

The treatment gap for deep brain stimulation in Parkinson's disease: a comparative analysis of cost and utilisation in high-income countries

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ABSTRACT

Objective. Parkinson's disease (PD) is one of the most prevalent neurodegenerative disorders, globally affecting approximately 120 per 100,000 people by age 70. Deep brain stimulation (DBS) is a US Federal Drug Administration (FDA)-approved and highly effective treatment for late-stage PD. However, country-specific reimbursement regulations and health policies may affect access to PD-DBS. We aimed to evaluate the uptake rate and 'treatment gap' for DBS across high-income countries. **Methods.** We reviewed previous literature to investigate the cost and utilisation of PD-DBS in high-income countries across Asia, Europe, Oceania, and North America (Australia, Canada, France, Germany, Hong Kong, Japan, Korea, the Netherlands, New Zealand, Norway, Spain, Switzerland, UK, and USA). Using previous estimates of DBS candidate eligibility rates, we calculated theoretical DBS uptake rates and treatment gaps nationally. **Results.** PD-DBS utilisation was highest in Australia and the USA and lowest in Korea and New Zealand. The total cost of PD-DBS in the first 12 months was highest in the USA and France and lowest in the UK and Germany. The utilisation rate (i.e. uptake rate) of PD-DBS (% DBS surgeries per PD case) was highest in Australia and the USA, and lowest in New Zealand and the UK, where the treatment gap reflected these trends. **Conclusions.** Our results highlight differences in access to DBS for PD patients among high-income countries, which we discuss in the context of health systems. Better access to effective PD treatments such as DBS is critical given the increasing prevalence of PD in an ageing world and the associated, avoidable morbidity.

Keywords: comparative analysis, cost, DBS, deep-brain stimulation, movement disorders, Parkinson's disease, treatment gap, utilisation.

Introduction

Parkinson's disease and deep brain stimulation

Parkinson's disease (PD) is one of the most prevalent neurodegenerative disorders, affecting approximately 120 per 100,000 people at 70 years in most Western societies.^{1,2} Due to population aging, the number of people affected is expected to double by 2031.³ Symptoms of PD begin, on average, at age 59 years and progressively worsen with age, significantly reducing quality of life.^{4,5} The pathophysiology of PD involves the degeneration and loss of dopaminergic neurons in the substantia nigra, characterised by Lewy body formation in dopaminergic neurons. These changes result in resting tremor, rigidity, postural instability, and bradykinesia.⁴ PD survival reduces by approximately 5% at each year of follow-up, where the mean duration until death ranges from 6.9 to 14.3 years.⁶ Current gold standard treatment of PD involves dopamine replacement therapies. However, over time these medications become ineffective, causing patients to develop involuntary muscle movements (dyskinesias) and motor fluctuations (on-off phases).^{3,7}

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Furthermore, dopaminergic medications are associated with side-effects including dyskinesias, nausea, sedation, orthostatic hypotension, and psychiatric symptoms such as hallucinations and compulsive behaviours, including pathological gambling.⁸

Surgical intervention may be offered when medications are ineffective in controlling PD symptoms. Deep brain stimulation (DBS) is a costly neurosurgical treatment offered to patients suffering from severe PD.⁹ PD-DBS involves delivering high-frequency stimulation via surgically implanted electrodes to subcortical regions of the brain, such as the subthalamic nucleus or globus pallidus internus,^{10,11} connected to an implanted pulse generator.¹⁰ DBS was first approved by the US Federal Drug Administration (FDA) for PD in 1997, but it has since been approved for related movement disorders, dystonia and essential tremor,¹² and treatment-resistant obsessive-compulsive disorder.¹³ More recently, it has been trialled as a treatment for eating disorders and severe depression.¹⁴ As of 2022, an estimated 208,000 DBS systems have been implanted to treat neurological or psychiatric conditions.¹⁵ However, the uptake of DBS varies widely across countries, likely affected by differences in DBS utilisation and cost across different health systems. We sought to analyse the differences in DBS uptake rates across several high-income countries, and considered how uptake rates might be influenced by healthcare regulations, reimbursement policies, and socioeconomic barriers to access.

