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Original Article

The impact of sociodemographic factors and surgical modalities on deep brain stimulation for Parkinson's disease

David Shin[1], Miguel Angel Lopez-Gonzalez[2]

[1]Department of School of Medicine, Loma Linda University, [2]Department of Neurological Surgery, Loma Linda University Medical Center, Loma Linda, California, United States.

E-mail: David Shin - davidshin@students.llu.edu; *Miguel Angel Lopez-Gonzalez - mlopezgonzalez@llu.edu

***Corresponding author:**
Miguel Angel Lopez-Gonzalez, Department of Neurological Surgery, Loma Linda University Medical Center, Loma Linda, California, United States.

mlopezgonzalez@llu.edu

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ABSTRACT

Background: This study evaluated the impact of sociodemographic factors, surgical modalities, and commercially available options of electrodes on deep brain stimulation (DBS) outcomes in Parkinson's disease.

Methods: We retrospectively analyzed 59 elective DBS surgeries performed at a single institution from 2016 to 2023. Hoehn and Yahr (HY) scale scores and levodopa equivalent daily dosages (LEDD) were assessed at baseline, 3 months, and 6 months postoperatively. Collected variables included length of stay (LOS), age, sex, race/ethnicity, language, body mass index, insurance status, marital status, religion, type of anesthesia, concurrent pulse generator implantation, location of the implant, and conventional or directional lead. DBS systems included Medtronic, Boston Scientific, and Abbott (also known as St. Jude Medical).

Results: The mean LOS was 2.36 days. Mean HY scores improved from baseline (3.17) to 3 months (2.83) and 6 months (2.85), and LEDD significantly decreased at both 3 and 6 months postoperatively. Divorced patients showcased a significantly larger improvement in HY scores at 3 months compared to other marital groups. Abbott leads were associated with a significantly longer LOS compared to Boston Scientific (+1.85 days) and Medtronic (+2 days). No other variables significantly affected DBS outcomes.

Conclusion: This study investigated the impact of sociodemographic factors and surgical modalities of DBS in PD patients, showcasing how DBS improved motor function and reduced medication usage at 3 and 6 months postoperative. Marital status and lead manufacturer significantly influenced DBS outcomes, highlighting the importance of personalized considerations in DBS management.

Keywords: Deep brain stimulation, Functional neurosurgery, Neuromodulation, Parkinson's disease, Sociodemographics

INTRODUCTION

Parkinson's disease (PD) is a neurodegenerative disorder resulting from the loss of dopaminergic neurons in the substantia nigra of the midbrain.[1] Lewy bodies are key sightings of patients with PD, with tremors, rigidity, and bradykinesia being the main triad of symptoms.[23] Despite there being over 6 million cases reported globally and the prevalence expected to double by 2040,[7,36] there are currently no known cures for PD, highlighting the importance of methods

of treatment to relieve symptoms. While many treatment options are available for PD, deep brain stimulation (DBS) has been utilized in increasing frequency due to its advantages compared to medication-based treatments as well as past surgical treatments that often involved irreversibly lesioning parts of the brain.[2] DBS involves implanting electrodes on parts of the brain involved with Parkinson's, most commonly the subthalamic nucleus (STN) and globus pallidus interna (GPi), and providing electrical stimulation to improve symptoms.[8,41] In more recent years, interest has grown around enhancing efficacy and technology, improving outcomes, and reducing adverse effects of DBS.[37] Investigation into different modalities of DBS has included variables such as implantation location, type of anesthesia,[14] and conventional or directional leads.[26,43] Conventional leads use ring-shaped electrodes that generate an approximately spherical electrical field, while directional electrodes are radially segmented and allow the stimulation field to be moved in the horizontal plane or for the current to be steered in a particular direction.[40] While the literature has shown that there seems to be no difference in primary outcomes between general anesthesia (GA) and local anesthesia (LA),[19] implantation of directional leads has showcased both advantages and challenges compared to conventional leads.[24,25,27] A better understanding is needed of the benefits of different modalities of DBS. In addition, no study has investigated differences between current commercially available directional leads and the effects of social determinants of health on DBS outcomes have yet to be established.[37] To address these needs, this study aimed to evaluate different modalities of DBS in Parkinson's patients as well as to investigate the differences between commercially available options for electrodes. Another goal of this study was to evaluate for differences in DBS outcomes based on patient demographics and anthropometrics.

