/satisfaction with the procedures. The authors indicated that this emphasizes the need for controlled studies, for long-term follow up, and the need to improve the selection of patients for DBS.

Steeves et al. (2012) conducted a systematic literature search for clinical trials on the treatment of tics. Three studies on deep brain stimulation (DBS) met the inclusion criteria. According to the authors, although evidence exists for the efficacy of DBS, the quality of this evidence is poor and the risks and burdens of the procedure are finely balanced with the perceived benefits. The author recommended that this intervention continues to be considered an experimental treatment for severe, medically refractory tics that have imposed severe limitations on quality of life. According to the authors, the procedure should only be performed within the context of research studies and by physicians who are expert in DBS programming and in the management of tics.

Sachdev et al. (2014) evaluated 17 patients who underwent deep brain stimulation (DBS) of the antero-medial globus pallidus interna (GPI) for severe Tourette Syndrome (TS). Follow up was at one month, three months and finally at a mean 24.1 months (range 8-46 months) following surgery. Overall, there was a 48.3% reduction in motor tics and a 41.3% reduction in phonic tics at one month, and this improvement was maintained at final follow-up. 12 out of 17 (70.6%) patients had a>50% reduction in YGTSS score at final follow up. Only 8 patients required ongoing pharmacotherapy for tics post-surgery. Patients improved significantly on all secondary measures. Adverse consequences included lead breakage in 4 patients, infection (1), transient anxiety (2), dizziness (1), poor balance (1) and worsening of stuttering (1). The authors concluded that this case series provides further support that antero-medial GPI DBS is an effective and well tolerated treatment for a subgroup of severe TS, with benefits sustained up to 4 years. This study was nonrandomized and not case controlled.
A European guideline on DBS was developed by a working group of the European Society for the Study of Tourette Syndrome (ESSTS). A systematic literature search was conducted and expert opinions of the guidelines group contributed also to the recommendations. Of 63 patients reported so far in the literature, 59 had a beneficial outcome following DBS with moderate to marked tic improvement. However, randomized controlled studies including a larger number of patients are still lacking. Although persistent serious adverse effects (AEs) have hardly been reported, surgery-related (e.g., bleeding, infection) as well as stimulation-related AEs (e.g., sedation, anxiety, altered mood, changes in sexual function) may occur. According to the ESSTS working group, at the present time, DBS in TS is still in its infancy. Due to both different legality and practical facilities in different European countries these guidelines, therefore, need to be understood as recommendations of experts. However, among the ESSTS working group on DBS in TS there is general agreement that, at present time, DBS should only be used in adult, treatment resistant, and severely affected patients. It is highly recommended to perform DBS in the context of controlled trials (Müller-Vahl et al. 2011).

The First World Congress on Tourette Syndrome and Tic Disorders was held in June of 2016 in London by the Tourette Association of America, Tourette's Action (UK), and the European Society for the Study of Tourette Syndrome. Topics included the use of depth and cortical surface electrodes to investigate the neurophysiology of tics on the background of the evolving field of deep brain stimulation (DBS). The authors indicated that in addition to the conventional treatments of pharmacotherapy and behavioral therapy, alternative approaches are also evolving, ranging from neurosurgical stereotactic DBS, which has a limited evidence base (Mathews and Stern, 2016).

**Chronic Pain**

Crucu et al. (2016) conducted a systematic review and meta-analysis of trials published between 2006 and December 2014 to update previous European Federation of Neurological Societies guidelines on neurostimulation for neuropathic pain, expanding the search to new techniques and to chronic pain conditions other than neuropathic pain, and assessing the evidence with the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system. Pain conditions included neuropathic pain, fibromyalgia, complex regional pain syndrome (CRPS) type I and post-surgical chronic back and leg pain (CLBP). Spinal cord stimulation (SCS), deep brain stimulation (DBS), epidural motor cortex stimulation (MCS), repetitive transcranial magnetic stimulation (rTMS) and transcranial direct electrical stimulation (tDCS) of the primary motor cortex (M1) or dorsolateral prefrontal cortex (DLPFC) were assessed. The GRADE system was used to assess quality of evidence and propose recommendations. For DBS, this review showed seven studies including 163 patients with heterogeneous conditions, mostly dominated by peripheral or central neuropathic pain. All were case series with major limitations, such as retrospective data collection, poor selection criteria, lack of accurate diagnosis of neuropathic pain and poor reporting of adverse events. They used heterogeneous methodological approaches and targeted structures. Although the mean pain intensity reduction approached 50%, results were imprecise (large confidence intervals) and inconsistent, with large variations in reported pain relief across studies. It was also impossible to define subgroups according to specific diseases. However, the best DBS results (effect exceeding 50%, with relatively narrow confidence intervals) were obtained with stimulation of the somatosensory thalamus in patients with peripheral neuropathic pain. Given the very low quality of evidence and the current uncertainty on DBS effects, the recommendation for DBS in neuropathic pain is inconclusive. Given the poor to moderate quality of evidence identified by this review, future large-scale multicentre studies of non-invasive and invasive neurostimulation are encouraged. The collection of higher quality evidence of the predictive factors for the efficacy of these techniques, such as the duration, quality and severity of pain, is also recommended.

