RESEARCH ARTICLE

A Cost Analysis of Intraoperative Microelectrode Recording During Subthalamic Stimulation for Parkinson's Disease

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ABSTRACT: Deep brain stimulation of the subthalamic nucleus is the standard of care for treating medically intractable Parkinson's disease. Although the adjunct of microelectrode recording improves the targeting accuracy of subthalamic nucleus deep brain stimulation in comparison with image guidance alone, there has been no investigation of the financial cost of intraoperative microelectrode recording. This study was performed to address this issue. A comprehensive literature search of large subthalamic nucleus deep brain stimulation series (minimum, 75 patients) was performed, revealing a mean operating room time of 223.83 minutes for unilateral and 279.79 minutes for simultaneous bilateral implantation. The baseline operating room time was derived from the published operating room time for subthalamic nucleus deep brain stimulation without microelectrode recording. The total cost (operating room, anesthesia, neurosurgery) was then calculated based on hospitals geographically representative of the entire United States. The average cost for subthalamic nucleus deep brain stimulation implantation with microelectrode recording per patient is $26,764.79 for unilateral, $33,481.43 for simultaneous bilateral, and $53,529.58 for staged bilateral. For unilateral implantation, the cost of microelectrode recording is $19,461.75, increasing the total cost by 267%. For simultaneous bilateral implantation, microelectrode recording costs $20,535.98, increasing the total cost by 159%. For staged bilateral implantation, microelectrode recording costs $38,923.49, increasing the total cost by 267%. Microelectrode recording more than doubles the cost of subthalamic nucleus deep brain stimulation for Parkinson's disease and more than triples the cost for unilateral and staged bilateral procedures. The cost burden of microelectrode recording to subthalamic nucleus deep brain stimulation requires the clinical efficacy of microelectrode recording to be proven in a prospective evidence-based manner in order to curtail the potential for excessive financial burden to the health care system. © 2011 *Movement* Disorder Society

Key Words: microelectrode recording; deep brain stimulation; Parkinson's disease; operating room; subthalamic nucleus; neurosurgery

Deep brain stimulation (DBS) has become the standard of care for treatment of medically intractable Parkinson's Disease (PD).[1] In the majority of centers worldwide, the optimal usage of DBS for PD involves intraoperative microelectrode recording (MER), in which neurophysiology is used to guide the implantation of DBS electrodes to their optimal target within the subthalamic nucleus (STN) following initial image-guided electrode targeting.[2,3] Evidence has demonstrated that the adjunct of MER improves the targeting accuracy of STN DBS compared with image guidance alone.[4,5]

However, this increased accuracy comes at a price, as MER markedly lengthens the intraoperative time of the surgery and increases the risk of intracerebral hemorrhage, particularly in patients with advanced age, hypertension, transventricular electrode trajectories, and/or requiring a large number of microelectrode passes.[6–9] Despite more than 2 decades of literature examining STN DBS, there has been no investigation of the financial cost involved in the addition of intraoperative MER to the procedure. This study was performed to address this issue.

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TABLE 1. Literature review* of operating room time in microelectrode recording-guided subthalamic nucleus deep brain stimulation

Author, year of publication	Number of STN DBS patients (electrodes)	Mean OR time for unilateral STN DBS with MER (min)	Mean OR time for simultaneous bilateral STN DBS with MER (min)
Benabid et al, 2000	127 (253)	NR	NR
DBS for PD group, 2001	102 (198)	NR	NR
Lyons et al, 2004	81 (155)	NR	210
Pilitsis et al, 2005	96 (192)	NA	390
Goodman et al, 2006	100 (191)	190.59	239.37
Tir et al, 2007	103 (206)	NA	NR
Seijo et al, 2007	130 (254)	NR	NR
Vergani et al, 2010	140 (280)	NA	NR
Follett et al, 2010	147 (294)	NA	NR

*Minimum of 75 STN DBS patients required for inclusion. NR, not reported; NA, not applicable (procedure was not performed).