Methods

Study design

Using a comparative analysis design, we reviewed previous literature to examine DBS cost and utilisation across high-income countries. Using this data, we calculated a DBS uptake rate and treatment gap for each country. High-income countries were defined according to Organisation for Economic Co-operation and Development (OECD) criteria. We also conducted exploratory analyses to examine the associations between DBS cost, DBS uptake, PD incidence, and health expenditure.

Literature search

Peer-reviewed literature was retrieved through a database search, including APAIS-health, Cochrane Library, EMBASE, Medline, OECD iLibrary, PsycINFO, PubMed, Scopus, Web of Science, and World Bank e-library. Grey literature was sourced from governmental websites and databases. Data for the utilisation of DBS in PD were retrieved using database searches (see Supplementary Table S2). The incidence of PD in each country (new cases/100,000 population/year) was retrieved from the University of Washington Global Burden of Disease Survey.¹⁶ Cost data were retrieved from the relevant health technology assessment (HTA) agency as listed by the

International Network of Agencies for Health Technology Assessment, public and private healthcare databases, as well as literature search (see Supplementary Tables S1 and S2).

Outcomes

Deep brain stimulation utilisation and treatment gap

Our main analysis estimated the uptake rate of PD-DBS as the percent of PD cases that receive DBS surgery (expressed as ‘% DBS surgeries/PD case’) and calculated the ‘treatment gap’ for DBS (cases/100,000 population/year), given by the case shortfall if 5% or 10% of all PD patients were eligible to utilise DBS. This eligibility rate was derived from conservative recent estimates which suggest that of the newly diagnosed PD patients every year, between 5% and 10% of PD patients will be eligible to receive DBS during the later stages of the disease.^{17–20} We use PD incidence as an outcome measure rather than prevalence, because prevalence would be further confounded by life expectancy post-diagnosis. For example, in countries where people live longer after a PD diagnosis without the use of DBS (e.g. due to earlier intervention or better pharmacological management) outcomes would appear poorer due to a lower rate of DBS usage. As an exploratory outcome, we examined Pearson’s correlations between utilisation of DBS and PD incidence, and DBS uptake and national healthcare expenditure.

Deep brain stimulation cost

In order to draw accurate comparisons of costs in different countries at different time points, we followed the recommendations of Turner *et al.* (2019).²¹ Here, each country’s respective cost figures were first converted to USD, and then adjusted for inflation to 2022 US national purchasing power parity. Cost data was not collected prior to 2000. Where multiple sources provided data for the same country, the most recent figure was reported. The costs of DBS hardware and total cost over 12 months were summarised from the available literature. Where possible, costs were summarised from either the payer (e.g. patient, insurance) or provider (e.g. hospital) perspective.

Costs for DBS were summarised according to the following

- Hardware costs:
 - DBS electrode leads
 - DBS extensions
 - Therapy access controller/patient controller unit
 - Dual or single-channel implantable pulse generator.
- Reported total costs over 12 months:
 - Hardware and implantation costs, as well as follow-up visits up to 12 months (including DBS-associated hospitalisations).

Finally, as an exploratory analysis we used Pearson’s correlations to examine the association between DBS cost and DBS uptake rate.

Ethics

In this study, data was acquired only through literature review and therefore ethical approval was not obtained.

Results

Utilisation and uptake rate

Utilisation data were available for nine countries. The utilisation of DBS for PD was between 1 case/100,000/year

(Norway, Switzerland, and Canada) and 1.4 cases/100,000/year (Australia), with substantially lower rates in South Korea (0.3 case/100,000/year), New Zealand (0.3 case/100,000/year), and the UK (0.45 case/100,000/year) (Fig. 1b). The median value for utilisation of DBS was 1 case/100,000/year.

The uptake rate of PD-DBS (% DBS surgeries/PD cases) varied between 1.22% of patients (New Zealand) and 5.87% of patients (USA), with a median of 3.81%. All countries were below the 10% eligibility estimate, with only the USA and Australia (5.79%) above the 5% estimate (Fig. 1c).