MATERIALS AND METHODS

Following Institutional Review Board (IRB) approval (#5230488), we analyzed 59 elective DBS surgeries performed from 2016 to 2023 using our institution's database of longitudinally collected electronic medical information. Patient consent was not required due to the nature of this retrospective chart review study. All patients included in the study were considered based on a diagnosis of PD, current indications and selection criteria for DBS, subsequent DBS surgery, and successful 3 and 6-month postoperative follow-up.[32,33] Exclusion criteria consisted of patients with existing neurological hardware, previous neurological surgery, traumatic brain injury, infection, malignancy, and patients who were lost to follow-up. Patient demographic data collected consisted of age, sex, race, ethnicity, language, body mass index (BMI), insurance status, marital status, and religion and were obtained through the patient's self-reported answers in the electronic medical record.

Hoehn and Yahr (HY) scale scores were collected from the patient's preoperative visit, 3-month postoperative visit, and 6-month postoperative visit, which evaluated the severity of functional disability associated with PD.[18] While a modified HY scale with 0.5 increments exists, the original five-point scale was maintained due to recommendations from the Movement Disorder Society (MDS) task force for rating scales for PD.[13] Additional variables collected consisted of the type of anesthesia utilized for the DBS procedure (LA or GA) if the operation concurrently included pulse generator implantation (yes or no), location of the implant (STN or GPi), hospital length of stay (LOS) after the DBS procedure, type of lead (conventional or directional), and levodopa equivalent daily dosage (LEDD). LEDD was calculated based on patient medication lists utilizing the conversion formulas provided by Tomlinson *et al.*[46] Categories of different commercially available options for DBS leads were determined to be Medtronic, Boston Scientific, and Abbott (also known as St. Jude Medical).[26] Table 1 showcases a list of collected variables.

Statistical analyses

Data collection and visualization were performed using Microsoft Excel version 16.58 (Microsoft Corporation, 2022, Redmond, WA, USA). The Statistical Package for the Social Sciences version 28 (IBM Corporation, 2021, Armonk, NY, USA) was utilized for all subsequent statistical analyses with alpha defined as $P < 0.05$. Associations were assessed among patient demographic and anthropometric variables, DBS procedure-specific variables, and DBS outcomes. DBS outcomes were measured through hospital LOS after DBS implantation, the difference between preoperative and 3-month postoperative HY scores, and the difference between preoperative and 6-month postoperative HY scores.

Age, BMI, and LOS were categorized as continuous variables and were analyzed utilizing a linear regression analysis, with Pearson correlation tests performed to assess associations. Sex, insurance, language, type of anesthesia, concurrent pulse generator implantation, implantation location, and type of lead were considered categorical variables and were analyzed through an independent sample *t*-test with equal variances not assumed/assumed, based on Levene's test of variance. Regarding race, religion, and marital status, a one-way analysis of variance (ANOVA) with Bonferroni and Tukey *post hoc* analysis was utilized for the analysis of significance between groups. Differences in DBS outcomes modality based on the manufacturer of lead were assessed

Table 1: Collected variables and number of patients.