Materials and Methods

Determination of Average Operating Room Time for STN DBS With and Without MER Guidance

The estimated operating room (OR) time of unilateral and bilateral STN DBS involving MER was acquired from a literature search of the largest published STN DBS series (minimum of 75 patients) using the Entrez gateway of the PubMed database (http://www.ncbi.nlm.nih.gov/pubmed/), the results of which are shown in Table 1.[10–18] The search yielded 9 studies, of which only 1 included the mean intraoperative time per implanted electrode for both unilateral and simultaneous bilateral implantation (Table 1). Based on that study, in which the intraoperative time for MER-guided STN DBS was 190.59 minutes for unilateral implants and 239.37 minutes for simultaneous bilateral implantations, the procedure time for unilateral implantation was calculated as a function of the ratio between these 2 times, which was (190.59/239.37) = 0.80 × (simultaneous bilateral implantation time). The mean intraoperative time for bilateral STN DBS with MER in studies meeting the search criteria was ([210 + 390 + 239.37]/3) = 279.79 minutes,[12–14] and using the ratio between unilateral and simultaneous bilateral implantation, yielded a mean intraoperative time of 223.83 minutes for unilateral STN DBS with MER. The intraoperative time in these studies involved stage 1 (DBS electrode placement) only and was not inclusive of stage 2 (pulse generator implantation). Staged bilateral STN DBS implantation was defined as 2 unilateral STN DBS procedures, but unlike unilateral and simultaneous bilateral STN DBS procedures, involved 2 separate trips to the OR.

To approximate the intraoperative time of STN DBS performed without MER, a literature search was performed to find the published operative time of the procedure. Two studies involving bilateral STN DBS performed without MER revealed an average intraoperative time of 48.75 minutes per electrode implanted, yielding a total OR time of 97.5 minutes per bilateral STN DBS case.[19,20]

Determination of Time-Dependent Operating Room Costs for STN DBS

To augment the applicability of the operating cost calculations to the entire United States, the OR costs per minute for 1 academic hospital each from the East (Cornell Medical Center, New York, NY), Midwest (Ohio State University Medical Center, Columbus, OH), West (University of California at San Francisco Medical Center, San Francisco, CA), and South (Emory University Hospital, Atlanta, GA) were amalgamated to obtain an average value (Table 2A). OR and anesthesia costs were obtained through telephone inquiries with the billing departments of each hospital using current procedural terminology (CPT) codes 61867 (DBS with MER) and 61863 (DBS without MER). The total OR time cost for STN DBS was calculated by multiplying the geographically averaged cost by the previously calculated average OR time of STN DBS.

Total anesthesia cost was determined by multiplying the total number of anesthesia units for STN DBS by the cost per anesthesia unit. For CPT codes 61867 and 61863, the anesthesia base unit was 11 units, plus an additional unit for every 15 minutes of OR time. The total OR cost was then combined with the total

TABLE 2A. Time-dependent operating room cost estimate (staff, setup, nursing, and anesthesia) for CPT code 61867 in the United States

Geographic region	OR cost per minute	Cost per anesthesia unit[a]
East	$60.78	$150
Midwest	$131.44	$85
West	$119.44	$124
South	$90.71	$102
Average	$100.59	$115.25

[a]Each anesthesia unit represents 15 minutes of OR time.

TABLE 2B. Time-dependent operating room cost (staff, setup, nursing) for STN DBS electrode implantation in the United States

Procedure and total OR time (min)	OR cost of procedure	Time in OR due to MER (min)	OR cost attributable to MER	Proportion of OR cost due to MER	Increase of cost from baseline due to MER
Unilateral STN DBS (223.83)	$22,515.06	175.08	$17,611.30	78.2%	359.1%
Simultaneous bilateral STN DBS (279.79)	$28,144.08	182.29	$18,336.55	65.2%	187.0%
Staged bilateral STN DBS (447.66)	$45,030.12	350.16	$35,222.59	78.2%	359.1%

anesthesia cost to determine the cost of MER-guided STN DBS dependent on OR duration time.

Calculation of Time-Independent Costs (Neurosurgeon Reimbursement)

Surgeon reimbursement was calculated for STN DBS both with and without MER via relative value unit (RVU) and CPT codes using the CodeCorrect program (MedAssets, Inc., Alpharetta, GA). The CPT codes used for DBS were 61867 (with MER) and 61863 (without MER). Of the total RVUs per procedure, only the work RVUs were calculated for this study because (1) they are the least variable geographically across the United States and (2) they best represent the reimbursement to the surgeon and not to malpractice or transition facility practice expenses.

Results

Intraoperative Time of STN DBS Attributable to MER

The OR time of STN DBS with MER attributable to MER was estimated as the calculated time minus the estimated baseline time of the procedure without MER, as described in the Materials and Methods section. For unilateral STN DBS implantation, the OR time attributable to MER was (223.83 − 48.75) = 175.08 minutes (2.92 hours). For simultaneous bilateral STN DBS implantation, MER accounted for (279.79 − 97.5) = 182.29 minutes (3.04 hours). For staged bilateral STN DBS implantation, MER accounted for (223.83 − 48.75) × 2 = 350.16 minutes (5.84 hours).

