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The Japan Neurosurgical Database: Statistics Update 2018 and 2019

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Abstract

Each year, the Japan Neurosurgical Society (JNS) reports up-to-date statistics from the Japan Neurosurgical Database regarding case volume, patient demographics, and in-hospital outcomes of the overall cohort and neurosurgical subgroup according to the major classifications of main diagnosis. We hereby report patient demographics, in-hospital mortality, length of hospital stay, purpose of admission, number of medical management, direct surgery, endovascular treatment, and radiosurgery of the patients based on the major classifications and/or main diagnosis registered in 2018 and 2019 in the overall cohort (523283 and 571143 patients, respectively) and neurosurgical subgroup (177184 and 191595 patients, respectively). The patient demographics, disease severity, proportion of purpose of admission (e.g., operation, 33.9–33.5%) and emergent admission (68.4–67.8%), and in-hospital mortality (e.g., cerebrovascular diseases, 6.3–6.5%; brain tumor, 3.1–3%; and neurotrauma, 4.3%) in the overall cohort were comparable between 2018 and 2019. In total, 207783 and 225217 neurosurgical procedures were performed in the neurosurgical subgroup in 2018 and 2019, respectively, of which endovascular treatment comprised 19.1% and 20.3%, respectively. Neurosurgical management of chronic subdural hematoma (19.4–18.9%) and cerebral aneurysm (15.4–14.8%) was most common. Notably, the proportion of management of ischemic stroke/transient ischemic attack, including recombinant tissue plasminogen activator infusion and endovascular acute reperfusion therapy, increased from 7.5% in 2018 to 8.8% in 2019. The JNS statistical update represents a critical resource for the lay public, policy makers, media professionals, neurosurgeons, healthcare administrators, researchers, health advocates, and others seeking the best available data on neurosurgical practice.

Keywords: national database, neurosurgery, performance measure, quality of care, registry

Introduction

In response to an increasing interest in evidence-based medicine, improving the quality of patient care, patient safety, and neurosurgical training, the Japan Neurosurgical Society (JNS) established the Japan Neurosurgical Database (JND) in 2017, a prospective observational study registry.[1] Unlike the National Neurosurgery Quality and Outcomes Database in the US[2] and the Neurosurgical National Audit Program in the UK,[3] the JND registers all patients' clinical data primarily from the JNS training institutions. We previously reported the overview of the JND and results of the first-year 2018 survey (523283 cases), related to patient demographics and in-hospital outcomes in a nationwide, real-world situation. We found unique aspects of neurosurgical practice in Japan such as significant engagement not only in neurosurgical but also in non-neurosurgical patient care.[1]

Each year, the JNS reports the most up-to-date JND statistics related to caseload, patient demographics, and in-hospital outcomes of the overall cohort and a neurosurgical subgroup according to the major classification of main diagnosis. Additionally, they have reported the annual number of neurosurgical, endovascular, and radiosurgical procedures performed in 2018 and 2019 in the participating hospitals. The JND statistical update represents a critical resource for the lay public, policy makers, media professionals, neurosurgeons, healthcare administrators, researchers, health advocates, and others seeking the best available data on neurosurgical practice.[1] Herein, we report up-to-date JND statistics of procedures performed in 2018 and 2019.

Methods

Ethics statement

This study was approved by the research ethics committee of the JNS (2017009) and the Yamagata University Institutional Review Board (2017009R2-1), which waived the requirement for individual informed consent. Patients were provided with an opportunity to indicate whether they wanted to share their clinical information when they registered for care. Our study protocol followed the "opt-out" rule.

Data sources and collection

All hospitals belonging to the JNS training programs were asked to participate in the JND project. Additionally, other hospitals where JNS board-certified neurosurgeons are enrolled were permitted to participate in this project for the renewal of their board certification. The inclusion criteria and registration items of the JND have been reported previously.[1] Briefly, the database consists of multiple hierarchical levels. The first level contains basic clinical information such as data identification number, age, sex, postal code of home address, level of consciousness on admission as measured by the Japan Coma Scale, and route (e.g., emergency transportation) or mode (emergency or scheduled) of admission. The second level consists of the major classifications of the JND diseases, main diagnosis, and purposes of admission. The following are the seven major classifications: 1) cerebrovascular diseases, 2) brain tumor, 3) neurotrauma, 4) hydrocephalus/developmental anomalies, 5) functional neurosurgery, 6) spinal and peripheral nerve disorders, and 7) encephalitis/infection/inflammatory and miscellaneous diseases. The main diagnosis is selected from a list linked to the major classification, and up to three subsidiary diagnoses can be registered for each admission. The mode of operation is selected from a list of operations based on the relevant main or subsidiary diagnoses. Up to five operations can be registered for each diagnosis. The mode of operation is classified into types of interventions (e.g., direct surgery versus endovascular procedure, burr hole surgery, and craniotomy versus endoscopy). Clinical outcomes at discharge are measured by the modified Rankin Scale and/or Glasgow Outcome Scale (GOS; specifically for neurotrauma); in-hospital mortality, short-term functional outcome, length of hospital stay, and destination after discharge are registered. The data are fixed and summarized on a yearly basis (January 1 to December 31), and the chief neurosurgeons are responsible for the submission of patient clinical data within 3 months of discharge.

Annual case volume based on the major classification

The number of registered cases in 2019 in the overall cohort and neurosurgical subgroup was calculated based on the major classification of the main diagnosis as reported previously.[1] The neurosurgical subgroup consisted of patients who had undergone at least one neurosurgical procedure related to the main diagnosis. Patient demographics (age and sex), length of hospital stay, and in-hospital mortality were examined based on the main diagnosis of the overall cohort and neurosurgical subgroup, respectively.

Annual neurosurgical, endovascular, and radiosurgical case volume based on the main diagnosis

In this study, the number of registered neurosurgical, endovascular, and radiosurgical procedures performed in 2018 and 2019 in the participating hospitals was calculated based on the corresponding main and/or subsidiary diagnoses.

Statistical analysis

We described the number and proportion of registered patients in the overall cohort and neurosurgical subgroup based on the major classification of the main diagnosis. Age and length of hospital stay were described using mean ± standard deviation, and median and 25th to 75th quartile. P values <0.05 were judged to indicate statistical significance. All statistical analyses were performed with JMP software (version pro 13; SAS Institute, Cary, NC, USA).