Total patients=59	
Sex	
Male	41
Female	18
Race/Ethnicity	
White	41
Hispanic	16
Asian	2
Language	
English	52
Spanish	6
N/A	1
Insurance status	
Public	31
Private	28
Marital status	
Single	10
Married	39
Divorced	2
Widowed	6
N/A	2
Religion	
Christian	10
Catholic	12
Protestant	6
Lutheran	2
Presbyterian	2
Jehovah's Witness	2
Mormon	2
7th-day adventist	4
Muslim	2
Jewish	1
Nondenominational	4
None	12
Type of anesthesia	
GA	21
LA	36
N/A	2
Concurrent pulse generator implantation	
Yes	21
No	38
Location of implantation	
STN	53
GPi	6
Type of lead	
Conventional	22
Directional	37
Manufacturer of lead	
Medtronic	33
Boston Scientific	18
Abbot (St. Jude Medical)	8
	Mean value
Age	67.15 years
BMI	27.29 kg/m^2
LOS	2.36 days
Hoehn and Yahr preoperative score	3.17
Hoehn and Yahr 3-month postoperative score	2.83
Hoehn and Yahr 6-month postoperative score	2.85
Preoperative levodopa equivalent daily dosage	1098 mg
3-month postoperative levodopa equivalent daily dosage	916 mg
6-month postoperative levodopa equivalent daily dosage	773 mg

GA: General anesthesia, LA: Local anesthesia, STN: Subthalamic Nucleus GPi: Globus pallidus internus, BMI: Body mass index, LOS: length of stay, N/A: Not available

using a multiple variable ANOVA with *post hoc* Bonferroni and Tukey corrections.

RESULTS

Cohort description

Of the 59 patients included in this study, 41 were male, and 18 were female. With respect to race and ethnicity, 41 were White, 16 were Hispanic, and 2 were Asian. The mean patient age was 67.15 years, and the mean BMI was 27.29 kg/m^2. Regarding language, 52 preferred English, 6 preferred Spanish, and one patient's preferred language was unavailable and was subsequently withheld from analysis. Fifty-four operations were bilateral implantations. Twenty-two patients utilized conventional leads, and 37 utilized directional leads. Regarding DBS lead manufacturers, the leads utilized were from Medtronic, Boston Scientific, and Abbott. Thirty-three patients utilized *Medtronic*, 18 utilized *Boston Scientific*, and 8 utilized *Abbott*. The mean LOS was 2.36 days. The mean HY preoperative score was 3.17; the mean HY 3-month postoperative score was 2.83; the mean HY 6-month postoperative score was 2.85; the mean preoperative LEDD was 1098 mg; mean 3-month postoperative LEDD was 916 mg, and mean 6-month postoperative LEDD was 773 mg. Table 1 showcases a description of our cohort along with collected variables.

Patient demographics and anthropometrics

Tables 2 and 3 showcase differences in DBS outcomes based on patient demographic and anthropometric variables for 3-month and 6-month postoperative HY scores, respectively. Regarding marital status, divorced patients showcased significantly larger mean differences (MDs) between preoperative and 3-month postoperative HY scores compared to all other relationship groups. No other statistically significant associations were found between DBS

Table 2: Differences in deep brain stimulation outcomes based on patient demographics and anthropometrics.

Outcome Measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
Preop-HY and 3 Month-HY Difference	Sex	Male	Female	−0.067	0.704
		Female	Male	0.067	0.724
	Language	English	Spanish	0.428	0.249
		Spanish	English	−0.428	0.117
	Insurance Status	Public	Private	0.061	0.712
		Private	Public	−0.061	0.713
	Race/Ethnicity	White	Hispanic	−0.218	0.674
			Asian	0.157	0.965
		Hispanic	White	0.218	0.674
			Asian	0.375	0.827
		Asian	White	−0.157	0.965
			Hispanic	−0.375	0.827
	Marital Status	Married	Divorced	−2.314	0.001
			Widowed	0.186	1.00
			Single	0.257	1.00
			N/A	0.186	1.00
		Divorced	Married	2.314	0.001
			Widowed	2.500	0.001
			Single	2.571	0.001
			N/A	2.500	0.013
		Widowed	Married	−0.186	1.00
			Divorced	−2.500	0.001
			Single	0.071	1.00
			N/A	0	1.00
		Single	Married	−0.257	1.00
			Divorced	−2.571	0.001
			Widowed	−0.071	1.00
			N/A	−0.071	1.00
		N/A	Married	−0.186	1.00
			Divorced	−2.500	0.013
			Widowed	0	1.00
			Single	0.071	1.00
	Religion	Catholic	Christian	0.782	1.00
			Church of Jesus Christ of Latter-day Saints	0.682	1.00
			Jehovah's Witness	0.182	1.00
			Lutheran	0.182	1.00
			Muslim	0.182	1.00
			Nondenominational	0.682	1.00

(Contd...)