Jung et al. (2015) evaluated the long-term effect of subthalamic nucleus deep brain stimulation (STN DBS) on pain in Parkinson disease (PD). Twenty-four patients who underwent STN DBS were studied. The assessments of pain were performed preoperatively and 8 years after surgery. Because 13 of the total 24 patients had additional 2-year postoperative data, the serial change between the preoperative and the 2- and 8-year follow-ups after surgery was also evaluated. Sixteen of the 24 patients (67%) experienced pain at baseline when not taking medication (off-state). All off-state pain at baseline improved or disappeared at 8 years after surgery. The number of body parts with pain was 21 at baseline and decreased to 11 at 8 years after the surgery. The mean (SD) and median scores of the off-state pain were 6.2 (2.5) and 7.0 at baseline and improved to 3.5 (2.2) and 2.5 at 8 years after the surgery, respectively. However, new pain developed in 18 of 24 patients (75%) during the 8-year follow-up period. The number of body parts with newly developed pain was 47. The types of new pain at 8 years were musculoskeletal in 11 patients, central in 4 patients, radiculoneuritic in 3 patients, and dystonic in 1 patient. Pain associated with PD is improved by STN DBS, and the beneficial effect persists after a long-term follow-up of 8 years. However, new pain, especially the musculoskeletal type, developed in most patients, becoming a long-term distressing problem.

In a National Institute for Health and Care Excellence (NICE) Guidance for refractory chronic pain syndromes (excluding headache), NICE stated that current evidence on the safety of deep brain stimulation for refractory chronic pain syndromes (excluding headache) shows that there are serious but well-known risks. There is evidence that the procedure is efficacious in some patients who are refractory to other forms of pain control. Therefore, NICE recommends that this procedure may be used provided that normal arrangements are in place for clinical governance, consent and audit (NICE 2011).
**Cluster Headache**

Fontaine et al. (2010) conducted a prospective crossover, double-blind, multicenter study assessing the efficacy and safety of unilateral hypothalamic DBS in 11 patients with severe refractory chronic cluster headache (CCH). The randomized phase compared active and sham stimulation during 1-month periods, and was followed by a 1-year open phase. During the randomized phase, no significant change in primary and secondary outcome measures was observed between active and sham stimulation. At the end of the open phase, 6/11 patients responded to the chronic stimulation (weekly frequency of attacks decreased by at least 50%), including three pain-free patients. There were three serious adverse events, including subcutaneous infection, transient loss of consciousness and micturition syncope. According to the investigators, randomized phase findings of this study did not support the efficacy of DBS in refractory CCH, but open phase findings suggested long-term efficacy in more than 50% patients, confirming previous data. Discrepancy between these findings justifies additional controlled studies.

**Depression**

Berlim et al. (2014) conducted a systematic review and exploratory meta-analysis to investigate deep brain stimulation (DBS) applied to the subgenual cingulate cortex (SCC) as a potential treatment for severe and chronic treatment-resistant depression (TRD). Data from 4 observational studies were included in the analysis, totaling 66 subjects with severe and chronic TRD. Twelve-month response and remission rates following DBS treatment were 39.9% and 26.3%, respectively. Also, depression scores at 12 months post-DBS were significantly reduced. There was a significant decrease in depression scores between 3 and 6 months, but no significant changes from months 6 to 12. Finally, dropout rates at 12 months were 10.8%. The authors concluded that DBS applied to the SCC seems to be associated with relatively large response and remission rates in the short- and medium- to long-term in patients with severe TRD. Also, its maximal antidepressant effects are mostly observed within the first 6 months after device implantation. According to the authors, these findings are clearly preliminary and future controlled trials should include larger and more representative samples, and focus on the identification of optimal neuroanatomical sites and stimulation parameters.

Morishita et al. (2014) performed a systematic review of the literature pertaining to DBS for treatment-resistant depression to evaluate the safety and efficacy of this procedure. The reviewers identified 22 clinical research papers with 5 unique DBS approaches using different targets, including nucleus accumbens, ventral striatum/ventral capsule, subgenual cingulate cortex, lateral habenula, inferior thalamic nucleus, and medial forebrain bundle. Among the 22 published studies, only 3 were controlled trials, and 2, as yet unpublished, multicenter, randomized, controlled trials evaluating the efficacy of subgenual cingulate cortex and ventral striatum/ventral capsule DBS were recently discontinued owing to inefficacy based on futility analyses. Overall, the published response rate to DBS therapy, defined as the percentage of patients with > 50 % improvement on the Hamilton Depression Rating Scale, is reported to be 40-70 %, and outcomes were comparable across studies. The authors concluded that DBS for MDD shows promise, but remains experimental and further accumulation of data is warranted.