Results

The number of the participating hospitals in the JND increased from 1373 in 2018 to 1497 in 2019. The number of registered patients in the JND increased from 523283 (414.8/100000 people/year) to 571423 (451.9/100000 people/year) in the overall cohort and 177184 (140.1/100000 people/year) to 191595 (151.9/100000 people/year) in the neurosurgical subgroup from 2018 to 2019 (Fig. 1).

Patient demographics and clinical outcomes based on the major classification of the main diagnosis in the overall cohort in 2019

The proportion of major classification for the overall cohort in 2019 (Table 1) was quite similar to that reported in the first-year survey. Briefly, cerebrovascular diseases comprised 53.9% of all cases, followed by neurotrauma, brain tumor, functional neurosurgery, spinal and peripheral nerve

disorders, encephalitis/infection/inflammatory and miscellaneous diseases, and hydrocephalus/developmental anomalies.

Patient demographics, length of hospital stay, and in-hospital mortality remained approximately the same as those observed in the first-year survey.

Males comprised the largest proportion in neurotrauma (63.4%), followed by spinal and peripheral nerve disorders (57.8%). For the remaining classifications, the proportion of males ranged between 50 and 55%. In-hospital mortality was highest for cerebrovascular diseases (6.3%), followed by neurotrauma (4.3%). The median length of hospital stay was longest for those with cerebrovascular diseases (range 8–16 days, for all major classifications).

Patient demographics and clinical outcomes based on the major classification of the main diagnosis in the neurosurgical subgroup in 2019

The proportion of major classification for the neurosurgical subgroup in 2019 (Table 2) were quite similar to those reported in the first-year survey. Cerebrovascular diseases comprised 41.7% of all cases, followed by neurotrauma, brain tumor, spinal and peripheral nerve disorders, hydrocephalus/developmental anomalies, functional neurosurgery, and encephalitis/infection/inflammatory and miscellaneous diseases. As with the overall cohort, patient demographics, length of hospital stay, and in-hospital mortality remained approximately the same as those observed in the first-year survey.

The proportion of males ranged from 47.0% in functional neurosurgery to 68.1% in neurotrauma. In-hospital mortality was the highest in cerebrovascular diseases (5.8%), followed by neurotrauma (3.4%), and the lowest in functional neurosurgery (0.1%). The median length of hospital stay was the longest for those with encephalitis/infection/inflammatory and miscellaneous diseases (range, 10–22 days for all major classifications).

Proportion of major classification of the overall cohort by age in 2019

When patients in the overall cohort were divided based on decades (age), patients aged 70–79 years comprised the largest proportion (28.7%), followed by those aged 80–89 years (23.2%) and 60–69 years (17.7%) (Fig. 1). Regarding the proportion of major classification of patients in each decade of the overall cohort, similar findings were observed in 2019 compared to those observed in 2018. Briefly, cerebrovascular diseases comprised more than 50% of patients of each decade aged ≥40 years, and neurotrauma classification showed bimodal peaks greater than 25% in patients of each decade aged 0–19 years and 80–100 years. The proportion of brain tumor was more than 10% in those of each decade aged between 0 and 69 years with a peak (19.7%) at 30–39 years. The proportion of hydrocephalus/developmental anomalies was 34.4% in patients aged 0–9 years and markedly decreased in patients aged >10 years. Functional neurosurgery peaked in patients who were aged 20–29 years (24.3%), followed by those aged 10–19 years and 30–39 years; spinal and peripheral nerve disorders remained approximately constant (4.1–7.6%) in those aged 10–89 years with a peak (7.6%) at 30–39 years.

Proportion of major classification of the neurosurgical subgroup by age group in 2019

In total, 191581 neurosurgical procedures were performed in 2019. When patients in the neurosurgical subgroup were divided into decades, patients aged 70–79 years comprised the largest proportion (30.4%), followed by those aged 80–89 years (20.9%)

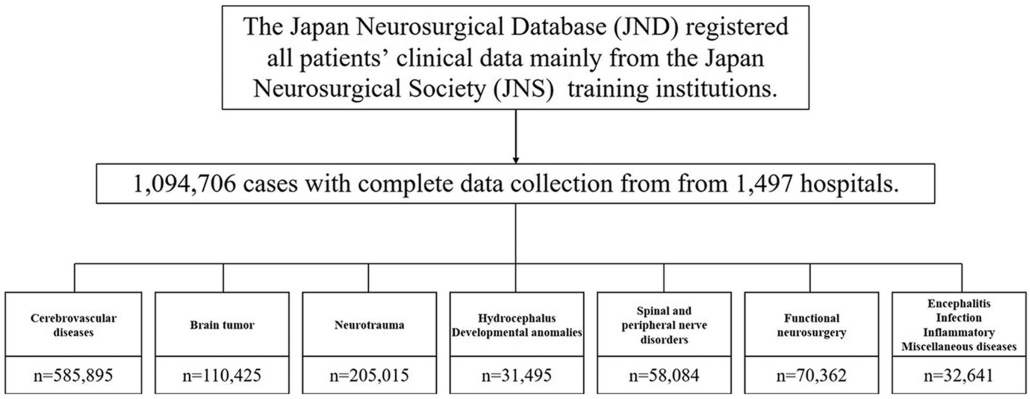

Fig. 1 The Japan Neurosurgical Database. Registered case volume in 2018 and 2019 based on the major classifications.