Table 2: *(Continued).*

Outcome Measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
			None	0.610	1.00
			Presbyterian	0.182	1.00
			Protestant	0.182	1.00
			7th-day adventist	1.182	1.00
		Christian	Catholic	−0.782	1.00
			Church of Jesus Christ of Latter-day Saints	−0.100	1.00
			Jehovah's Witness	−0.600	1.00
			Lutheran	−0.600	1.00
			Muslim	−0.600	1.00
			Nondenominational	−0.100	1.00
			None	−0.171	1.00
			Presbyterian	−0.600	1.00
			Protestant	−0.600	1.00
			7th-day adventist	0.400	1.00
		Church of Jesus Christ of Latter-day Saints	Catholic	−0.682	1.00
			Christian	0.100	1.00
			Jehovah's Witness	−0.500	1.00
			Lutheran	−0.500	1.00
			Muslim	−0.500	1.00
			Nondenominational	0	1.00
			None	−0.071	1.00
			Presbyterian	−0.500	1.00
			Protestant	−0.500	1.00
			7th-day adventist	0.500	1.00
		Jehovah's Witness	Catholic	−0.182	1.00
			Christian	0.600	1.00
			Church of Jesus Christ of Latter-day Saints	0.500	1.00
			Lutheran	0	1.00
			Muslim	0	1.00
			Nondenominational	0.500	1.00
			None	0.429	1.00
			Presbyterian	0	1.00
			Protestant	0	1.00
			7th-day adventist	1.00	1.00
		Lutheran	Catholic	−0.182	1.00
			Christian	0.600	1.00
			Church of Jesus Christ of Latter-day Saints	0.500	1.00
			Jehovah's Witness	0	1.00
			Muslim	0	1.00
			Nondenominational	0.500	1.00
			None	0.429	1.00
			Presbyterian	0	1.00
			Protestant	0	1.00
			7th-day adventist	1.00	1.00

(Contd...)

Table 2: *(Continued).*

Outcome Measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
		Muslim	Catholic	−0.182	1.00
			Christian	0.600	1.00
			Church of Jesus Christ of Latter-day Saints	0.500	1.00
			Jehovah's Witness	0	1.00
			Lutheran	0	1.00
			Nondenominational	0.500	1.00
			None	0.429	1.00
			Presbyterian	0	1.00
			Protestant	0	1.00
			7th-day adventist	1.00	1.00
		Nondenominational	Catholic	−0.682	1.00
			Christian	0.100	1.00
			Church of Jesus Christ of Latter-day Saints	0	1.00
			Jehovah's Witness	−0.500	1.00
			Lutheran	−0.500	1.00
			Muslim	−0.500	1.00
			None	−0.071	1.00
			Presbyterian	−0.500	1.00
			Protestant	−0.500	1.00
			7th-day adventist	0.500	1.00
		None	Catholic	−0.610	1.00
			Christian	0.171	1.00
			Church of Jesus Christ of Latter-day Saints	0.071	1.00
			Jehovah's Witness	−0.429	1.00
			Lutheran	−0.429	1.00
			Muslim	−0.429	1.00
			Nondenominational	0.0714	1.00
			Presbyterian	−0.429	1.00
			Protestant	−0.429	1.00
			7th-day adventist	0.5714	1.00
		Presbyterian	Catholic	−0.182	1.00
			Christian	0.600	1.00
			Church of Jesus Christ of Latter-day Saints	0.500	1.00
			Jehovah's Witness	0	1.00
			Lutheran	0	1.00
			Muslim	0	1.00
			Nondenominational	0.500	1.00
			None	0.429	1.00
			Protestant	0	1.00
			7th-day adventist	1.00	1.00
		Protestant	Catholic	−0.182	1.00
			Christian	0.600	1.00
			Church of Jesus Christ of Latter-day Saints	0.500	1.00

(Contd...)