Time-Dependent OR Costs

The cost of OR time (including initial setup charge, staff, use of room, and nursing) and cost per anesthesia unit are shown in Table 2A. Based on the previously calculated average OR time of STN DBS, the OR time cost of STN DBS is $22,515.06, $28,144.08, and $45,030.12 for unilateral, simultaneous bilateral, and staged bilateral STN DBS, respectively (Table 2B). Given the OR time attributable to MER, the OR cost of MER for STN DBS is $17,611.30, $18,336.55, and $35,222.59 for unilateral, simultaneous bilateral, and staged bilateral STN DBS, respectively, comprising 78.2%, 65.2%, and 78.2%, respectively, of the total OR costs of STN DBS (Table 2B).

The anesthesia cost of STN DBS is $2996.50, $3457.50, and $5993.00 for unilateral, simultaneous bilateral, and staged bilateral STN DBS, respectively (Table 2C). Based on the OR time attributable to MER, the anesthesia cost of MER for STN DBS is $1383.00, $1498.25, and $2766.00 for unilateral, simultaneous bilateral, and staged bilateral STN DBS, respectively, comprising 46.2%, 43.3%, and 46.2%, respectively, of the total anesthesia OR costs of STN DBS (Table 2C).

Time-Independent OR Costs

The neurosurgeon reimbursement for STN DBS both with and without MER is depicted in Table 3. For STN DBS with MER, 37.3% of the neurosurgeon reimbursement is attributable to the use of MER: $467.45 of the total $1253.23 reimbursement for unilateral STN DBS with MER, $701.18 of the total $1878.85 reimbursement for simultaneous bilateral STN DBS with MER, and $934.90 of the total $2506.46 reimbursement for staged bilateral STN DBS with MER (Table 3A,B).

TABLE 2C. Average time-dependent anesthesia cost for STN DBS electrode implantation in the United States

Procedure and total OR time (min)	Total anesthesia units[a]	Total anesthesia cost	Minutes in OR due to MER (anesthesia units)	Anesthesia cost from MER[b]	Proportion of anesthesia cost from MER	Increased anesthesia cost from baseline due to MER
Unilateral STN DBS (223.83)	26	$2996.50	175.08 (12)	$1383.00	46.2%	85.7%
Simultaneous bilateral STN DBS (279.79)	30	$3457.50	182.29 (13)	$1498.25	43.3%	76.5%
Staged bilateral STN DBS (447.66)	52	$5993.00	350.16 (24)	$2766.00	46.2%	85.7%

[a]For CPT codes 61867 and 61863, the anesthesia base unit is 11; for staged DBS, the base unit is multiplied by 2 because of the 2 separate OR visits.
[b]Secondary to the number of anesthesia units because of additional OR time secondary to MER.

TABLE 3A. Time-independent cost of neurosurgeon reimbursement in STN DBS* using maximum Medicare-allowable reimbursement from current procedural terminology (CPT) codes and relative value units (RVUs)

Procedure	CPT code	Work RVU	Work RVU reimbursement to neurosurgeon
Unilateral STN DBS with MER	61867	33.03	$1253.23
Unilateral STN DBS without MER	61863	20.71	$785.78
Simultaneous bilateral STN DBS with MER	61867 + modifier 50	49.55	$1879.85
Simultaneous bilateral STN DBS without MER	61863 + modifier 50	31.06	$1178.67
Staged bilateral STN DBS with MER	61867 + 61867	66.06	$2506.46
Staged bilateral STN DBS without MER	61863 + 61863	41.42	$1571.56

*Costs include electrode placement only and do not include pulse generator implantation.

Compared with STN DBS without MER, MER increases the cost of the neurosurgeon reimbursement portion of the procedure by 59.5%, whether the procedure is unilateral STN DBS, simultaneous bilateral STN DBS, or staged bilateral STN DBS (Table 3B). Regardless of inclusion or absence of MER, staged bilateral STN DBS increases reimbursement cost 33.3% compared with simultaneous bilateral STN DBS: by $392.89 without MER and by $626.61 with MER (Table 3A).

Total OR Costs

Total costs (time dependent + time independent), depicted in Table 4, are $26,764.79, $33,481.43, and $53,529.58 for unilateral, simultaneous bilateral, and staged bilateral STN DBS with MER, respectively. For unilateral procedures, 72.7% of the total cost is attributable to MER, and for bilateral procedures, MER accounts for 61.3% and 72.7% of the total cost for simultaneous and staged procedures, respectively (Table 4). MER increases total costs by 267% for unilateral, by 159% for simultaneous bilateral, and by 267% for staged bilateral STN DBS compared with STN DBS without MER (Table 4). Furthermore, staged bilateral STN DBS increases total cost by 60% compared with simultaneous bilateral STN DBS (Table 4).