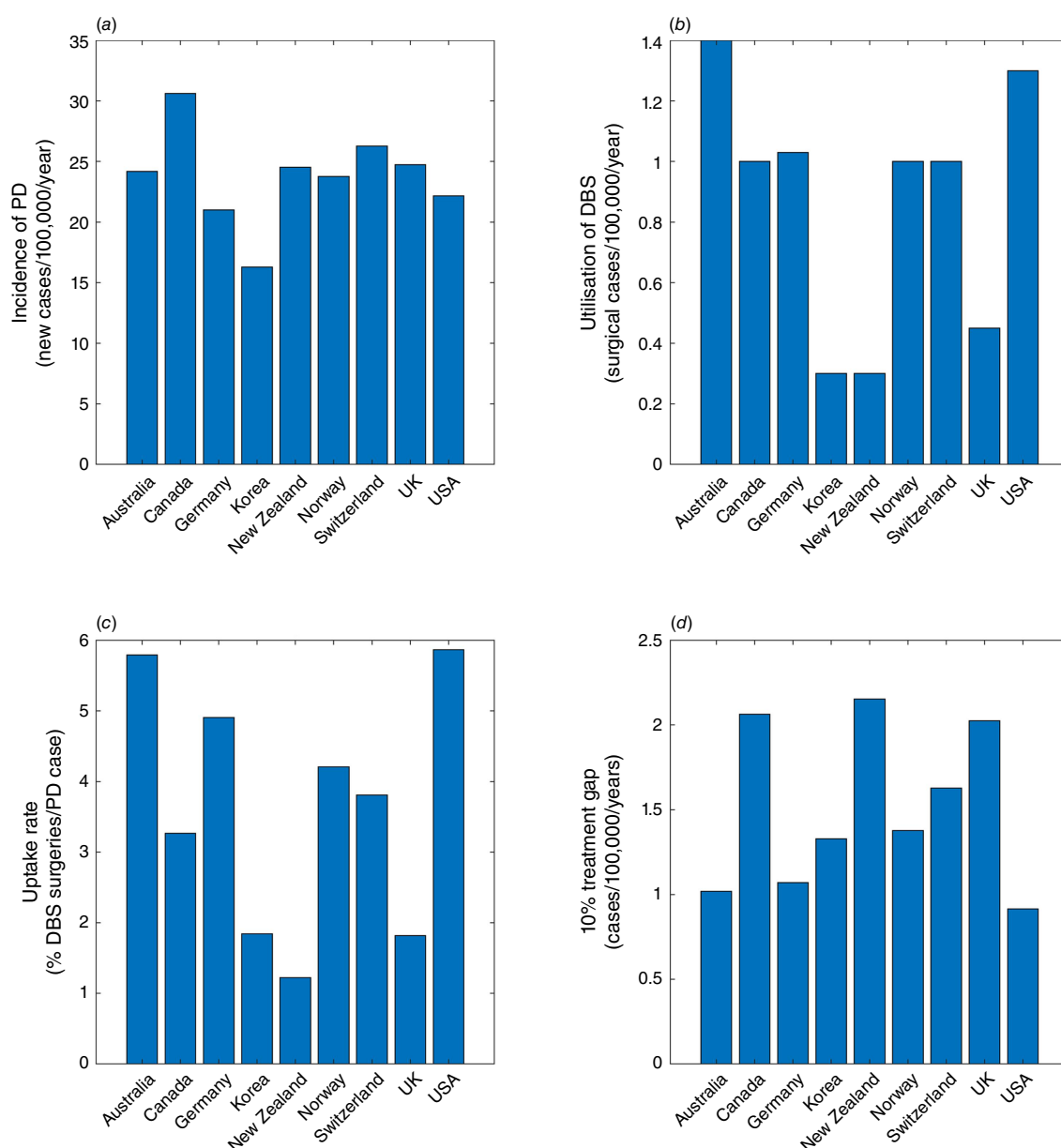


Fig. 1. Summary data of the utilisation of deep brain stimulation (DBS) for Parkinson's disease (PD) in nine high-income countries. (a) Incidence of PD. (b) Utilisation of DBS. (c) Uptake rate of DBS for PD. (d) Treatment shortfall assuming a 10% eligibility rate.