Table 2: *(Continued).*

Outcome Measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
			Jehovah's Witness	0	1.00
			Lutheran	0	1.00
			Muslim	0	1.00
			Nondenominational	0.500	1.00
			None	0.429	1.00
			Presbyterian	0	1.00
			7th-day adventist	1.00	1.00
		7th-day adventist	Catholic	−1.182	1.00
			Christian	−0.400	1.00
			Church of Jesus Christ of Latter-day Saints	−0.500	1.00
			Jehovah's Witness	−1.00	1.00
			Lutheran	−1.00	1.00
			Muslim	−1.00	1.00
			Nondenominational	−0.500	1.00
			None	−0.571	1.00
			Presbyterian	−1.00	1.00
			Protestant	−1.00	1.00
	Age	*	*	*	0.177
	BMI	*	*	*	0.678
	Length of stay	*	*	*	0.833

HY: Hoehn and Yahr, BMI: Body mass index, MD: Mean difference,*is placeholder for blank/empty space in table

Table 3: Differences in deep brain stimulation outcomes based on patient demographics and anthropometrics.

Outcome measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
Preop-HY and 6 month-HY difference	Sex	Male	Female	−0.084	0.687
		Female	Male	0.084	0.725
	Language	English	Spanish	0.342	0.334
		Spanish	English	−0.342	0.200
	Insurance Status	Public	Private	0.069	0.714
		Private	Public	−0.069	0.715
	Race/Ethnicity	White	Hispanic	−0.134	0.866
			Asian	0.081	0.990
		Hispanic	White	0.134	0.866
			Asian	0.214	0.935
		Asian	White	−0.081	0.990
			Hispanic	−0.214	0.935
	Marital Status	Married	Divorced	−1.345	0.209
			Widowed	0.155	1.00
			Single	0.489	1.00
			N/A	0.155	1.00
		Divorced	Married	1.345	0.209
			Widowed	1.500	0.210
			Single	1.833	0.055

(Contd...)

Table 3: *(Continued)*

Outcome measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
			N/A	1.500	0.568
		Widowed	Married	−0.155	1.00
			Divorced	−1.500	0.210
			Single	0.333	1.00
			N/A	0	1.00
		Single	Married	−0.489	1.00
			Divorced	−1.833	0.055
			Widowed	−0.333	1.00
			N/A	−0.333	1.00
		N/A	Married	−0.155	1.00
			Divorced	−1.500	0.568
			Widowed	0	1.00
			Single	0.333	1.00
	Religion	Catholic	Christian	0.691	1.00
			Lutheran	0.091	1.00
			Nondenominational	1.091	0.732
			None	0.758	1.00
			Presbyterian	0.091	1.00
			Protestant	0.291	1.00
			7th-day adventist	0.591	1.00
		Christian	Catholic	−0.691	1.00
			Lutheran	−0.600	1.00
			Nondenominational	0.400	1.00
			None	0.067	1.00
			Presbyterian	−0.600	1.00
			Protestant	−0.400	1.00
			7th-day adventist	−0.100	1.00
		Lutheran	Catholic	−0.091	1.00
			Christian	0.600	1.00
			Nondenominational	1.00	1.00
			None	0.667	1.00
			Presbyterian	0	1.00
			Protestant	0.200	1.00
			7th-day adventist	0.500	1.00
		Nondenominational	Catholic	−1.091	0.732
			Christian	−0.400	1.00
			Lutheran	−1.00	1.00
			None	−0.333	1.00
			Presbyterian	−1.00	1.00
			Protestant	−0.800	1.00
			7th-day adventist	−0.500	1.00
		None	Catholic	−0.758	1.00
			Christian	−0.067	1.00
			Lutheran	−0.667	1.00
			Nondenominational	0.333	1.00

(Contd...)