Table 1 Demographic data of the overall cohort in the JND in 2018 and 2019

Major classification	Calendar Year	Case volume		Age	Men (%)	In-hospital mortality (%)	Length of hospital stay
		no.	%	(mean ± SD)			(median ± IQR)
Cerebrovascular diseases	2019	308010	53.9	70.8 (15.0)	53.5	6.3	16 (7–31)
	2018	277885	53.1	70.5 (14.9)	53.7	6.5	16 (8–31)
Brain tumor	2019	56093	9.8	61.1 (18.1)	50.1	3.1	12 (3–25)
	2018	54332	10.4	60.9 (18.0)	50.5	3	12 (3–25)
Neurotrauma	2019	105268	18.4	70.8 (21.2)	63.4	4.3	9 (4-18)
	2018	99747	19.1	70.3 (21.2)	63.8	4.3	9 (4–18)
Hydrocephalus/ Developmental anomalies	2019	16564	2.9	56.7 (31.2)	53.5	1.1	12 (4–21)
	2018	14931	2.9	56.2 (31.0)	53	1.2	12 (5–23)
Spinal and peripheral nerve disorders	2019	31369	5.5	66.4 (16.6)	57.8	0.6	15 (9–24)
	2018	26715	5.1	66.4 (16.6)	57.9	0.5	15 (9–25)
Functional neurosurgery	2019	36841	6.4	60.5 (21.2)	53.3	1	8 (3–15)
	2018	33521	6.4	60.5 (21.2)	52.8	1.1	8 (4–16)
Encephalitis/Infection/ Inflammatory/ Miscellaneous diseases	2019	17278	3	64.8 (21.2)	50	3.8	8 (3–20)
	2018	15363	2.9	64.9 (20.0)	49.6	3.8	8 (3–20)

JND: Japan Neurosurgical Database, SD: standard deviation, IQR: interquartile range.

Table 2 Demographic data of the neurosurgical subgroup in the JND in 2018 and 2019

Major classification	Calendar year	Case volume		Age	Men (%)	In-hospital mortality (%)	Length of hospital stay
		no.	%	(mean ± SD)			(median ± IQR)
Cerebrovascular diseases	2019	79924	41.7	67.7 (15.1)	50.6	5.8	19 (10–37)
	2018	72607	41	67.1 (14.9)	50.5	6	20 (11–37)
Brain tumor	2019	23460	12.2	58.8 (18.2)	47.8	1.9	20 (14–36)
	2018	22641	12.8	58.6 (18.2)	48.3	1.8	20 (14–36)
Neurotrauma	2019	46904	24.5	76.4 (14.2)	68.1	3.4	10 (8–19)
	2018	45216	25.5	76.0 (14.3)	68.2	3.4	10 (8–19)
Hydrocephalus/ Developmental anomalies	2019	9926	5.2	56.0 (30.6)	52.3	1.4	16 (11–29)
	2018	9309	5.3	54.9 (30.7)	51.2	1.6	17 (12–30)
Spinal and peripheral nerve disorders	2019	21028	11	66.1 (15.4)	59.6	0.3	16 (11–25)
	2018	17969	10.1	66.0 (15.4)	59.6	0.3	16 (11–26)
Functional neurosurgery	2019	7295	3.8	54.8 (19.8)	47	0.1	12 (10–19)
	2018	6643	3.7	55.0 (19.7)	45.1	0.1	13 (10–19)
Encephalitis/Infection/ Inflammatory/ Miscellaneous diseases	2019	3058	1.6	60.8 (20.4)	54.8	2.6	22 (11–44)
	2018	2799	1.6	60.8 (19.8)	54.2	2.5	23 (12–44)

JND: Japan Neurosurgical Database, SD: standard deviation, IQR: interquartile range.

and 60–69 years (18.8%) (Fig. 2). Regarding the proportion of major classification of patients in each decade of the neurosurgical subgroup, similar findings were observed in 2019 as those observed in 2018. Compared to the overall cohort, a higher proportion of neurotrauma and a lower proportion of cerebrovascular diseases were observed in elderly patients (aged >80 years) in the neurosurgical

subgroup. A higher proportion of spinal and peripheral nerve disorders and a lower proportion of functional neurosurgery across a broad range of age were also observed in 2019.

Basic clinical information and patient management in 2018 and 2019

Basic clinical information of the registered patients of the overall cohort in 2018 and 2019 is shown in Table 3. In 2018, alert and Japan Coma Scale 1-, 2-, and 3-digit patients comprised 50.5%, 34.2%, 8.4%, and 6.7%, respectively, of all cases. The proportion of patients within the overall cohort in 2018 and 2019, measured using GCS, is also shown. Regarding the route of admission, direct admission from the patients' home comprised 83.1% of all cases, followed by transfer from another hospital or clinic. Emergency admission and transportation by ambulance were noted in 68.4% and 44.6% of all cases, respectively, in 2018. Home was the most common destination of discharge, followed by transfer to another hospital. Short-term functional outcomes measured by the modified Rankin Scale have also been included (Table 3). Similar results were obtained in the overall cohort in 2019.

The purpose of admission, diagnostic modalities/examination, and medical management are reported in Table 4. Computed tomography and magnetic resonance imaging were the most common diagnostic modalities, followed by catheter angiography and higher cognitive function tests. Medial management and diagnosis/investigation were the most common purposes of admission, followed by rehabilitation. Approximately one-third of the patients underwent operation for each admission. Adjuvant therapies such as radiotherapy and chemotherapy comprised less than 4% and 2% of all cases, respectively. Details of medical management based on the types of drugs and route of administration of chemotherapy have also been included (Table 4). Neurointensive treatment under monitoring was performed in approximately 6% of cases. The use of stereotactic radiotherapy, other radiotherapy, and other adjuvant therapy for brain tumors are reported in Table 4. Basic clinical information based on the major classifications is shown in Figs. 2–5.

Annual case volume of direct surgery, endovascular treatment, and other treatment based on the main diagnosis

The annual number of all admitted patients in the overall cohort and direct surgery and endovascular treatment based on the main diagnosis are reported for the seven major diagnoses. The proportion of specific direct surgery and endovascular treatment for each main diagnosis is shown in Tables 5–11. In 2018 and 2019, endovascular treatment comprised 19.1% and 20.3% of all neurosurgical procedures.

1) Cerebrovascular diseases

In the overall cohort, the most common main diagnoses, defined as those comprising more than 10%, were ischemic stroke/transient ischemic attack, cerebral aneurysm, and hypertensive intracerebral hemorrhage (45.8%, 18.8%, and 18.4%, respectively, in 2018).

In the neurosurgical subgroup, the total case volume of cerebrovascular diseases increased by 10.5% between 2018 and 2019, and the most common main diagnoses were cerebral aneurysm, ischemic stroke/transient ischemic attack, carotid stenosis, and hypertensive intracerebral hemorrhage (38.5%, 18.8%, 14.9%, and 11.3%, respectively, in 2018). Similar results were obtained in 2019. For cerebrovascular diseases, endovascular treatment was performed in 45.8% and 48% of all procedures in 2018 and 2019, respectively.

