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Changes in deep brain stimulation surgeries between 2019 and 2020: A national inpatient sample analysis

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ABSTRACT

Background: Deep brain stimulation (DBS) surgery is a neurosurgical procedure that implants electrodes into the brain to treat a variety of neurological and psychiatric conditions. The COVID-19 pandemic resulted in significant disruptions in elective surgeries, but the impact on DBS surgeries remains largely unknown.
Methods: The National Inpatient Sample (NIS), an all-payors database of inpatient hospitalizations in the US, was queried for DBS implantation procedural codes in 2019 and 2020.
Results: There were a total of 7,625 hospitalizations (95% CI: 6,664 to 8,586) for the implantation of a DBS lead in the 2019 NIS, which reduced by 11.9% to 6,715 hospitalizations (95% CI: 5,872 to 7,558) in the 2020 NIS. Procedural numbers declined in March 2020, with a peak 92.7% decline in volume in April of 2020 relative to 2019. Case numbers for July through December 2020 were 96.1% of the 2019 volume. Overall patient demographics and primary discharge diagnoses for hospitalizations involving DBS implantation were similar in the two study years.
Conclusions: Surgical volume for DBS implantation reduced by 92.7% in April of 2020 relative to 2019, which is among the highest declines reported for any surgical procedure. While procedural volume increased in the second half of 2020, this did not make up for the reduction in procedures earlier in the year, highlighting the disruption in DBS surgeries in 2020.

1. Introduction

Deep brain stimulation (DBS) surgery is a neurosurgical procedure that implants electrodes into specific brain regions for the treatment of a range of neurologic and psychiatric indications, including Parkinson's disease,[1] essential tremor,[2] dystonia,[3] obsessive-compulsive disorder,[4] and epilepsy.[5–7] DBS surgeries are elective and improve patient quality of life. The early stages of the COVID-19 pandemic resulted in reductions in surgical volumes nationwide, with recommendations to eliminate elective cases.[8] This was linked to a 45% decline in elective surgeries in the early stages of the COVID-19 pandemic, with subsequent rebound in treatments to equal 2019 rates beginning in July 2020,[9] depending on the type of surgery.[10] For DBS cases, recommendations were made to postpone new implantations and programming of DBS systems but to replace implantable pulse generators, on a case-by-case basis, balancing battery status with patient tolerance to therapy interruption.[11] The magnitude of change in surgical volume for DBS during the pandemic, however, has not been explored. This study characterizes billing for DBS implantation in 2019 and 2020 using a nationally representative sample of discharges from hospitals in the United States (US).

2. Methods

2.1. Data source

This analysis utilized the 2019 and 2020 editions of the National Inpatient Sample (NIS), a database published by the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality. The NIS is an administrative claims dataset which includes data from all insurance sources (including Medicare, Medicaid, commercial

Abbreviations: DBS, deep brain stimulation; NIS, National Inpatient Sample; ICD-10, International Classification of Diseases-10; SPSS, Statistical Package for the Social Sciences.

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insurance, and self-pay patients), and samples non-federal hospitals in 49 states, covering 98% of the US population. Included in the dataset are inpatient hospitalizations in general hospitals. Structurally, the NIS stratifies hospitals (based on geographic region, urban vs. rural location, teaching status, bed size, and ownership) and then samples 20% of discharges within each stratum. The methodology allows for extrapolation from the sampled hospitalizations to provide national estimates, with associated sampling variances. The NIS provides demographic information, information about hospital length of stay and overall hospital charges (including charges for the DBS device itself), and codes for up to 40 discharge diagnoses and 25 procedures. After review of the specific database, this study was determined to be Not Human Subjects Research by the Mass General Brigham Institutional Review Board.