Table 3: *(Continued)*

Outcome measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
			Presbyterian	−0.667	1.00
			Protestant	−0.467	1.00
			7th-day adventist	−0.167	1.00
		Presbyterian	Catholic	−0.091	1.00
			Christian	0.600	1.00
			Lutheran	0	1.00
			Nondenominational	1.00	1.00
			None	0.667	1.00
			Protestant	0.200	1.00
			7th-day adventist	0.500	1.00
		Protestant	Catholic	−0.291	1.00
			Christian	0.400	1.00
			Lutheran	−0.200	1.00
			Nondenominational	0.800	1.00
			None	0.467	1.00
			Presbyterian	−0.200	1.00
			7th-day adventist	0.300	1.00
		7th-day adventist	Catholic	−0.591	1.00
			Christian	0.100	1.00
			Lutheran	−0.500	1.00
			Nondenominational	0.500	1.00
			None	0.167	1.00
			Presbyterian	−0.500	1.00
			Protestant	−0.300	1.00
	Age	*	*	*	0.076
	BMI	*	*	*	0.667
	Length of Stay	*	*	*	0.878

HY: Hoehn and Yahr, BMI: Body mass index, MD: Mean difference, *is placeholder for blank/empty space in table, N/A: Not available

outcomes and patient demographic and anthropometric variables.

Modalities of DBS

Table 4 showcases differences in outcomes based on the modality of DBS. Table 5 showcases differences in DBS outcomes based on manufacturer. Regarding the manufacturer of DBS lead, patients who utilized Abbott (St. Jude) had a significantly longer LOS of 2 days than those who used Medtronic and 1.85 days longer than patients who used Boston Scientific. No other statistically significant relationships were found between the modality of DBS and outcome measures.

DISCUSSION

Our study investigated the impact of sociodemographic factors and surgical modalities on DBS outcomes in PD, utilizing patient LOS and HY scores as outcome measures. When looking at DBS outcomes within a year, our study found no differences in most of our demographic variables, such as race, age, and insurance status. While the efficacy of DBS has been long established, many of our findings do differ from established research that has showcased how social determinants of health significantly impact neurosurgical outcomes, with younger PD patients tending to have better DBS outcomes.[11,12,15,17,29,44,50] Age has long been an important consideration for DBS candidacy, as aging is associated with declining cognitive status and comorbidities that can increase the risk for surgical complications and are related to a lack of access to DBS.[6,10,38,48] However, if postoperative complications of DBS are not associated with increasing age, perhaps its usage as a primary exclusion factor for DBS candidacy can be more deeply evaluated.[48] While proper consideration of all patient factors is essential for DBS candidacy, such findings highlight the importance of recognizing how bias and skewed perception of patient social history could hinder access to treatment and healthcare.

Table 4: Differences in Deep Brain Stimulation Outcomes Based on Surgical Modality.

Outcome measure	Variable type	Reference (R)	Comparison (C)	MD (R - C)	*P*-value
Preop-HY and 3 month-HY difference	Anesthesia	General	Local	0.059	0.744
		Local	General	−0.059	0.724
	Concurrent pulse generator implantation	Yes	No	−0.266	0.115
		No	Yes	0.266	0.119
	Location of implantation	STN	GPi	−0.196	0.490
		GPi	STN	0.196	0.407
	Type of lead	Conventional	Directional	−0.138	0.562
		Directional	Conventional	0.138	0.546
Preop-HY and 6 month-HY difference	Anesthesia	General	Local	0.042	0.841
		Local	General	−0.042	0.824
	Concurrent pulse generator implantation	Yes	No	−0.278	0.145
		No	Yes	0.278	0.145
	Location of implantation	STN	GPi	−0.275	0.358
		GPi	STN	0.275	0.264
	Type of lead	Conventional	Directional	−0.032	0.897
		Directional	Conventional	0.032	0.896

HY: Hoehn and Yahr, STN: Subthalamic Nucleus GPi: Globus pallidus internus, DBS: Deep brain stimulation, MD: Mean difference

Table 5: Differences in deep brain stimulation outcomes based on manufacturer of lead.