Blomstedt et al. (2011) conducted a review of the literature on DBS in the treatment of major depressive disorder (MDD). According to the authors, the results of DBS in MDD have been presented in 2 case reports and 3 studies of 47 patients operated upon in 5 different target areas. Positive effects were presented in all studies and side effects have been minor. DBS in the nucleus accumbens resulted in a mean reduction of Hamilton depression rating scale (HDRS) of 36% after 1 year and 30% of the 10 patients achieved remission. DBS in the internal capsule/ventral striatum resulted in a reduction of 44% after 1 year, and at the last evaluation after in mean 2 years, 40% of the 15 patients were in remission. The 20 patients with subcallosal cingulated gyrus DBS had a reduction of HDRS of 52% after 1 year, and 35% were within 1 point from remission or in remission. The authors concluded that DBS is a promising treatment for therapy-refractory MDD. However, the authors also stated that the published experience is limited, and the method is at present an experimental therapy.

Smith (2014) conducted an exploratory meta-analysis to address deep brain stimulation for treatment of major depressive disorder. Data on benefits of deep brain electrical stimulation came from a recent review. Expert opinion plus random number software was used to generate hypothetical values for sham responding. An effect size of 1.71 was obtained for deep brain stimulation versus sham treatment in patients suffering from long-term treatment-resistant depression. The authors concluded that preliminary findings on deep brain electrical stimulation suggest that the procedure may be 71% more effective than sham treatment. Expressing these findings as patients-needed-to-treat, deep brain electrical stimulation is required by 2.9 patients with long-term treatment-resistant depression in order for one of them to benefit.

Kubu et al. (2016) reported the neuropsychological outcomes of 25 patients with treatment-resistant major depressive disorder (TRD) who participated in an Institutional Review Board (IRB)-approved randomized double-blind trial (trial registration number NCT00837486) comparing active to sham deep brain stimulation (DBS) in the anterior limb of the ventral capsule/ventral striatum (VC/VS). Participants were randomized to active (n=12) versus sham (n=13) DBS for 16 weeks. Data were analyzed at the individual and group levels. Group differences were analyzed
using repeated measures ANOVAs. Relationships between depression severity and cognition were examined using partial correlations. The false discovery rate method controlled for multiple analyses. The results showed that no significant interactions comparing active versus sham stimulation over time were evident. Change in depression was unrelated to change in neuropsychological measures. The authors concluded that the data from this study suggest that VC/VS DBS in patients with TRD does not significantly affect neuropsychological function.

Dougherty et al. (2015) evaluated 30 patients with treatment-resistant depression who participated in a sham randomized controlled trial of deep brain stimulation (DBS). Patients were randomized to active versus sham DBS treatment in a blinded fashion for 16 weeks, followed by an open-label continuation phase. The primary outcome measure was response, defined as a 50% or greater improvement on the Montgomery-Åsberg Depression Rating Scale from baseline. There was no significant difference in response rates between the active (3 of 15 subjects; 20%) and control (2 of 14 subjects; 14.3%) treatment arms and no significant difference between change in Montgomery-Åsberg Depression Rating Scale scores as a continuous measure upon completion of the 16-week controlled phase of the trial. According to the authors, future studies utilizing alternative study designs and stimulation parameters are needed.

A Comparative Effectiveness Review was prepared for the Agency for Healthcare Research and Quality (AHRQ) on Nonpharmacologic Interventions for Treatment-Resistant Depression in Adults. The report indicated that clinical trial data on some of the developing nonpharmacologic interventions, such as deep brain stimulation were insufficient (from the published literature) to include them in the report. The authors stated that as the evidence bases grow to support the efficacy of such nonpharmacologic interventions, the newer strategies should be included in comparative effectiveness study designs (Gaynes et al. 2011).

**Professional Societies**

*Canadian Psychiatric Association and the Canadian Network for Mood and Anxiety Treatments (CANMAT)*

In 2008-2009, the Canadian Psychiatric Association and the CANMAT partnered to produce evidence-based clinical guidelines for the treatment of depressive disorders. Among the four forms of neurostimulation for depression reviewed in the guidelines, electroconvulsive therapy (ECT) had the most extensive evidence, spanning seven decades. The investigators indicated that deep brain stimulation remains an investigational treatment (Kennedy, 2009).

*American Psychiatric Association (APA)*

In a clinical practice guideline for the treatment of patients with major depressive disorder, the APA states that electroconvulsive therapy remains the treatment of best established efficacy against which other stimulation treatments (e.g., VNS, deep brain stimulation, transcranial magnetic stimulation, other electromagnetic stimulation therapies) should be compared. The APA did not assign a rating for the use deep brain stimulation in treating depression (Gelenberg et al. 2010).