Regarding specific treatment (≥10 cases in 2018), there was a marked increase (≥20%) from 2018 to 2019 in the use of flow diverters for cerebral aneurysm, intravenous t-PA infusion and endovascular acute reperfusion therapy for ischemic stroke/transient ischemic attack, percutaneous angioplasty with stent for intracranial occlusive disease (other than moyamoya disease), cranioplasty for skull defect after external decompression, and trapping and combined bypass for cerebral arterial dissection. Contrastingly, percutaneous angioplasty without stenting and proximal artery clipping for cerebral artery dissection decreased by more than 20%.

2) Brain tumors

In the overall cohort, the most common main diagnoses were metastatic brain tumor, meningioma, and glioblastoma (31.2%, 18.7%, and 12.5%, respectively, in 2018).

In the neurosurgical subgroup, the total case volume of brain tumor increased by 3.6% between 2018 and 2019, and the most common main diagnoses were meningioma, metastatic brain tumor, pituitary adenoma, and glioblastoma (29.0%, 14.1%, 12.3%, and 10.8%, respectively, in 2018). Similar results were obtained in 2019. For brain tumors, endovascular treatment was performed in 5.9% and 6.2% of all procedures in 2018 and 2019, respectively. Regarding specific treatment (≥10 cases in 2018), there was a marked increase (≥20%) from 2018 to 2019 in extensive skull base tumor resection with reconstruction and decompressive craniectomy for meningioma, removal and extensive skull base tumor resection with reconstruction of pituitary adenoma, extensive skull base tumor

Table 3 Basic clinical information of the overall cohort in the JND in 2018 and 2019

Overall cohort	Case no.	%	Case no.	%
JCS on admission	**2018**		**2019**	
0. normal	264213	50.5	289406	50.6
1. Almost fully conscious	79518	15.2	86286	15.1
2. Unable to recognize time, place, and person	48201	9.2	53477	9.4
3. Unable to recall name or date of birth	51604	9.9	57137	10.0
10. Can be aroused easily by being spoken to	27713	5.3	30094	5.3
20. Can be aroused with a loud voice or shaking of shoulders	8543	1.6	8797	1.5
30. Can be aroused only by repeated mechanical stimuli	7494	1.4	7871	1.4
100. Responds with movements to avoid the stimulus	11316	2.2	12024	2.1
200. Responds with slight movements, including decerebrate and decorticate posture	13918	2.7	14329	2.5
300. Does not respond at all except for changes in respiratory rhythm	9842	1.9	10173	1.8
900. Unknown	921	0.2	1829	0.3
GCS (summed score; for the neurotrauma cases only)	**2018**		**2019**	
3	1480	2.1	1612	2.0
4	859	1.2	1026	1.3
5	481	0.7	541	0.7
6	1347	1.9	1427	1.8
7	1058	1.5	1104	1.4
8	906	1.3	941	1.2
9	1063	1.5	1142	1.4
10	1416	2.0	1555	1.9
11	1697	2.4	1801	2.2
12	2209	3.1	2453	3.0
13	4887	7.0	5240	6.5
14	16775	23.9	19367	24.0
15	34052	48.5	40588	50.2
Eye opening (E)	**2018**		**2019**	
4. Open spontaneously	54004	76.9	63520	78.6
3. Open to verbal command	7825	11.1	8388	10.4
2. Open to pain	1524	2.2	1602	2.0
1. No eye opening	5193	7.4	5699	7.1
Verbal response (V)	**2018**		**2019**	
5. Oriented	36544	52.0	43223	53.5
4. Confused	19256	27.4	22106	27.4
3. Inappropriate words	3752	5.3	4066	5.0
2. Incomprehensive sounds	2349	3.3	2515	3.1
1. No verbal response/1: Intubated (T)	6642	9.5	7206	8.9
Verbal response (V)	**2018**		**2019**	
6. Obeys commands	56475	80.4	65983	81.6
5. Localising pain	5881	8.4	6343	7.8
4. Withdrawal from pain	2843	4.0	3031	3.8

Table 3 (Continued)

Overall cohort	Case no.	%	Case no.	%
3. Flexion to pain	664	0.9	766	0.9
2. Extension to pain	972	1.4	1125	1.4
1. No motor response	1743	2.5	1919	2.4
Route of admission	**2018**		**2019**	
1. In-hospital referral from other department	13531	2.6	14667	2.6
2. Direct admission from patient home	434591	83.1	476736	83.4
3. Transfer from other hospital or clinic	46440	8.9	49159	8.6
4. Transfer from nursing home, welfare facility	24263	4.6	26968	4.7
5. In-hospital birth	195	0.0	216	0.0
6. Others	4263	0.8	3677	0.6
Scheduled/emergent admission	**2018**		**2019**	
Scheduled	165390	31.6	183822	32.2
Emergent admission	357893	68.4	387601	67.8
Ambulance use		**2018**	**2019**	
No	290089	55.4	318180	55.7
Yes	233194	44.6	253243	44.3
Destination of discharge	**2018**		**2019**	
1. In-hospital other department	20319	3.9	22919	4.0
2. Home	333169	63.7	361711	63.3
3. Transfer to other hospital	115249	22.0	126943	22.2
4. Geriatric health services facility	14836	2.8	16484	2.9
5. Nursing home other than hospitals	13482	2.6	15547	2.7
6. In-hospital death	25162	4.8	26878	4.7
7. Others	1066	0.2	941	0.2
mRS at discharge	**2018**		**2019**	
0. No symptoms	144947	27.7	154379	27.0
1. No significant disability. Able to carry out all usual activities, despite some symptoms	116821	22.3	128810	22.5
2. Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities	77996	14.9	83815	14.7
3. Moderate disability. Requires some help, but able to walk unassisted.	59199	11.3	65860	11.5
4. Moderately severe disability. Unable to attend to own bodily needs without assistance and unable to walk unassisted	62737	12.0	71028	12.4
5. Severe disability. Requires constant nursing care and attention, bedridden, incontinent	36245	6.9	40466	7.1
6. Dead	25338	4.8	27065	4.7
GOS at discharge	**2018**		**2019**	
1. Dead	3492	5.5	3897	5.2
2. Vegetative state	1194	1.9	1404	1.9
3. Severely disabled	13757	21.7	16672	22.5
4. Moderately disabled	7839	12.4	9975	13.4
5. Good recovery	35025	55.3	40264	54.2

JND: Japan Neurosurgical Database, GCS: Glasgow Outcome Scale, mRS: modified Rankin Scale.