Outcome Measure	Reference (R)	Comparison (C)	MD (R - C)	*P*	95% confidence interval	
					Lower bound	Upper bound
Preop-HY and 3 month-HY difference	Medtronic	Boston Scientific	0.025	0.993	−0.497	0.546
		Abbott (St. Jude Medical)	0.069	0.965	−0.584	0.721
	Boston Scientific	Medtronic	−0.025	0.993	−0.546	0.497
		Abbott (St. Jude Medical)	0.044	0.988	−0.671	0.759
	Abbott (St. Jude Medical)	Medtronic	−0.069	0.965	−0.721	0.584
		Boston Scientific	−0.044	0.988	−0.759	0.671
Preop-HY and 6 month-HY difference	Medtronic	Boston Scientific	0.102	0.883	−0.418	0.621
		Abbott (St. Jude Medical)	0.354	0.389	−0.295	1.004
	Boston Scientific	Medtronic	−0.102	0.883	−0.621	0.418
		Abbott (St. Jude Medical)	0.253	0.667	−0.459	0.965
	Abbott (St. Jude Medical)	Medtronic	−0.354	0.389	−1.004	0.295
		Boston Scientific	−0.253	0.667	−0.965	0.459
Length of stay	Medtronic	Boston Scientific	−0.15	0.957	−1.48	1.18
		Abbott (St. Jude Medical)	−2.00	0.015	−3.66	−0.34
	Boston Scientific	Medtronic	0.15	0.957	−1.18	1.48
		Abbott (St. Jude Medical)	−1.85	0.047	-3.67	−0.02
	Abbott (St. Jude Medical)	Medtronic	2.00	0.015	0.34	3.66
		Boston Scientific	1.85	0.047	0.02	3.67

HY: Hoehn and Yahr, DBS: Deep brain stimulation, MD: Mean difference

In addition, while marital status has been found to impact surgical outcomes and postoperative functional recovery, few studies have looked at how relationship status affects DBS outcomes.[35] Our analysis found that divorced patients had a larger MD of HY scores between baseline and 3 months postoperative, showcasing greater improvement

compared to other marital groups. These results differ from established findings of how patients recovering from DBS greatly benefit from social support, as they must recover from surgery, take medications accurately and appropriately, regularly visit physicians, and adhere to a complex treatment plan.[3,21,28] However, research has showcased that even with substantial motor improvement, DBS can result in increased caregiver burden and marital dissatisfaction.[47] Despite the benefits of social support, significant role changes and increased familial burden due to the unique complexities of DBS could result in poorer outcomes in the early stages of recovery. While this relationship was not seen between preoperative and 6-month postoperative HY scores, our findings highlight the importance of adequate support and monitoring for patients and their families in the early recovery stages of DBS.

In terms of surgical modalities, the current literature has focused on variables such as anesthesia and implantation location, finding similar effectiveness for GA and LA as well as STN and GPi-DBS implantation in improving motor dysfunction.[5,9,30,51] This is supported by our lack of significant differences for most of our surgical modalities, such as anesthesia, implantation location, concurrent IPGs, and type of lead.[39] While directional leads do have advantages and disadvantages, our findings notably differ from the literature that determined how directional leads offer enhanced control and improved motor function and side-effect management.[20,24,25,40] In addition, DBS settings (i.e., amplitude, pulse width, frequency, and impedance), the activation of directional stimulation, and the use of individualized programs were not examined and could explain the lack of significant findings regarding directional leads. When looking at LEDD, our findings showcased a significant decrease between preoperative and 3-month ($P < 0.001$) LEDD, preoperative and 6-month ($P < 0.001$) LEDD, and 3-month and 6-month ($P = 0.001$) LEDD. While the literature has showcased that DBS can reduce LEDD by 21–65%, research has focused on more long-term effects, looking at changes in medication from 1 year to 15 years.[31,34,45] While the effect of our variables on LEDD was not considered, our findings showcase insight into the short-term efficacy of DBS on LEDD and further support the established improvement in the quality of life that DBS can offer.