**Epilepsy**

In a Cochrane review, Sprengers et al. (2014) assessed the efficacy, safety and tolerability of deep brain and cortical stimulation for refractory epilepsy based on randomized controlled trials (RCTs). Ten RCTs comparing one to three months of intracranial neurostimulation to sham stimulation were identified. One trial was on anterior thalamic DBS (n= 109); two trials on centromedian thalamic DBS (n = 20), but only one of the trials (n= 7; 14 treatment periods) reported sufficient information for inclusion in the quantitative meta-analysis; three trials on cerebellar stimulation (n= 22); three trials on hippocampal DBS (n = 15); and one trial on responsive ictal onset zone stimulation (n= 191). Evidence of selective reporting was present in four trials and the possibility of a carryover effect complicating interpretation of the results could not be excluded in 4 cross-over trials without any washout period. Moderate-quality evidence could not demonstrate statistically or clinically significant changes in the proportion of patients who were seizure-free or experienced a 50% or greater reduction in seizure frequency (primary outcome measures) after 1 to 3 months of anterior thalamic DBS in (multi)focal epilepsy, responsive ictal onset zone stimulation in (multi)focal epilepsy patients and hippocampal DBS in (medial) temporal lobe epilepsy. However, a statistically significant reduction in seizure frequency was found for anterior thalamic DBS, responsive ictal onset zone stimulation and hippocampal DBS. Both anterior thalamic DBS and responsive ictal onset zone stimulation do not have a clinically meaningful impact on quality life after three months of stimulation (high-quality evidence). The authors concluded that only short term RCTs on intracranial neurostimulation for epilepsy are available. Compared to sham stimulation, one to three months of anterior thalamic DBS ((multi)focal epilepsy), responsive ictal onset zone stimulation ((multi)focal epilepsy) and hippocampal DBS (temporal lobe epilepsy) moderately reduce seizure frequency in refractory epilepsy patients. Anterior thalamic DBS is associated with higher rates of self-reported depression and subjective memory impairment. SUDEP rates require careful monitoring in patients undergoing responsive ictal onset zone stimulation. The authors stated that there is insufficient evidence to make firm conclusive statements on the efficacy and safety of hippocampal DBS, centromedian thalamic DBS and cerebellar stimulation. According to the authors, there is a need for more, large and well-designed RCTs to validate and optimize the efficacy and safety of invasive intracranial neurostimulation treatments for epilepsy.
In a National Institute for Health and Care Excellence (NICE) Guidance for deep brain stimulation for refractory epilepsy, NICE stated that the evidence on the efficacy of deep brain stimulation for refractory epilepsy is limited in both quantity and quality. NICE recommends that this procedure should only be used with special arrangements for clinical governance, consent and audit or research (NICE 2012).

**Obsessive Compulsive Disorder (OCD)**

Alonso et al. (2015) evaluated the efficacy and tolerability of deep brain stimulation (DBS) in obsessive-compulsive disorder (OCD) and the existence of clinical predictors of response using meta-analysis. Thirty-one studies involving 116 subjects were identified in a literature search. Global percentage of Yale-Brown Obsessive Compulsive Scale (Y-BOCS) reduction was estimated at 45.1% and global percentage of responders at 60.0%. Better response was associated with older age at OCD onset and presence of sexual/religious obsessions and compulsions. No significant differences were detected in efficacy between targets. Five patients dropped out, but adverse effects were generally reported as mild, transient and reversible. The authors concluded that their analysis confirms that DBS constitutes a valid alternative to lesion surgery for severe, therapy-refractory OCD patients. According to the authors, well-controlled, randomized studies with larger samples are needed to establish the optimal targeting and stimulation conditions and to extend the analysis of clinical predictors of outcome.

Hamani et al. (2014) conducted a systematic review of the literature and developed evidence-based guidelines on DBS for OCD that was 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. Of 353 articles identified, 7 were retrieved for full-text review and analysis. The quality of the articles was assigned to each study and the strength of recommendation graded according to the guidelines development methodology of the American Association of Neurological Surgeons/Congress of Neurological Surgeons Joint Guidelines Committee. Of the 7 studies, 1 class I and 2 class II double-blind, randomized, controlled trials reported that bilateral DBS is more effective in improving OCD symptoms than sham treatment. The authors concluded that based on the data published in the literature, the following recommendations can be made: (1) There is Level I evidence, based on a single class I study, for the use of bilateral subthalamic nucleus DBS for the treatment of medically refractory OCD. (2) There is Level II evidence, based on a single class II study, for the use of bilateral nucleus accumbens DBS for the treatment of medically refractory OCD. (3) There is insufficient evidence to make a recommendation for the use of unilateral DBS for the treatment of medically refractory OCD. The authors noted that additional research is needed to determine which patients respond to deep brain stimulation and if specific targets may be more suitable to treat a specific set of symptoms.

Kisely et al. (2014) conducted a systematic review and meta-analysis of double-blind, randomized controlled trials (RCTs) of active versus sham treatment to evaluate the effectiveness of DBS for psychiatric conditions. Inclusion criteria were met by five studies, all of which were for OCD. Forty-four subjects provided data for the meta-analysis. The main outcome was a reduction in obsessive symptoms as measured by the Yale-Brown Obsessive Compulsive Scale (YBOCS). Patients on active, as opposed to sham, treatment had a significantly lower mean score representing partial remission. However, one-third of patients experienced significant adverse effects (n = 16). There were no differences between the two groups in terms of other outcomes. The authors concluded that DBS may show promise for treatment-resistant OCD but there are insufficient randomized controlled data for other psychiatric conditions. According to the authors, DBS remains an experimental treatment in adults for severe, medically refractory conditions until further data are available.