Table 4 Purpose of admission, in-hospital diagnostic modalities, medical management, short-time clinical outcomes, and adjuvant therapies of the overall cohort in the JND in 2018 and 2019

	Case no.	%	Case no.	%
Overall cohort	523283		571423	
Purpose of admission		**2018**		**2019**
Diagnosis/Investigation	292239	55.8	356963	62.5
Education admission	1406	0.3	1165	0.2
Medical management	296842	56.7	341341	59.7
Operation	177184	33.9	191595	33.5
Chemotherapy	6851	1.3	7313	1.3
Radiotherapy	19302	3.7	19190	3.4
Rehabilitation	207005	39.6	260957	45.7
Terminal care	4899	0.9	5854	1.0
Other adjunctive therapy for brain tumor	176	0.0	151	0.0
Diagnostic modalities/examination		**2018**		**2019**
CT	219655	42.0	269530	47.2
MRI	190739	36.5	235538	41.2
EEG	12750	2.4	15697	2.7
Nuclear medicine (SPECT, PET)	11964	2.3	13759	2.4
Higher cognitive function test	37051	7.1	52612	9.2
Myelography	2626	0.5	3041	0.5
Catheter angiography and interpretation	57085	10.9	66026	11.6
Others	29953	5.7	44312	7.8
Medical management		**2018**		**2019**
Antiplatelet therapy	93881	17.9	111537	19.5
Anticoagulation therapy	48795	9.3	58994	10.3
Brain protective therapy (edaravone)	74327	14.2	84620	14.8
Anti-edema therapy (glycerol, mannitol)	41191	7.9	45288	7.9
Medical management of seizure and epilepsy	45402	8.7	52275	9.1
Medical management of headache	28972	5.5	36171	6.3
Neurointensive treatment under monitoring	31916	6.1	36858	6.5
Medical management of infection	16038	3.1	20414	3.6
Others	104560	20.0	133425	23.3
Chemotherapy		**2018**		**2019**
Oral	3295	0.6	3617	0.6
Intravenous	4509	0.9	4832	0.8
Intrathecal	119	0.0	129	0.0
Intracerebral	188	0.0	208	0.0
Intra-arterial	14	0.0	11	0.0
Others	30	0.0	31	0.0
SRS		**2018**		**2019**
Total	15759	3.0	15570	2.7
Cerebrovascular diseases	553		587	
Brain tumor	14870		14614	

Table 4 (Continued)

	Case no.	%	Case no.	%
Neurotrauma	4		6	
Hydrocephalus/Developmental anomalies	10		7	
Spinal and peripheral nerve disorders	70		74	
Functional neurosurgery	242		273	
Encephalitis/Infection/Inflammatory/Miscellaneous diseases	10		9	
Radiotherapy other than SRS	**2018**		**2019**	
Local	4412	0.8	4505	0.8
Whole brain	1416	0.3	1433	0.3
Whole spinal	67	0.0	102	0.0
Others (proton, heavy particle radiotherapy)	54	0.0	42	0.0
Other adjuvant therapy for brain tumors	**2018**		**2019**	
Immunotherapy	56	0.0	30	0.0
Optune	19	0.0	17	0.0

JND: Japan Neurosurgical Database, SRS: stereotactic radiosurgery, CT: computed tomography, MRI: magnetic resonance imaging, EEG: electroencephalogram, SPECT: single photon emission computed tomograph, PET: positron emission tomography.

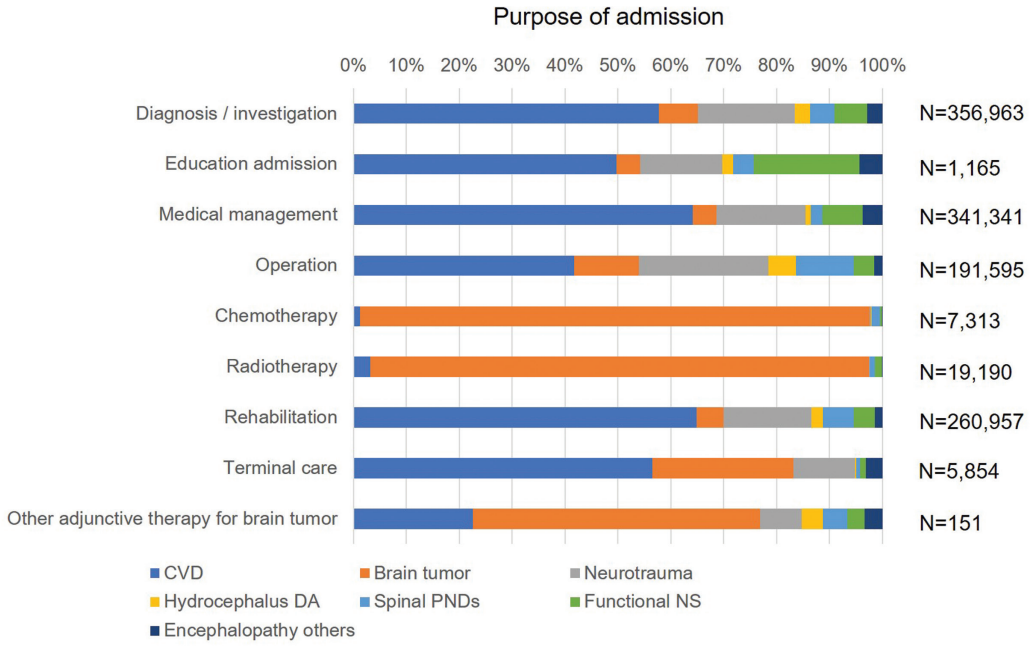

Fig. 2 The purpose of admission of the registered patients in 2018 and 2019. CVD: cerebrovascular diseases.

resection with reconstruction for other brain tumors, embolization of hemangioblastoma, removal of cystic lesion (other than dermoid, epidermoid, and arachnoid cyst), transnasal surgery and other treatment such as Ommaya reservoir placement for germ cell tumor and pineal tumor, removal and extensive skull base tumor resection with reconstruction of chordoma and chondrosarcoma, and cranioplasty for skull defect after external decompression. Contrastingly, biopsy of pituitary adenoma, schwannoma, craniopharyngioma, and intraorbital tumor; other treatments such as Ommaya reservoir placement for astrocytoma, oligodendroglioma, and cystic lesion (other than dermoid, epidermoid, and arachnoid cyst); tumor embolization for glioblastoma and other neuroepithelial tumor; and extensive skull base tumor resection with reconstruction for craniopharyngioma and dermoid and epidermoid decreased by more than 20%.