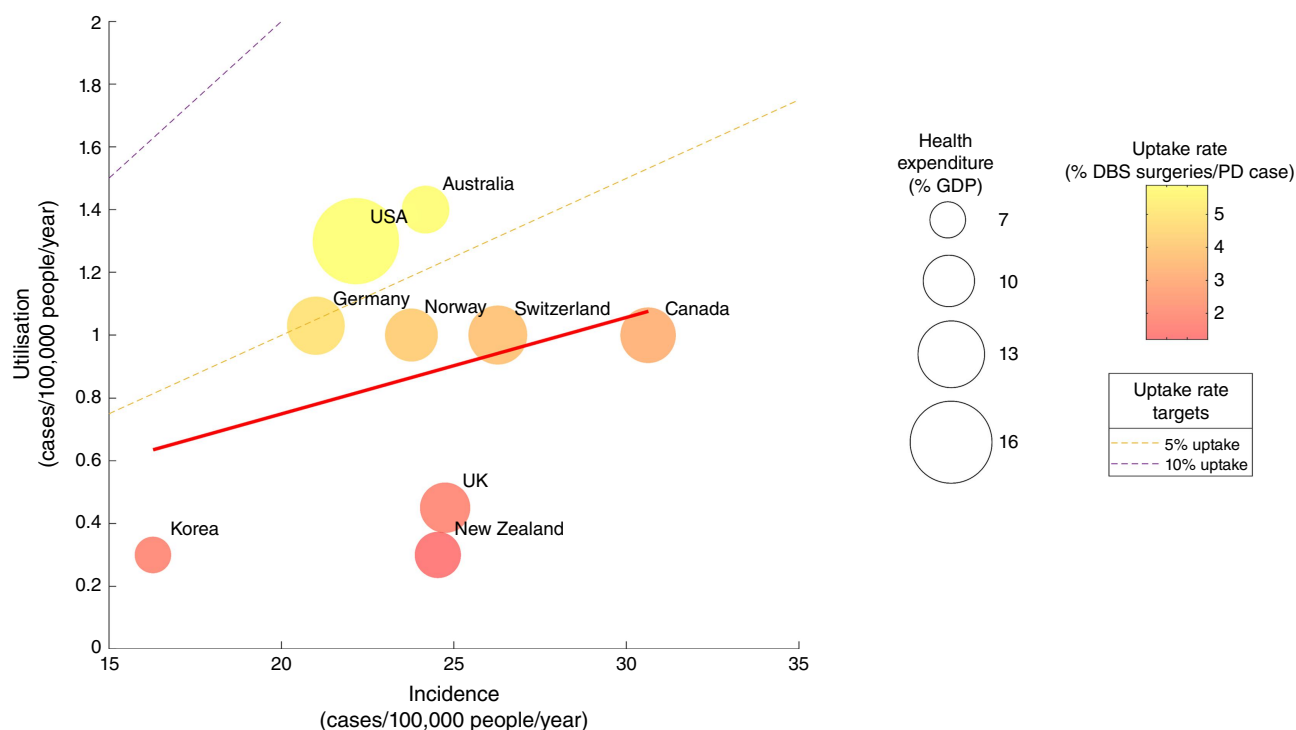


Fig. 2. The relationship between incidence of Parkinson's disease (PD) and utilisation of deep brain stimulation (DBS) in nine high-income countries. The solid line shows the mean trend across the nine countries ($r^2 = 0.08$, P -value non-significant). The colour and the size of each data point represents the uptake rate and total health expenditure (as percentage of GDP) in each country. The two dashed lines indicate the expected utilisation of DBS under the assumptions of 5% uptake rate (yellow) and 10% uptake rate (purple).

Assuming 10% patient eligibility for DBS, treatment gaps in DBS for PD were found across all countries analysed (Fig. 1d). New Zealand was found to have the largest gap, at 2.15 patients/100,000/year, followed by Canada (2.06 patients/100,000/year) and closely by the UK (2.02 patients/100,000/year). The smallest treatment gaps were found in the USA and Australia, at 0.92 patients/100,000/year and 1.0 patients/100,000/year, respectively. The median treatment gap was 1.377 patients/100,000/year.