Maarouf et al. (2016) conducted a retrospective trial involving four patients (three female, one male) aged 31-48 years, suffering from therapy-refractory OCD that underwent high-frequency DBS of the MD and VA. In two patients (de novo group) the thalamus was chosen as a primary target for DBS, whereas in two patients (rescue DBS group) lead implantation was performed in a rescue DBS attempt following unsuccessful primary stimulation. The study showed that continuous thalamic stimulation yielded no significant improvement in OCD symptom severity. Over the course of thalamic DBS symptoms improved in only one patient who showed "partial response" on the Yale-Brown Obsessive Compulsive (Y-BOCS) Scale. Beck Depression Inventory scores dropped by around 46% in the de novo group; anxiety symptoms improved by up to 34%. The authors concluded in the de novo DBS group no effect of DBS on anxiety and mood was observable and MD/VA-DBS yielded no adequate alleviation of therapy-refractory OCD and the overall strategy in targeting MD/VA as described in this paper can thus not be recommended in DBS for OCD.

**Professional Societies**

*American Psychiatric Association (APA)*

In a Guideline Watch Practice Guideline for the Treatment of Patients with Obsessive-Compulsive Disorder, the APA states that new studies are available on deep brain stimulation (DBS) and other somatic treatments, but the overall strength of evidence for these treatments remains low (APA, 2013).
Deep Brain Stimulation (DBS) has also been investigated for other disorders including Alzheimer’s disease (Laxton, 2010; Smith, 2012; Hardenacke et al., 2013), impulsive or violent behavior (Franzini, 2005), and movement disorders of multiple sclerosis (Hosseini, 2012; Hyam, 2007; Thevathasan, 2011; Mandat, 2010). Studies investigating DBS for treatment of other conditions are mainly case series with small sample sizes and short-term follow-up. Further well-designed studies are needed to demonstrate the benefits of deep brain stimulation for these disorders.

Directional Deep Brain Stimulation

Steigerwald et al. (2016) evaluated directional deep brain stimulation (DBS) effects on parkinsonian motor features and adverse effects of subthalamic neurostimulation. Seven Parkinson's disease (PD) patients were implanted with the novel directional DBS system for bilateral subthalamic DBS underwent an extended monopolar review session during the first postoperative week, in which current thresholds were determined for rigidity control and stimulation-induced adverse effects using either directional or ring-mode settings. Effect or adverse effect thresholds were modified by directional settings for each of the 14 subthalamic nucleus (STN) leads. Magnitude of change varied markedly between leads, as did orientation of optimal horizontal current steering. The authors concluded that directional current steering through chronically implanted segmented electrodes is feasible, alters adverse effect and efficacy thresholds in a highly individual manner, and expands the therapeutic window in a monopolar review as compared to ring-mode DBS. According to the authors, study limitations include the unblinded and subjective clinical rating of rigidity and adverse effect thresholds, no comparison to standard ring DBS, lack of long-term clinical follow-up, and small number of subjects.

Timmermann et al. (2015) conducted a prospective, multicentre, non-randomized, open-label intervention study of an implantable DBS device (Vercise PC System using the DBS Directional Lead manufactured by Boston Scientific) at six specialist DBS centers at universities in six European countries. Patients were included if they were aged 21-75 years and had been diagnosed with bilateral idiopathic Parkinson's disease with motor symptoms for more than 5 years. Participants underwent bilateral implantation in the subthalamic nucleus of a multiple-source, constant-current, eight-contact, rechargeable DBS system, and were assessed 12, 26, and 52 weeks after implantation. The primary endpoint was the mean change in unified Parkinson's disease rating scale (UPDRS) III scores (assessed by site investigators who were aware of the treatment assignment) from baseline (medication-off state) to 26 weeks after first lead implantation (stimulation-on, medication-off state). Of 53 patients enrolled in the study, 40 received a bilateral implant in the subthalamic nucleus and their data contributed to the primary endpoint analysis. Improvement was noted in the UPDRS III motor score 6 months after first lead implantation compared with baseline, with a mean difference of 23.8. One patient died of pneumonia 24 weeks after implantation, which was judged to be unrelated to the procedure. 125 adverse events were reported, the most frequent of which were dystonia, speech disorder, and apathy. 18 serious adverse events were recorded, three of which were attributed to the device or procedure (one case each of infection, migration, and respiratory depression). All serious adverse events resolved without residual effects and stimulation remained on during the study. The authors concluded that the multiple-source, constant-current, eight-contact DBS system suppressed motor symptoms effectively in patients with Parkinson's disease, with an acceptable safety profile. According to the authors, future trials are needed to investigate systematically the potential benefits of this system on postoperative outcome and its side-effects. This study was funded by Boston Scientific.

There is limited evidence comparing directional deep brain stimulation with traditional deep brain stimulation methods of stimulation. Long-term follow-up of large cohorts are needed to determine the effectiveness and long-term results of directional deep brain stimulation.