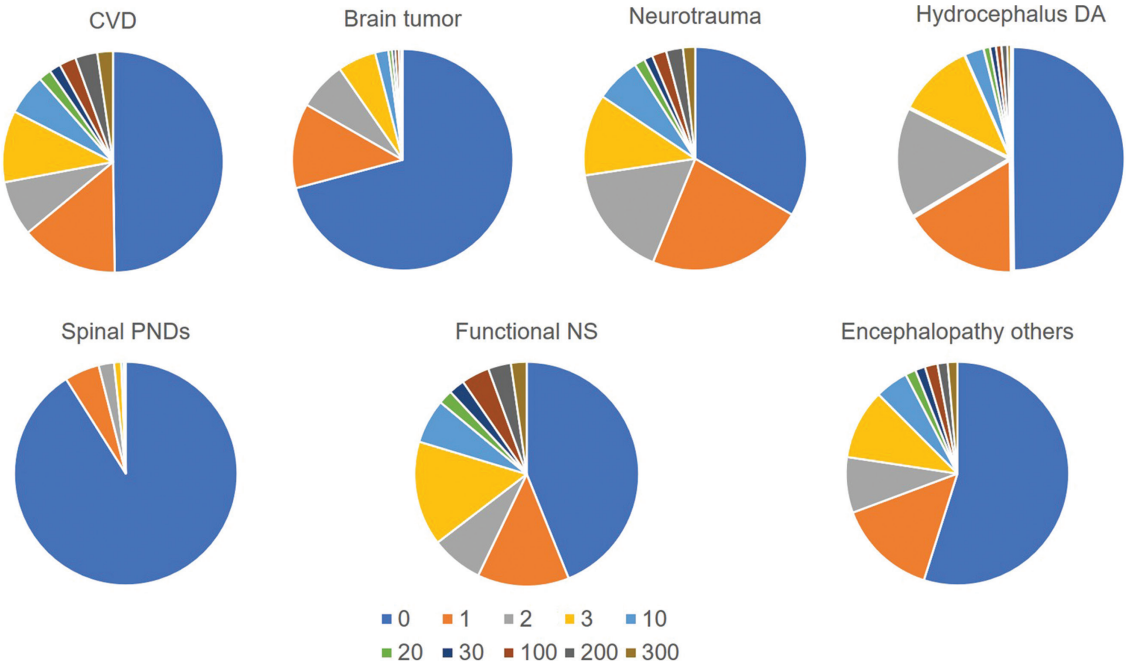

Fig. 3 Impaired level of consicousness on admission of the registered patients based on the major classifications in 2018 and 2019. CVD: cerebrovascular diseases, DA: developmental anomalies, PNDs: peripheral nerve disorders, NS: neurosurgery.

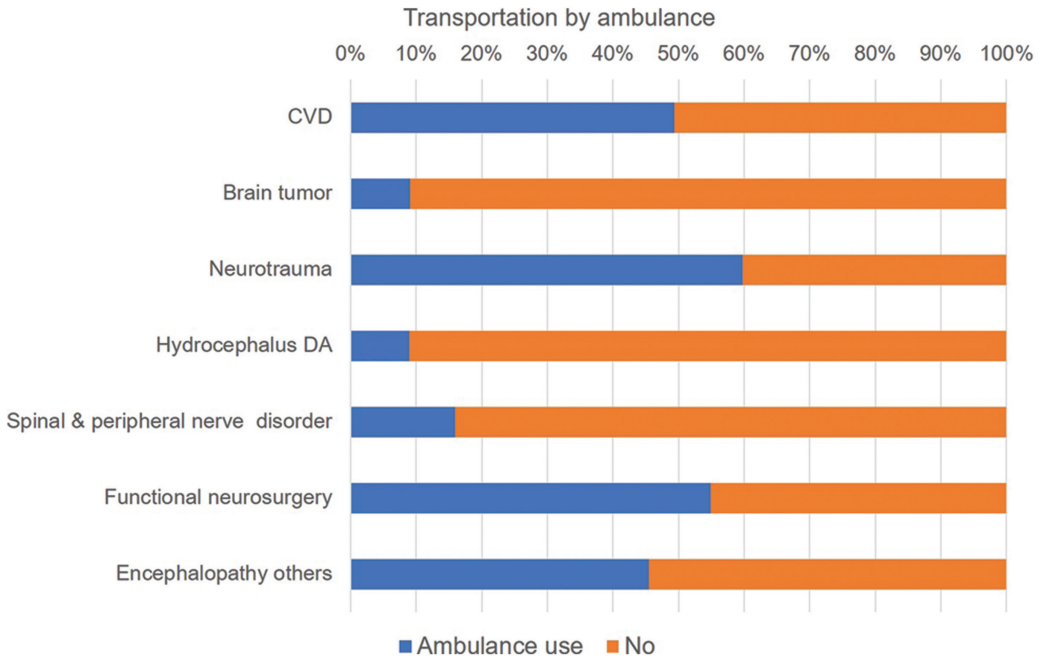

Fig. 4 The proportion of ambulance use based on the major classifications in 2018 and 2019. CVD: cerebrovascular diseases, DA: developmental anomalies.

3) Neurotrauma

In the overall cohort, the most common main diagnoses were traumatic intracranial hemorrhagic group and chronic subdural hematoma (CSDH; 39.6% and 38.4%, respectively, in 2018).

In the neurosurgical subgroup, the total case volume of neurotrauma increased by 3.7% between 2018 and 2019, and the most common main diagnoses were CSDH and traumatic intracranial hemorrhaging (80% and 14.6%, respectively, in 2018).