This is the first study to investigate differences between DBS leads manufactured by Medtronic, Boston Scientific, and Abbott. However, currently, available options for leads and DBS systems also include companies such as Patient Is No. 1 alwayS (PINS) Medical and SceneRay.[26] Our results showcased that patients who utilized Abbott had a significantly longer LOS of 2 days than Medtronic and 1.85 days longer than Boston Scientific, but no differences were found in terms of HY scores and subsequent motor outcomes. As each manufacturer's DBS systems have unique attributes such as battery type, programming and software interfaces, and lead design, no recommendations can be made regarding different companies. The type and manufacturer of lead used for each patient are determined through a consideration of different medical indications, patient preferences, and familiarity with the programming platform by relevant movement disorder neurologists. Despite this, our findings warrant a more comprehensive approach to choosing appropriate DBS leads, considering patient comfort and preference as well as maximizing symptom improvement. Future research could spread awareness and education regarding specific nuances and differences between different available manufacturers to both patients and providers. The PD patient population is incredibly large and diverse, and as DBS technology continues to advance, it is essential that physicians consider a patient's individual and unique needs to determine which modality of DBS would be most beneficial.[49]

Limitations

This study investigated a comprehensive variety of DBS factors but is not without limitations, as seen with our usage of HY staging as one of our outcome measures. Despite the HY scale being one of the most widely utilized and referenced methods for staging PD severity, HY has been known to suffer from several limiting factors.[13,18] Such factors include ambiguity toward cognitive impairment and disability, as well as being heavily weighted toward motor aspects such as postural instability and mobility issues.[42] As behavioral and cognitive complications frequently occur during PD and after DBS, HY scores have been primarily superseded by the Unified PD Rating Scale (UPDRS) and revised UPDRS scale by the MDS, known as the MDS-UPDRS.[16,22] However, research has found that despite the focus on motor symptoms, HY staging was able to accurately reflect differences in all aspects of PD measured by the MDS-UPDRS, and MDS-UPDRS scores significantly increased with every HY stage.[42] The lack of differences in our HY scoring could reflect the similarity in motor outcomes for many of our variables. As such, future usage of HY staging, in conjunction with other validated methods of assessing PD, could better determine the comprehensive effect of different modalities of DBS in PD.

Furthermore, sample sizes between our compared groups were occasionally skewed, which could potentially limit the generalizability of our findings. Our patient population was not necessarily representative of larger demographics across the United States, notably lacking any African–American patients. Literature has showcased that demographic and socioeconomic-based disparities affect frequency and access to DBS, with white PD patients being 5 times more likely than

African–American PD patients to undergo DBS.[4,10,38] Finally, all data were collected from a single institution, resulting in a relatively small sample size of 59 patients. This potentially limits the accuracy and validity of our findings, notably for subgroup analysis. Controlling for these limitations, as well as increasing our sample size and study's statistical power, could also modulate the lack of significance of race and other modalities of DBS on outcome measures.

CONCLUSION

This study investigated the outcomes of different surgical modalities of DBS in PD patients, as well as the effects of patient sociodemographics, utilizing patient LOS and HY scores as outcome measures. The mean LOS was 2.36 days, the mean HY preoperative score was 3.17, the mean HY 3-month postoperative score was 2.83, and the mean HY 6-month postoperative score was 2.85. LEDD significantly decreased at both 3 and 6 months postoperatively. Divorced patients showcased significantly larger MDs between preoperative and 3-month postoperative HY scores compared to all other relationship groups. Patients who utilized Abbott (St. Jude) had a significantly longer LOS of 2 days than Medtronic and 1.85 days longer than Boston Scientific. No differences in HY scores were found regarding all other variables, including age, race, insurance status, gender, GA versus LA anesthesia, directional versus conventional leads, and lead manufacturer. This study makes no recommendations regarding different companies, but as DBS technology continues to advance, it is essential to consider which modality of DBS would be most beneficial for a growing and diversified patient base.

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