Responsive Cortical Stimulation

Morrell et al. (2011) conducted a multicenter, double-blind, randomized controlled trial that assessed the safety and effectiveness of responsive cortical stimulation as an adjunctive therapy for partial onset seizures in adults with medically refractory epilepsy. A total of 191 adults with medically intractable partial epilepsy were implanted with a responsive neurostimulator connected to depth or subdural leads placed at 1 or 2 predetermined seizure foci. The neurostimulator was programmed to detect abnormal electrocorticographic activity. One month after implantation, subjects were randomized 1:1 to receive stimulation in response to detections (treatment) or to receive no stimulation (sham). Efficacy and safety were assessed over a 12-week blinded period and a subsequent 84-week open-label period during which all subjects received responsive stimulation. Seizures were significantly reduced in the treatment compared to the sham group during the blinded period and there was no difference between the treatment and sham groups in adverse events. During the open-label period, the seizure reduction was sustained in the treatment group and seizures were significantly reduced in the sham group when stimulation began. There were significant improvements in overall quality of life and no deterioration in mood or neuropsychological function. According to the authors, responsive cortical stimulation reduces the frequency of disabling partial seizures, is associated with improvements in quality of life, and is well-tolerated with no mood or cognitive effects. This study provides Class I evidence that responsive cortical stimulation is effective in significantly reducing seizure frequency for 12 weeks in adults who have failed 2 or more antiepileptic medication trials, 3 or more seizures per month, and 1 or 2 seizure foci.
The RNS system manufacturer NeuroPace sponsored this study and participated in acquisition of data, statistical analysis, study supervision, and approval of the data. Therefore, a conflict of interest may exist.

Heck et al. (2014) published the final two-year results of the responsive neurostimulation (RNS) pivotal randomized multicenter double-blinded controlled trial described above (Morrell, et al., 2011) to assess the safety and effectiveness of responsive stimulation at the seizure focus as an adjunctive therapy to reduce the frequency of seizures in adults with medically intractable partial onset seizures arising from one or two seizure foci. Subjects with medically intractable partial onset seizures from one or two foci were implanted, and 1 month postimplant were randomized 1:1 to active or sham stimulation. After the fifth postimplant month, all subjects received responsive stimulation in an open label period (OLP) to complete 2 years of postimplant follow-up. All 191 subjects were randomized. The percent change in seizures at the end of the blinded period was -37.9% in the active and -17.3% in the sham stimulation group. The median percent reduction in seizures in the OLP was 44% at 1 year and 53% at 2 years, which represents a progressive and significant improvement with time. The serious adverse event rate was not different between subjects receiving active and sham stimulation. Adverse events were consistent with the known risks of an implanted medical device, seizures, and of other epilepsy treatments. There were no adverse effects on neuropsychological function or mood. According to the authors, responsive stimulation to the seizure focus reduced the frequency of partial-onset seizures acutely, showed improving seizure reduction over time, was well tolerated, and was acceptably safe.

Meador et al. (2015) reported on the patients from the Morrell, et al. (2011) and Heck et al. (2014) randomized controlled trial to evaluate quality of life, which was a supportive analysis, and for mood, which was assessed as a secondary safety endpoint. The study was a multicenter randomized controlled double-blinded trial of responsive neurostimulation in 191 patients with medically resistant focal epilepsy. During a 4-month postimplant blinded period, patients were randomized to receive responsive stimulation or sham stimulation, after which all patients received responsive neurostimulation in open label to complete 2 years. Quality of life (QOL) and mood surveys were administered during the baseline period, at the end of the blinded period, and at year 1 and year 2 of the open label period. The treatment and sham groups did not differ at baseline. Compared with baseline, QOL improved in both groups at the end of the blinded period and also at 1 year and 2 years, when all patients were treated. At 2 years, 44% of patients reported meaningful improvements in QOL, and 16% reported declines. There were no overall adverse changes in mood or in suicidality across the study. Findings were not related to changes in seizures and antiepileptic drugs, and patients with mesial temporal seizure onsets and those with neocortical seizure onsets both experienced improvements in QOL. The authors concluded that treatment with targeted responsive neurostimulation does not adversely affect QOL or mood and may be associated with improvements in QOL in patients, including those with seizures of either mesial temporal origin or neocortical origin.

Bergey et al. (2015) reported on patients who were involved in the Morrell et al. (2011) and Heck et al. (2014) studies and transitioned to this open-label study that assessed the long-term efficacy and safety of responsive direct neurostimulation in adults with medically refractory partial onset seizures. All participants were treated with a cranially implanted responsive neurostimulator that delivers stimulation to 1 or 2 seizure foci via chronically implanted electrodes when specific electrocorticographic patterns are detected (RNS System). Participants had completed a 2-year primarily open-label safety study (n = 65) or a 2-year randomized blinded controlled safety and efficacy study (n = 191); 230 participants transitioned into an ongoing 7-year study to assess safety and efficacy. The average participant was 34 (±11.4) years old with epilepsy for 19.6 (±11.4) years. The median preimplant frequency of disabling partial or generalized tonic-clonic seizures was 10.2 seizures a month. The median percent seizure reduction in the randomized blinded controlled trial was 44% at 1 year and 53% at 2 years and ranged from 48% to 66% over postimplant years 3 through 6 in the long-term study. Improvements in quality of life were maintained. The most common serious device-related adverse events over the mean 5.4 years of follow-up were implant site infection (9.0%) involving soft tissue and neurostimulator explantation (4.7%). The authors concluded that acute and sustained efficacy and safety were demonstrated in adults with medically refractory partial onset seizures arising from 1 or 2 foci over a mean follow-up of 5.4 years. This experience supports the RNS System as a treatment option for refractory partial seizures. This study provides Class IV evidence that for adults with medically refractory partial onset seizures, responsive direct cortical stimulation reduces seizures and improves quality of life over a mean follow-up of 5.4 years.