A comparison of the above features in addition to health expenditure in each country is also presented in Fig. 2 and Supplementary Fig. S1. These results suggest DBS utilisation has a small positive correlation with PD incidence ($r^2 = 0.09$) and a stronger relationship with national health-care expenditure ($r^2 = 0.38$).

Costs and expenditure

Cost data was available for 11 countries. DBS hardware was cheapest in the UK (\$9,718) and France (\$14,062). DBS hardware was most expensive in Australia (\$53,123) followed by Japan (\$32,195) and the USA (\$27,841). The median cost of DBS was \$21,462 (Fig. 3a).

In terms of total costs after 12 months, the USA had the highest total cost, at \$84,756, followed by France, at

\$59,716. The UK had the lowest total cost after 12 months, at \$14,846, followed by Germany at \$20,157. The median total cost after 12 months was \$37,060 (Fig. 3b).

Notably, the uptake rate of DBS for PD was positively correlated with the DBS hardware cost and total procedure costs. In countries where the hardware/surgical cost was greater, the proportion of patients utilising DBS was also greater (Fig. 4a, b). The treatment gap decreased as the costs increased (Supplementary Fig. S2). Countries with greater national healthcare expenditure (as a percentage of gross domestic product (GDP)) also showed higher uptake of DBS for PD (Fig. 5) and a smaller treatment gap (Supplementary Fig. S4). However, the relationship between health expenditure and DBS cost was unclear (Supplementary Fig. S4).

Parkinson's disease incidence

In most countries, incidence of PD varied between 21 patients/100,000/year (Germany) and 30.6 patients/100,000/year (Canada), with substantially lower rates in South Korea at 16.3 patients/100,000/year (Fig. 1a). Across the nine countries analysed, the median value of incidence of PD was 24.2 patients/100,000/year. PD incidence was positively correlated with health expenditure (Supplementary Fig. S1).

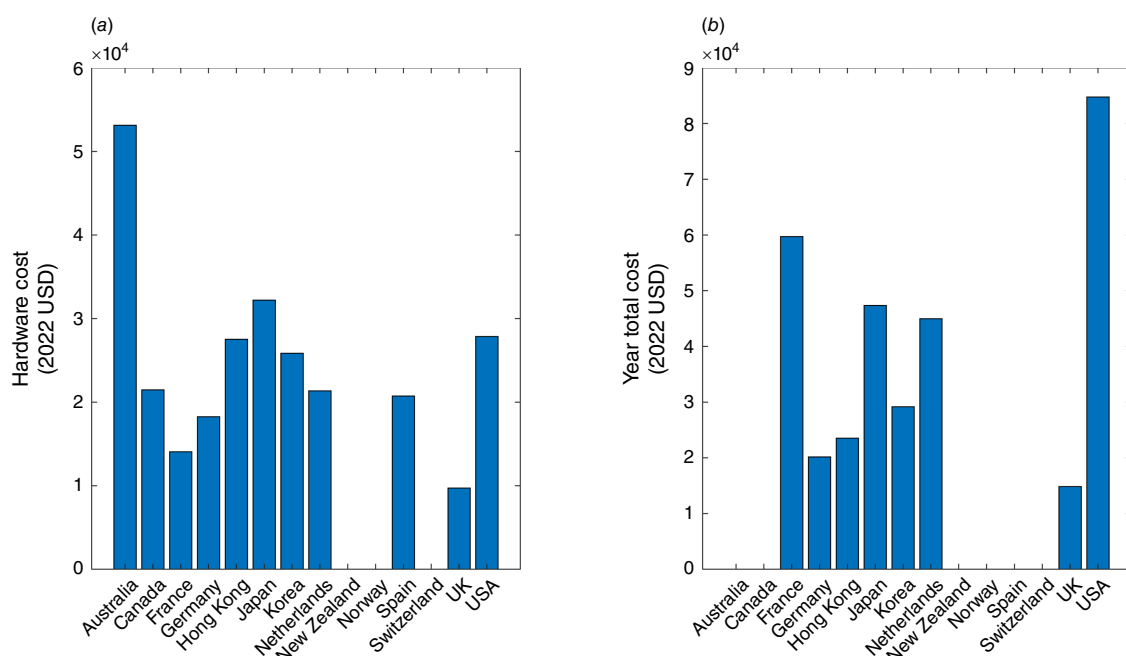


Fig. 3. Costs of Parkinson's disease deep brain stimulation (PD-DBS). (a) Cost of hardware for PD-DBS, adjusted to 2022 USD. (b) Total costs after 1 year, including peri- and post-operative costs (see Methods for details), adjusted to 2022 USD.