2.2. Selection of hospitalizations involving DBS

Hospitalizations involving DBS were identified based on the Procedure Coding System from the *International Statistical Classification of Diseases, Tenth Revision, Clinical Modification* (ICD-10-CM/PCS). DBS hospitalizations were defined as those including the ICD-10-PCS codes 00H03MZ (insertion of neurostimulator lead into brain, percutaneous approach) or 00HZ00MZ (insertion of neurostimulator lead into the brain, open approach). Hospitalizations involving patients of any age were included in the sample if the discharge diagnosis included a DBS procedural code.

2.3. Statistical analysis

All analyses were conducted on data weighted according to the appropriate NIS discharge weight to obtain nationwide estimates. As the NIS is a survey, all values come with an associated variance derived from the sampling methodology.[12,13] This variance is used to present sample uncertainty for the overall number of discharges, whereas weighted point estimates are reported for all subsequent analyses, as described previously.[14] Analyses were conducted using SPSS (version 29; IBM Software, Inc, Armonk, NY).

3. Results

In the 2019 NIS there were 7625 hospitalizations (95% CI: 6664 to 8586) for the implantation of a DBS lead. In 2020, this reduced by 11.9% to 6715 hospitalizations (95% CI: 5872 to 7558). Demographics for DBS recipients were similar in both years, with 60.3% males in 2019 and 60.8% in 2020. The median age of patients was 66 in 2019 and 65 in 2020 (Table 1). Most hospitalizations across the two years were paid by Medicare (57.6%–58.8%) followed by private insurance (30%–30.2%). The majority of patients were discharged home (87.9%–89.2%), and there were no deaths during this hospitalization. The average length of hospitalization was 1 day, and the median hospital charges were $105,987 in 2019 and $112,948 in 2020.

Monthly DBS implantations were similar in January 2019 and 2020, with 20% more procedures performed in February 2020 relative to the prior year. Procedural numbers declined in March 2020, with a peak 92.7% decline in volume in April of 2020 relative to 2019 (50 cases in April 2020 compared to 685 in 2019). There was an increase in case numbers beginning in June 2020, and case numbers for July through December 2020 were 96.1% of the 2019 volume (Fig. 1). Changes in DBS volume varied among regions of the US, with the New England area demonstrating a 6.9% increase in cases in 2020 relative to 2019. All other regions had fewer DBS hospitalizations in 2020, with the Middle Atlantic and Mountain regions each showing a decline of >22% (Fig. 2).

For both years, Parkinson's disease was the most common primary discharge diagnosis for DBS hospitalizations, representing 51.7% of 2019

Table 1
Demographics and treatment characteristics of hospitalizations involving DBS in 2019 and 2020.

	2019		2020	
	N	%	N	%
N (95% CI)	7625 (6664 to 8586)		6715 (5872 to 7558)	
Age (yrs)	66 (54–72)		65 (52–72)	
Sex				
Male	4595	60.3	4080	60.8
Female	3030	39.7	2635	39.2
Race				
White	6145	80.6	5560	82.8
Black	205	2.7	175	2.6
Hispanic	540	7.1	490	7.3
Asian or Pacific Islander	230	3.0	130	1.9
Native American	35	0.5	<11	<0.1
Other	210	2.8	150	2.2
Missing	260	3.4	200	3.0
Census Division of hospital				
New England	290	3.8	310	4.6
Middle Atlantic	995	13.0	775	11.5
East North Central	1065	14.0	920	13.7
West North Central	685	9.0	650	9.7
South Atlantic	1255	16.5	1230	18.3
East South Central	425	5.6	370	5.5
West South Central	765	10.0	620	9.2
Mountain	770	10.1	600	8.9
Pacific	1375	18.0	1240	18.5
Population of County of Residence				
Central metro county >1 million	2170	28.5	1830	27.3
Fringe metro county >1 million	1990	26.1	1710	25.5
Metro Area 250,000–999,999	1685	22.1	1445	21.5
Metro Area 50,000–249,000	665	8.7	665	9.9
Micropolitan	625	8.2	645	9.6
Non-core county	465	6.1	415	6.2
Primary Payor				
Medicare	4485	58.8	3870	57.6
Medicaid	480	6.3	460	6.9
Private Insurance	2290	30.0	2025	30.2
Self Pay	60	0.8	75	1.1
Other	305	4.0	275	4.1
Disposition of patient				
Discharged Home	6700	87.9	5990	89.2
Transfer to Short-term Hospital	15	0.2	10	0.1
Transfer to Other Facility Type	370	4.9	180	2.7
Home Health Care	540	7.1	535	8.0
Died During Hospitalization	0	0.0	0	0.0
Hospital Length of Stay, d (median, IQR)	1 (1–2)		1 (1–2)	
Total Charges (median, IQR)	$105,987 ($68,735 to $166,744)		$112,948 ($72,567 to $187,198)	