Cox et al (2014) conducted a systematic review of implantable neurostimulation devices, including RNS along with vagus nerve stimulation (VNS) and DBS for refractory epilepsy. The evidence included on RNS in this review is primarily the pivotal RCT described previously by Morrell et al. (2011). The authors concluded that RNS is promising, but that improvements in the accuracy of the seizure prediction method and standardization of electrical stimulation parameters are needed.

Loring et al. (2015) collected neuropsychological data from subjects participating in the open-label arm of a randomized controlled trial of responsive neurostimulation with the RNS System from (Morrell et al. (2011) and Heck et al. (2014). Primary cognitive outcomes were the Boston Naming Test (BNT) and Rey Auditory Verbal Learning
Deep brain stimulation is a procedure and, therefore, not subject to FDA regulation. However, any medical devices, drugs, and/or tests used as part of this procedure may require FDA regulation.

**Parkinson’s Disease and Essential Tremor**

The FDA approved the Activa® Tremor Control System (Medtronic) on July 31, 1997. The device is indicated for unilateral thalamic stimulation for the suppression of tremor in the upper extremity in patients who are diagnosed with essential tremor or Parkinsonian tremor not adequately controlled by medications and where the tremor constitutes a significant functional disability. Available at: [http://www.accessdata.fda.gov/cdrh_docs/pdf/p960009.pdf](http://www.accessdata.fda.gov/cdrh_docs/pdf/p960009.pdf). (Accessed March 10, 2017)

A January 14, 2002 Premarket Approval (PMA) supplement expanded use to include bilateral stimulation of the internal globus pallidus (GPI) or the subthalamic nucleus (STN) as an adjunctive therapy in reducing some of the symptoms of advanced, levodopa-responsive Parkinson’s disease that are not adequately controlled with medication. Available at: [http://www.accessdata.fda.gov/cdrh_docs/pdf/P960009S007b.pdf](http://www.accessdata.fda.gov/cdrh_docs/pdf/P960009S007b.pdf). (Accessed March 10, 2017)

On June 12, 2015, the FDA approved the Brio Neurostimulation System (St. Jude Medical), an implantable deep brain stimulation device intended to help reduce the symptoms of Parkinson’s disease and essential tremor. See the following website for more information: [http://www.accessdata.fda.gov/cdrh_docs/pdf14/P140009a.pdf](http://www.accessdata.fda.gov/cdrh_docs/pdf14/P140009a.pdf). (Accessed March 10, 2017)

**Dystonia**

On April 15, 2003, the Activa® Dystonia Therapy System (Medtronic) received a Humanitarian Device Exemption (HDE) from the FDA for unilateral and bilateral stimulation of the internal globus pallidus or the subthalamic nucleus and is indicated as an aid in the treatment of chronic, intractable (drug refractory), primary dystonia, including generalized and segmental dystonia, hemidystonia and cervical dystonia. Activa Dystonia Therapy is limited to use in implanting centers that receive Institutional Review Board (IRB) approval for the procedure. The safety and effectiveness of Activa Dystonia Therapy have not been established through a full PMA study. The therapy is approved for patients who are seven years of age and older. Available at: [https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfHDE/hde.cfm?id=H020007](https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfHDE/hde.cfm?id=H020007). (Accessed May 2, 2017)

**Obsessive Compulsive Disorder**

On March 28, 2005, the Activa® Deep Brain Stimulation Therapy System was designated as a Humanitarian Use Device (HUD) for the treatment of chronic, treatment-resistant obsessive compulsive disorder (OCD) in a subset of patients. However, the FDA does not list a Humanitarian Device Exemption (HDE) approval for authorization to market the device.

On February 19, 2009, the Reclaim™ Deep Brain Stimulation Therapy device was designated as an HUD for the treatment of obsessive compulsive disorder (OCD). This device is indicated for bilateral stimulation of the anterior limb of the internal capsule (AIC) as an adjunct to medications and as an alternative to anterior capsulotomy for treatment of chronic, severe, treatment-resistant OCD in adult patients who have failed at least three selective serotonin reuptake inhibitors (SSRIs). See the following website for more information: [https://www.accessdata.fda.gov/cdrh_docs/pdf5/H050003a.pdf](https://www.accessdata.fda.gov/cdrh_docs/pdf5/H050003a.pdf). (Accessed May 2, 2017)
Epilepsy

The Medtronic DBS therapy for refractory epilepsy (also known as the Intercept™ Epilepsy Control System) is under review by the FDA. On March 12, 2010, the FDA Neurological Devices Panel voted seven to five to recommend approval with conditions for the Medtronic DBS System for Epilepsy, and a final decision from FDA is pending. Medtronic submitted a premarket approval application (PMA) supplement in July 2009 for the Medtronic DBS System for Epilepsy as adjunctive treatment for partial-onset seizures in adults with medically refractory (i.e., treatment-resistant) epilepsy. Results from the Stimulation of the Anterior Nucleus of the Thalamus for Epilepsy (SANTE) trial supported Medtronic’s PMA. With the exception of the Intercept Patient Programmer, all components of the Medtronic system currently have U.S. marketing approval for other DBS indications as part of the Medtronic Activa PC Neurostimulation System for Tremor Control and Parkinson’s disease. The panel recommended the following conditions of approval for epilepsy:

- Labeling changes to address the increased risk of adverse events, including suicidal thoughts and actions, depression, memory problems, anxiety, and stimulation-related increased seizure frequency
- A five-year post-approval study that is hypothesis-driven, that has a control group, and targets various subgroups not well-defined in previous trials and that includes input from psychiatric experts to create an appropriate screening tool for suicidal tendencies

Directional Deep Brain Stimulation

On September 19, 2016, the FDA approved a Premarket Approval (PMA) application bundles supplement (P140009/S001) approving the use of the St. Jude Medical Infinity™ DBS System. One of the Infinity DBS System’s features is a directional lead, which will send the electrical impulses only toward its intended target instead of in all directions as current systems do. The FDA approval for the Infinity DBS System is a supplement to an earlier PMA (P140009) for the St. Jude Medical Brio Neurostimulation system. According to the manufacturer, the Infinity DBS System and the Brio Neurostimulation System have the same indications for use. See the following website for more information:


Responsive Cortical Stimulation

The FDA approved the NeuroPace RNS Neurostimulator System on November 14, 2013. The device is indicated as an adjunctive therapy in reducing the frequency of seizures in individuals 18 years of age or older with partial onset seizures who have undergone diagnostic testing that localized no more than two epileptogenic foci, are refractory to two or more antiepileptic medications, and currently have frequent and disabling seizures (motor, partial seizures, complex partial seizures and/or secondarily generalized seizures). The RNS System has demonstrated safety and effectiveness in patients who average three or more disabling seizures per month over the three most recent months (with no month with fewer than two seizures), and has not been evaluated in patients with less frequent seizures.

The RNS System is contraindicated for:
- Patients with risk factors for surgical complications such as active systemic infection, coagulation disorders (such as the use of antithrombotic therapies), or platelet count below 50,000
- Patients who have implanted medical devices that deliver electrical energy to the brain
- Patients who are unable or do not have the necessary assistance to properly operate the NeuroPace remote monitor or magnet

The following medical procedures are contraindicated for patients with an implanted RNS System. The procedures may send energy through the implanted brain stimulation system causing permanent brain damage, which may result in severe injury, coma, or death. Brain damage can occur from any of the listed procedures even if the RNS neurostimulator is turned off, the leads are not connected to the neurostimulator, or the neurostimulator has been removed and any leads (or any part of a lead) remain:

- MRI
- Diathermy procedures (high-frequency electromagnetic radiation, electric currents, or ultrasonic waves used to produce heat in body tissues.) (Patients should not be treated with any type of shortwave, microwave, or therapeutic ultrasound diathermy device, on any part of the body, regardless of whether the device is used to produce heat.)
- Electroconvulsive therapy
- Transcranial magnetic stimulation

See the following website for more information:

Additional Products

- Activa® Tremor Control Therapy (Medtronic, Inc.)
- Activa® Parkinson's Control Therapy (Medtronic, Inc.)
Activa® Dystonia Therapy (Medtronic, Inc.)
Intercept™ Epilepsy Control System
Kinetra® Neurostimulator (Medtronic, Inc.)
Soletra® Neurostimulator (Medtronic, Inc.)

CENTERS FOR MEDICARE AND MEDICAID SERVICES (CMS)

Medicare covers deep brain stimulation (DBS) when specific criteria are met. See the National Coverage Determination (NCD) for Deep Brain Stimulation for Essential Tremor and Parkinson’s Disease (160.24). Local Coverage Determinations (LCDs) do not exist at this time.

Medicare does not have an NCD for responsive cortical stimulation or directional deep brain stimulation. LCDs do not exist at this time.
(Accessed March 17, 2017)

REFERENCES


Isaias, IU, Alterman, RL, and Tagliati, M. Deep brain stimulation for primary generalized dystonia: long-term outcome


### POLICY HISTORY/REVISION INFORMATION

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| 08/01/2017 | • Revised coverage rationale:  
  o Replaced language indicating "deep brain stimulation is proven and medically necessary for treating the listed indications" with "deep brain stimulation (excluding directional deep brain stimulation) is proven and medically necessary for treating the listed indications"  
  o Added language to indicate directional deep brain stimulation that enables specific steering of current towards targeted lesions (e.g., Infinity™ DBS System) is unproven and not medically necessary for treating any condition including Parkinson’s disease, dystonia, or tremor  
  ▪ There is limited evidence comparing directional deep brain stimulation with traditional deep brain stimulation methods of stimulation  
  ▪ Long-term follow-up of large cohorts are needed to determine the effectiveness and long-term results of directional deep brain stimulation  
  • Updated supporting information to reflect the most current description of services, clinical evidence, FDA and CMS information, and references  
  • Archived previous policy version 2017T0321R |