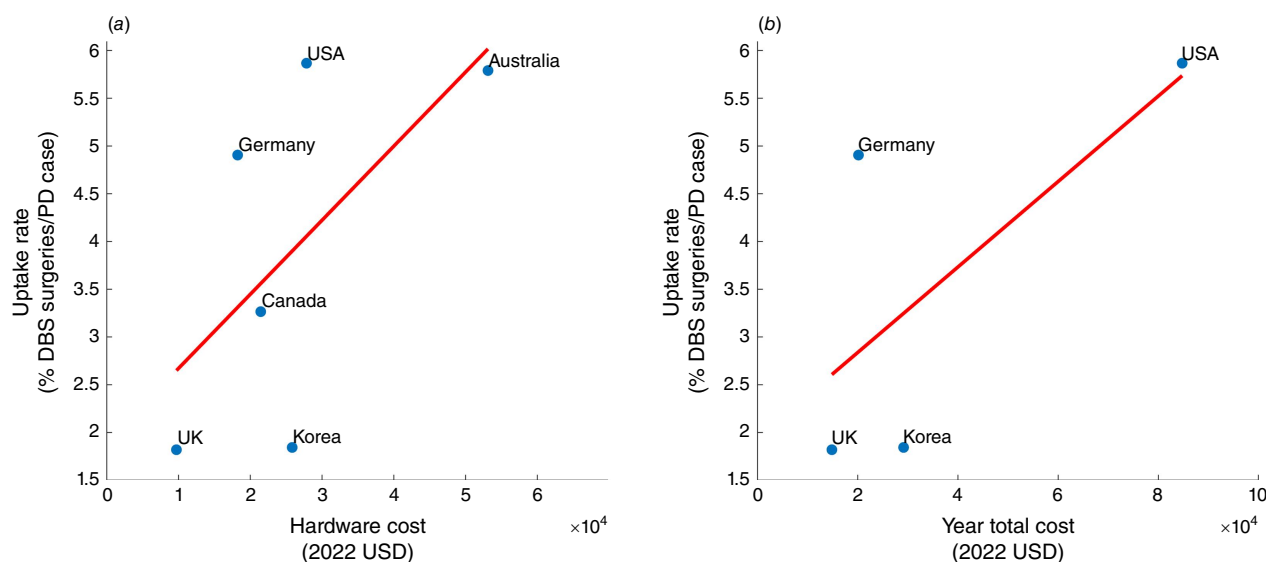


Fig. 4. Uptake of deep brain stimulation (DBS) is positively correlated with cost. (a) The relationship between uptake of DBS and cost of DBS hardware. The solid line shows the mean trend ($r^2 = 0.38$). (b) The relationship between uptake of DBS and total costs after 1 year ($r^2 = 0.48$, P -value non-significant).

Discussion

PD was the fastest-growing neurological disorder in terms of deaths and disability between 1990 and 2016,²² and currently affects more than 10 million people worldwide. Since its approval by the FDA in 1997, DBS has been used to treat over 200,000 patients.²³ However, despite increasing

commercialisation and procurement within healthcare systems, DBS remains an expensive intervention reserved for treatment-resistant PD patients. Specialist multi-disciplinary teams are necessary for the management of lengthy inpatient stays, battery replacements, and frequent pre- and post-surgical outpatient visits for device calibration and adjustment.^{24,25} We sought to identify differences in PD-DBS