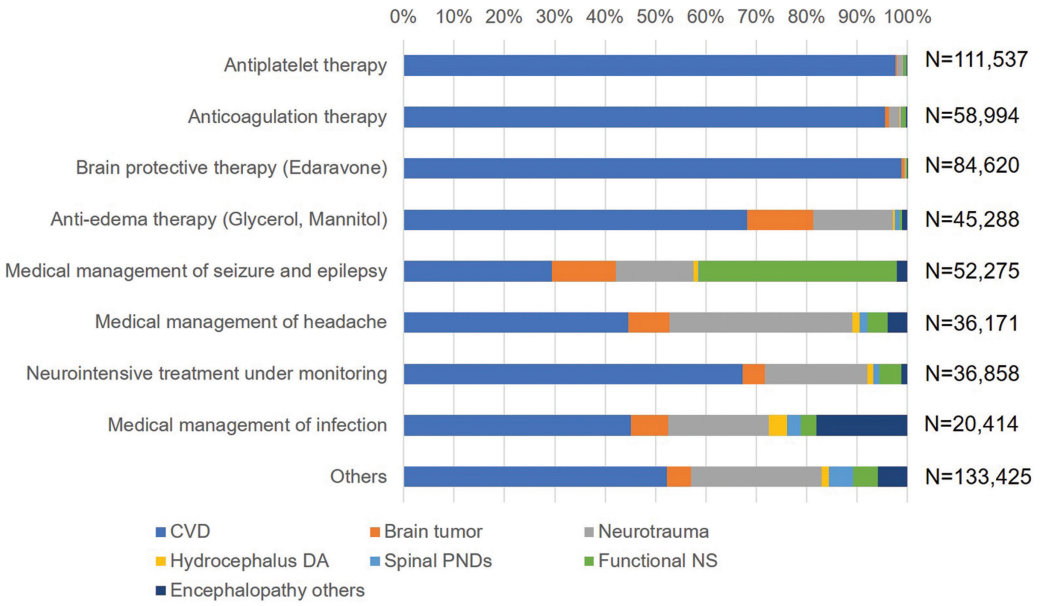

Fig. 5 Details of patient management in 2018 and 2019. CVD: cerebrovascular diseases, DA: developmental anomalies, PNDs: peripheral nerve disorders, NS: neurosurgery.

Similar results were obtained in 2019. Regarding neurotrauma, endovascular treatment was performed in 0.1% and 0.2% of all procedures in 2018 and 2019, respectively. Regarding specific treatment (≥10 cases in 2018), there was a marked increase (≥20%) from 2018 to 2019 in other treatments for CSDH (excluding burr hole and irrigation and removal of hematoma), endovascular treatment for traumatic cerebrovascular diseases, and optic nerve decompression for optic canal fracture.

4) Hydrocephalus and developmental anomalies

In the overall cohort, the most common main diagnoses were acquired hydrocephalus and idiopathic normal pressure hydrocephalus (47.0% and 35.1%, respectively, in 2018).

In the neurosurgical subgroup, the total case volume of hydrocephalus and developmental anomalies increased by 7.3% between 2018 and 2019, and the most common main diagnoses were acquired hydrocephalus and idiopathic normal pressure hydrocephalus (61.4% and 24.1%, respectively, in 2018). Similar results were obtained in 2019. Regarding specific treatment (≥10 cases in 2018), there was marked increase (≥20%) from 2018 to 2019 in ventriculoatrial shunt, shunt revision, third ventriculostomy, and other treatments for idiopathic normal pressure hydrocephalus, other treatments (e.g., removal of devices) for craniosynostosis, other treatments for other spinal cord/spinal anomaly and other cranial/cerebral anomaly, and other treatments for encephalocele. Contrastingly, the number of cases of lumboperitoneal shunt, ventriculoatrial shunt, ventricular drainage for congenital hydrocephalus, and foramen magnum decompression for Chiari malformation (Type II) decreased by more than 20% from 2018 to 2019.

5) Spinal and peripheral nerve disorders

In the overall cohort, the most common main diagnoses were spinal degenerative disorders and vertebral compression fracture caused by spinal trauma (56.3% and 11.8%, respectively, in 2018).

In the neurosurgical subgroup, the total case volume of spinal and peripheral nerve disorders increased by 16.7% from 2018 and 2019, and the most common main diagnoses were spinal degenerative disorders (67.1% of all cases in 2018). Similar results were obtained in 2019. Regarding spinal and peripheral nerve disorders, endovascular treatment was performed in 0.7% and 0.8% in 2018 and 2019, respectively. Regarding specific treatment (≥10 cases in 2018), there was a marked increase (≥20%) from 2018 to 2019 in posterior decompression and other treatments for spinal degenerative disorders; fixation and percutaneous vertebroplasty for vertebral compression fracture by spinal trauma; fixation for other spinal trauma; partial removal, biopsy, and other treatments for spinal intramedullary tumor; other treatment for spinal trauma without bone injury; total/subtotal and partial removal for spinal extramedullary tumor with extradural and paraspinal extension; endovascular obliteration of dural arteriovenous fistula and extradural arteriovenous fistula; removal and other treatments for spinal extradural hematoma; fixation and other treatments for spinal

Table 5 Case volume of DS and EVT for cerebrovascular diseases in the JND in 2018 and 2019