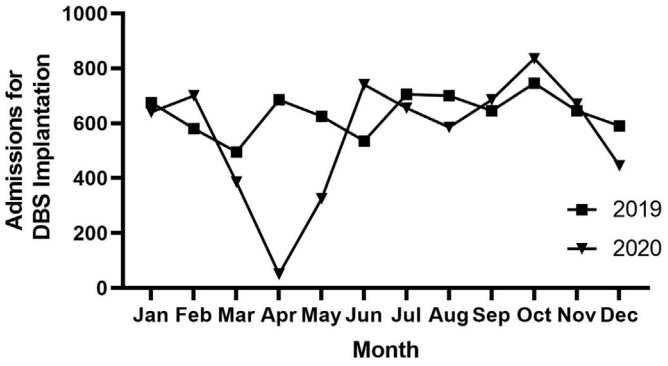

Fig. 1. Monthly hospitalizations involving DBS in 2019 (squares) and 2020 (triangles).

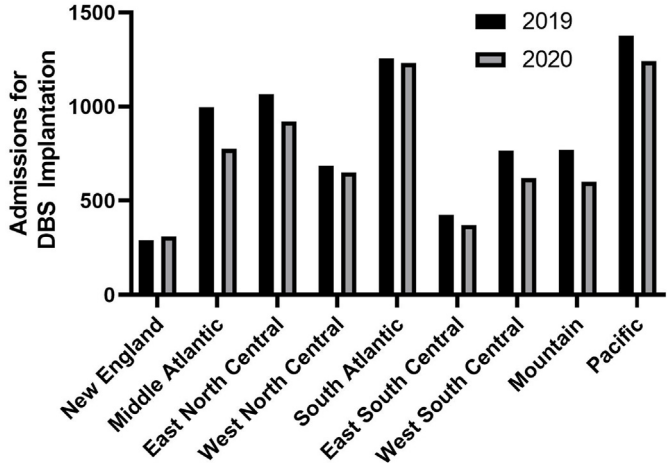

Fig. 2. Number of hospitalizations involving DBS in 2019 and 2020 for each region of the United States. Regions are defined as: New England (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut), Middle Atlantic (New York, Pennsylvania, New Jersey), East North Central (Wisconsin, Michigan, Illinois, Indiana, Ohio), West North Central (Missouri, North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa), South Atlantic (Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida), East South Central (Kentucky, Tennessee, Mississippi, Alabama), West South Central (Oklahoma, Texas, Arkansas, Louisiana), Mountain (Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico), and Pacific (Alaska, Washington, Oregon, California, Hawaii).

hospitalizations and 50.0% of 2020 hospitalizations. Essential tremor (25.6% in 2019 and 24.1% in 2020) and complex partial seizures (6.3% in 2019 and 6.4% in 2020) were the next most common diagnoses (Table 2).

4. Conclusions

Analysis of the 2019 and 2020 US NIS shows that the number of admissions for DBS lead placement declined in March, April, and May 2020 compared to 2019. The magnitude of reduction of surgeries in April 2020 (92.7%) is among the highest reported for elective procedures, exceeding even the 89% reduction in volume for cataract surgeries.[9] While surgical volume for DBS rebounded in the second half of 2020, this increase in cases did not make up for the decrease in cases earlier in the year. This may be in part because facilities were not offering admissions for these elective cases or potentially because patients were more willing to further optimize pharmacotherapy to mitigate the potential COVID risk related to an elective medical procedure. For example, DBS for Parkinson's disease is usually performed around 14–15 years after diagnosis,[15] and patients may decide that the risk of delaying the surgery due to COVID-19 pandemic may outweigh the benefits of contracting COVID prior to available vaccinations. However, there is emerging literature about the merits of earlier DBS implantation in this patient population,[16] and so the potential impacts of reduced DBS surgeries requires further investigation.