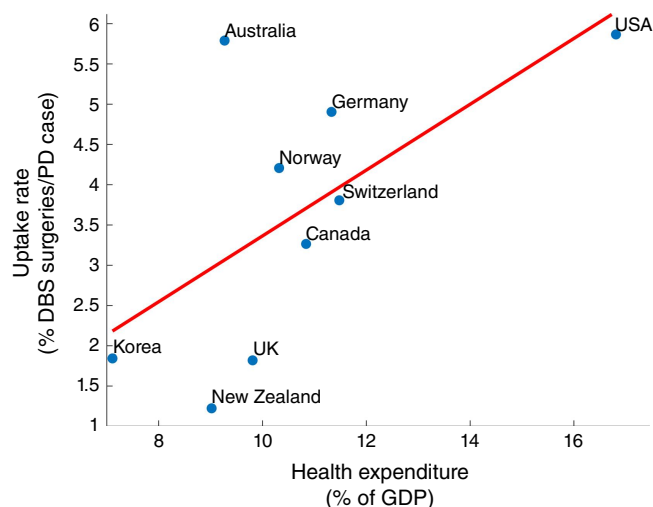


Fig. 5. Uptake of deep brain stimulation (DBS) is positively correlated with national healthcare expenditure. The solid line shows the mean trend across the nine countries ($r^2 = 0.40$, P -value non-significant).

uptake across several high-income countries. We then examined DBS cost and utilisation across countries as potential factors which may have affected the uptake rate of DBS. We discuss these findings below in the context of previous evidence related to PD incidence, health expenditure, and medical device regulation and reimbursement across countries.

Utilisation rises with Parkinson's disease incidence and health expenditure

The uptake rate of DBS was found to be higher in countries with a higher incidence of PD. This trend is expected as a higher PD incidence increases the number of patients eligible for DBS. A recent large epidemiological study found that PD incidence has increased significantly over the past two decades,²⁶ which is likely due to greater population aging, and may also potentially be due to environmental factors such as exposure to heavy metals and pesticides.^{27,28} With increasing life-expectancy and improvements in standards of care for chronic neurological diseases in high-income countries,²² it would be expected that countries with higher incidence of advanced PD (i.e. Canada, Switzerland, and Australia) would show higher DBS uptake.

We also found a small positive correlation between national health expenditure and DBS utilisation, although this was not significant. Although there are many complexities in the relationships between health spending and delivery, greater health expenditure is generally expected to be associated with greater population health.²⁹ It should be noted, however, that this association in our study was heavily skewed by the USA's high national health expenditure. Health delivery in the USA remains highly inequitable, with the USA ranking the lowest among OECD nations on the proportion of the population with health coverage.³⁰

Despite this, OECD data indicates a comparatively high number of specialists and higher overall utilisation of expensive medical technologies in the USA, which, in addition to the country's thriving medical research sector, may explain the high uptake rate of DBS.³¹ From a costs perspective, it is also reasonable to assume that patients in the USA may be subject to a greater number of costly investigations compared to other countries, further tipping the scales to more costly care in this system. Overall, international comparisons in healthcare expenditure are challenging due to differences in social, medical, cultural, demographic, and economic factors.

Theoretical deep brain stimulation uptake rates of 5 and 10% to estimate the treatment gap

We compared the theoretical utilisation of DBS (assuming 5% or 10% of PD patients are eligible for DBS^{17–20}), with the actual rates of DBS to calculate a 'treatment gap'. We found that all countries fell below the 10% theoretical uptake rate of DBS, and most fell below the 5% threshold, except for Australia and the USA. Patient eligibility for DBS is assessed based on strict criteria relating to severity of parkinsonian symptoms, neuropsychological evaluation, and the likelihood of benefit.³² Further, DBS surgery requires a multi-disciplinary team comprised of specially DBS-trained movement disorder neurologists, neurosurgeons, neuropsychologists, referring neurologists, primary care doctors, allied health clinicians, and nurses.³³ Specialist clinics are also limited to metropolitan regions. In 2015, South Korea had 22 specialist clinics performing DBS,³⁴ with only five performing more than 10 DBS surgeries yearly. Similarly, Norway had only three clinics in 2017, where the use of DBS varied widely across the country despite DBS becoming a national service in 2012.³⁵ Therefore, treatment gaps for DBS at least in part due to barriers of access to scarce DBS specialists and specialist clinics.