Discussion

The advent of MER as an intraoperative adjunct to STN DBS has become the worldwide standard of care in the treatment of medically intractable PD, predominantly because of its ability to millimetrically improve on the accuracy of DBS electrode placement achieved by image guidance alone.[4] The trade-off for this improved accuracy lies in increased OR time and increased risk of intracerebral hemorrhage.[6] The discussion surrounding the benefits and drawbacks of MER to date has failed to include one important variable: the cost of the increased OR time that MER requires. To address this variable, the current study was performed, using OR time and cost estimates from the published literature.

The findings of this study indicate that the use of MER increases unilateral and simultaneous bilateral implantation STN DBS by 3 hours and increases staged bilateral implantation by 6 hours and increases the total cost of STN DBS by no less than 158%. Limitations of this study include its retrospective nature, the dearth of published reports of intraoperative OR time in STN

TABLE 3B. Proportion of STN DBS neurosurgeon cost attributable to MER

Procedure	Cost secondary to MER	Proportion of cost due to MER	Increase of cost from baseline due to MER
Unilateral STN DBS	$467.45	37.3%	59.5%
Simultaneous bilateral STN DBS	$701.18	37.3%	59.5%
Staged bilateral STN DBS	$934.90	37.3%	59.5%

TABLE 4. Total (time-dependent + time-independent) operating room STN DBS costs and costs attributable to MER

Procedure	Total cost (OR + anesthesia + neurosurgery)	Total cost secondary to MER	Proportion of total cost due to MER	Increase of total cost from baseline due to MER
Unilateral STN DBS	$26,764.79	$19,461.75	72.7%	266.5%
Simultaneous bilateral STN DBS	$33,481.43	$20,535.98	61.3%	158.6%
Staged bilateral STN DBS	$53,529.58	$38,923.49	72.7%	266.5%

DBS, the inability to account for the non-OR time associated with STN DBS independent of MER (ie, preoperative frame placement with trajectory planning), and the differences between hospitals in both OR costs and cost per anesthesia unit, which consequently result in the figures presented in this study being estimates rather than precise monetary values. Nevertheless, the findings from this study provide the first systematic analysis of the financial cost associated with intraoperative MER in STN DBS surgery.

Although the improved targeting accuracy of MER as an adjunct has been proven, whether this improvement outweighs the increased risk of intracerebral hemorrhage remains in question, particularly because the advent of intracerebral hemorrhage is not only costly to the patient (because of the increasing duration of hospitalization), but potentially life-threatening as well. Furthermore, there currently exists no evidence to support that the increased millimetric accuracy gained by MER correlates with improved patient outcomes following STN DBS, nor is there evidence that MER prevents suboptimal STN DBS placement.[19–28] Despite the theoretical consideration that MER may prevent misplacement and/or suboptimization of electrode targeting, this has yet to be demonstrated in the literature; on the contrary, evidence exists that MER does not prevent suboptimal placement of STN DBS electrodes, even though MER has been shown to millimetrically improve STN DBS electrode placement accuracy compared with image-guidance alone.[4,5,27]

Given the cost burden of MER in STN DBS, particularly in staged bilateral DBS implantation, clinically significant improvements in efficacy as a result of the increased millimetric accuracy achieved by MER need to be demonstrated through high-level evidence in order to justify the cost of MER for patients, hospitals, insurance carriers, and the federal government. If such improvement cannot be demonstrated, it may be wise for the government to alter surgeon reimbursement to incentivize STN DBS without MER (CPT code 61863), as opposed to the current financial structure, where MER (CPT code 61867) increases surgeon reimbursement by 60% (Table 3B).

Conclusions

MER more than triples the cost of STN DBS for PD in unilateral and staged bilateral procedures and more than doubles the cost for simultaneous bilateral procedures. Future discussions regarding the merits and drawbacks of MER necessitate inclusion of the OR, anesthesia, and surgeon costs per patient for MER and how these costs are affected by surgeon choice of MER as well as the choice of simultaneous versus staged bilateral electrode implantation. The cost burden of MER to STN DBS requires the clinical efficacy of MER to be proven in a prospective evidence-based manner in order to curtail the potential for excessive financial burden to the health care system. ■

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