While the NIS does not allow for conclusive determination of causes of observed trends, as a speculative matter, the differences in observed procedural volume recovery between regions in the latter part of 2020 may be related to variable COVID-19 restrictions, hospital role-sharing, or differences in underlying patient populations. Likewise, the increase in volume in operations with primary epilepsy codes in 2020 could be related to increased adoption of DBS procedures for this indication following the 2018 FDA clearance of DBS devices for patients with focal epilepsy who have not achieved seizure control after trying three or more epilepsy medications; future years of NIS data may help clarify if this is indeed an increasing trend.

Strengths and limitations of this study both derive from its utilization of large-scale administrative claims data. As the NIS covers nearly all general hospitals in the US, it provides a comprehensive assessment of DBS implantation at these facilities, thereby avoiding limitations associated with single center or single payer-generated data. On the other hand, limitations of observational claims data are well-described.[17,18] Specifically, this data does not include ambulatory surgical facilities that may offer DBS implantation, or day surgeries that do not involve hospital admission. As DBS can be performed in these settings, we are unable to comment on the absolute number of procedures performed in 2019 and 2020. Furthermore there may be substation effects, with some patients choosing to have DBS procedures performed outpatient in 2020 in order to avoid hospitalization, which also would not be reflected in the NIS and may introduce bias into these results. Finally, the NIS tracks hospitalizations rather than individuals so if a patient was admitted for a staged implantation (i.e., electrodes placed in one brain hemisphere followed by the other at a later time point),[19] that patient may appear more than once in the database, and further cost breakdowns are not provided to parse out a one-stage or two-stages procedure.

In conclusion, using the 2019 and 2020 NIS database, the number of admissions for DBS lead placement declined significantly from March–May 2020 compared to the respective 2019 months, with one of the highest magnitude of reductions for surgeries in April 2020 (92.7%). For the remainder of the 2020 year, most parts of the country except the New England area continued to experience declines in admissions for DBS implantation.

Table 2
Principal discharge diagnoses for hospitalizations involving DBS implantation in 2019 and 2020.

		2019			2020		
Code	**Description**	**Rank**	**N**	**%**	**Rank**	**N**	**%**
G20	Parkinson's disease	1	3945	51.7	1	3355	50
G250	Essential tremor	2	1950	25.6	2	1615	24.1
G40219	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, intractable, without status epilepticus	3	480	6.3	3	430	6.4
G40119	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with simple partial seizures, intractable, without status epilepticus	4	185	2.4	5	165	2.5
G40919	Epilepsy, unspecified, intractable, without status epilepticus	5	165	2.2	4	215	3.2
G249	Dystonia, unspecified	6	80	1	7	80	1.2
G40019	Localization-related (focal) (partial) idiopathic epilepsy and epileptic syndromes with seizures of localized onset, intractable, without status epilepticus	7	75	1	6	95	1.4
G248	Other dystonia	8	60	0.8	11	35	0.5
G243	Spasmodic torticollis	9	60	0.8	8	65	1
G40211	Localization-related (focal) (partial) symptomatic epilepsy and epileptic syndromes with complex partial seizures, intractable, with status epilepticus	10	55	0.7	14	25	0.4

Statement of ethics

An ethics statement was not required for this study type, no human or animal subjects or materials were used.

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CRediT authorship contribution statement

Pratik Talati: Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **James Luccarelli:** Conceptualization, Data curation, Formal analysis, Software, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

JL has equity from Revival Therapeutics and PT has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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