Differences in utilisation between countries with comparable health systems

One unexpected finding was the disparate utilisation rates between similar high-income countries, notably Australia and the UK. Among these similarities, Australia and the UK share similar PD incidence rates and national health expenditures and have a similar proportion of the population over 65 years.³⁶ Furthermore, both countries show similar regulation and marketing for DBS, and conducted their initial PD-DBS health technology assessments in the same year.³⁷ Finally, these countries use similar risk classification systems, and the European Conformity (CE) marking of DBS in 1998 was heavily influential in the Australian Therapeutic Goods Administration's decision to licence DBS in Australia.³⁸ Despite these similarities, utilisation of DBS in the UK falls far below that of Australia.

One key factor that might explain the difference in DBS utilisation between these countries is the share of the population with private health insurance. Both Australia and the UK offer universal healthcare, but over half of Australians also have private health insurance, and a third of Australia's health spending is funded by voluntary healthcare and out-of-pocket payments.^{39,40} In contrast, according to the OECD, private insurance coverage in the UK is below average.⁴⁰ The UK National Health Service has the lowest healthcare expenditure per capita relative to other OECD countries in the same income grouping. It has a considerably low number of practising medical specialists and low remuneration of clinical specialists compared to countries with similar economies.^{30,40} Therefore, the share of private health insurance in the population may drive differences in DBS utilisation in countries with similar economies, such as Australia and the UK.

Nevertheless, the Australian Medicare scheme has capped budgets for DBS based on diagnostic-related groups. Though PD-DBS utilisation is high relative to other countries in this analysis, we estimate over 85% of Australian patients who receive DBS are privately paying, as the procedure is only fully reimbursed for patients with private health insurance. Most patients who qualify for DBS are required to purchase premium health insurance and cover extensive out-of-pocket expenses, estimated between A\$7000 and A\$25,000 beyond what private health insurance covers.⁴¹ These substantial costs of top-tier insurance premiums and out-of-pocket expenses serve as a key barrier to access for those with advanced PD who lack the financial means, perpetuating significant disparities in treatment availability for lower and middle SES communities. Australia is not unique in this regard; inequitable access to DBS remains a key issue within high-income countries despite rising utilisation rates. A recent Australian HTA agency consultation acknowledged that increasing public reimbursement for DBS services may serve to reduce barriers to access to treatment for vulnerable populations and stimulate additional supply, increasing equity of treatment.⁴²

Limitations and future directions

Data for PD incidence, DBS utilisation, and DBS cost were unavailable for several countries and therefore our inferences are not generalisable to all high-income countries. Due to data availability constraints, our analysis focused narrowly on high-income countries, excluding low- and middle-income countries.⁴³ Furthermore, we were unable to separate cost and reimbursement data. Future investigations of DBS utilisation should further investigate this under-reported data, perhaps through direct survey of health data from clinics offering DBS. Finally, costs were retrieved from published literature, rather than manufacturer or health provider prices. While we adjusted prices for inflation, we were unable to account for changes in medical

neurotechnology over time, such as developments in DBS hardware, and competitive pricing among manufacturers.^{44–46} Further research incorporating up-to-date cost data and accounting for market dynamics is warranted to enhance the accuracy and relevance of future analyses.

Conclusion

We used a literature review and comparative analysis to evaluate the cost, utilisation, uptake rate, and treatment gap for PD-DBS in nine high-income countries. The most notable trends related to relationships were between: (1) PD-DBS uptake rate and PD incidence; (2) PD-DBS and health expenditure; and (3) PD-DBS uptake rate and treatment cost. These trends were discussed in the context of health system regulation and DBS eligibility rates. The uptake rate of PD-DBS (% DBS surgeries per PD case) was highest in Australia and the USA and lowest in New Zealand and the UK, and similarly, the treatment gap was smallest in Australia and the USA but highest in New Zealand, the UK, and Canada. There is a need for increased access to treatment for PD patients in many high-income countries. Identifying national treatment gaps compared to other countries with comparable wealth can be utilised to guide future national policy decisions and advocacy efforts by patient organisations and specialist societies. Given the rapid rise of PD incidence due to population ageing, equitable access to DBS is a crucial issue to manage.

Supplementary material

Supplementary material is available [online](#).

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Data availability. Data sharing is not applicable to cost and utilisation data, as no new data were generated. For DBS uptake rate and treatment gap analyses, data will be shared upon reasonable request to the corresponding author.

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