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/EVT case)	Case no.	% (in all admission)	% (in DS/EVT case)
2001. Cerebral aneurysm		**52292**			**56466**		
DS	Neck clipping	15426	29.5	48.3	15305	27.1	45.9
	For ruptured	7819			7551		
DS	Coating	388	0.7	1.2	362	0.6	1.1
	For ruptured	116			132		
DS	Parent artery proximal occlusion (parent artery clipping)	228	0.4	0.7	238	0.4	0.7
	For ruptured	111			113		
DS	Trapping	325	0.6	1.0	278	0.5	0.8
	For ruptured	228			182		
DS	Bypass (combined)	378	0.7	1.2	362	0.6	1.1
	For ruptured	186			158		
DS	Others	1028	2.0	3.2	1013	1.8	3.0
	For ruptured	922			917		
EVT	Coil embolization (w/o stent)	9794	18.7	30.7	10671	18.9	32.0
	For ruptured	5210			5653		
EVT	Coil embolization (with stent)	3496	6.7	11.0	4166	7.4	12.5
	For ruptured	724			820		
EVT	Flow diverter	423	0.8	1.3	543	1.0	1.6
	For ruptured	4			14		
EVT	Others	283	0.5	0.9	308	0.5	0.9
	For ruptured	205			227		
EVT	Endovascular therapy for cerebral vasospasm (ruptured cases only)	1178	2.3	3.7	1278	2.3	3.8
2012. Ischemic stroke/transient ischemic attack		**127361**			**144999**		
	Intravenous t-PA infusion	6832	5.4	43.9	8830	6.1	44.3
EVT	Acute reperfusion therapy	9740	7.6	62.5	12493	8.6	62.7
DS	Decompression craniectomy	1304	1.0	8.4	1456	1.0	7.3
	Others	769	0.6	4.9	748	0.5	3.8
2005. Carotid stenosis (cervical)		**20171**			**22013**		
DS	Endarterectomy	3766	18.7	30.4	4053	18.4	29.7
DS	STA–MCA bypass	314	1.6	2.5	373	1.7	2.7
DS	Other bypass surgery	25	0.1	0.2	24	0.1	0.2
EVT	Carotid stenting	7595	37.7	61.4	8471	38.5	62.2
EVT	Percutaneous angioplasty (w/o stenting)	585	2.9	4.7	679	3.1	5.0
EVT	Percutaneous angioplasty (w/o stenting)	129	0.6	1.0	101	0.5	0.7
2009. Hypertensive intracerebral hemorrhage		**51251**			**56132**		
DS	Removal of hematoma	7312	14.3	77.9	7900	14.1	78.7

Table 5 (Continued)

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/EVT case)	Case no.	% (in all admission)	% (in DS/EVT case)
DS	Ventricular drainage	1967	3.8	20.9	2140	3.8	21.3
	Others	495	1.0	5.3	512	0.9	5.1
2007. Intracranial arterial occlusive disease (excluding moyamoya disease)		**5368**			**6029**		
DS	STA–MCA bypass	1165	21.7	53.4	1345	22.3	54.1
DS	OA–PICA bypass	8	0.1	0.4	8	0.1	0.3
DS	Other revascularization	32	0.6	1.5	32	0.5	1.3
EVT	Percutaneous angioplasty (with stent)	343	6.4	15.7	436	7.2	17.5
EVT	Percutaneous angioplasty (w/o stent)	491	9.1	22.5	567	9.4	22.8
EVT	Others	92	1.7	4.2	75	1.2	3.0
2003. Dural arteriovenous fistula		**4184**			**4735**		
DS	Shunt obliteration	258	6.2	12.3	273	5.8	12.2
EVT	Endovascular embolization	1752	41.9	83.2	1914	40.4	85.4
DS	Removal of hematoma	56	1.3	2.7	51	1.1	2.3
	Others	57	1.4	2.7	42	0.9	1.9
2002. Cerebral arteriovenous malformation		**3647**			**4080**		
DS	Removal	842	23.1	44.1	909	22.3	43.3
EVT	Endovascular embolization	772	21.2	40.4	890	21.8	42.4
DS	Removal of hematoma	297	8.1	15.5	305	7.5	14.5
	Others	132	3.6	6.9	136	3.3	6.5
2008. Moyamoya disease		**4274**			**4837**		
DS	Direct bypass	1301	30.4	70.1	1378	28.5	69.0
DS	Indirect bypass	974	22.8	52.5	1023	21.1	51.2
DS	Removal of hematoma	138	3.2	7.4	151	3.1	7.6
DS	Ventricular drainage	133	3.1	7.2	135	2.8	6.8
	Others	73	1.7	3.9	67	1.4	3.4
2010. Nonhypertensive intracerebral hemorrhage (excluding moyamoya disease and vascular malformation)		**6797**			**7012**		
DS	Removal of hematoma	1198	17.6	76.3	1250	17.8	81.3
DS	Ventricular drainage	219	3.2	13.9	185	2.6	12.0
	Others	148	2.2	9.4	124	1.8	8.1
2014. Skull defect (after external decompression)		**1149**			**1419**		
DS	Cranioplasty	1125	97.9	97.8	1398	98.5	98.3
2006. Extracranial arterial occlusive disease (excluding cervical carotid stenosis)		**2084**			**2177**		
DS	Endarterecotomy	37	1.8	2.0	41	1.9	4.0
DS	STA–MCA bypass	257	12.3	13.8	303	13.9	29.7
DS	OA–PICA bypass	1	0.0	0.1	1	0.0	0.1
DS	Other revascularization	42	2.0	2.3	46	2.1	4.5

Table 5 (Continued)

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/EVT case)	Case no.	% (in all admission)	% (in DS/EVT case)
EVT	Percutaneous angioplasty (with stent)	489	23.5	26.3	487	22.4	47.7
EVT	Percutaneous angioplasty (w/o stent)	152	7.3	8.2	153	7.0	15.0
EVT	Others	20	1.0	1.1	26	1.2	2.5
2011. Cerebral arterial dissection		**3722**			**4152**		
DS	Coating	5	0.1	0.7	4	0.1	0.5
DS	Proximal artery clipping	38	1.0	5.3	23	0.6	3.1
DS	Trapping	47	1.3	6.6	75	1.8	10.1
DS	Bypass (combined)	28	0.8	3.9	44	1.1	5.9
DS	Others	49	1.3	6.9	64	1.5	8.6
EVT	Coil embolization (with stent)	327	8.8	46.0	347	8.4	46.7
EVT	Coil embolization (w/o stent)	166	4.5	23.3	145	3.5	19.5
EVT	Others	77	2.1	10.8	100	2.4	13.5
2004. Cavernous malformation		**1291**			**1427**		
DS	Removal	270	20.9	92.2	296	20.7	94.0
	Others	15	1.2	5.1	18	1.3	5.7
2013. Cerebral venous thrombosis		**519**			**559**		
EVT	Endovascular surgery	53	10.2	54.6	46	8.2	48.4
DS	Decompression craniectomy	20	3.9	20.6	28	5.0	29.5
	Others	21	4.0	21.6	17	3.0	17.9
2090. Other cerebrovascular diseases		**743**			**658**		

DS: direct surgery, EVT: endovascular treatment, JND: Japan Neurosurgical Database, w/o: without.

infection with abscess formation; foramen magnum decompression and other treatments for syringomyelia with tonsillar descent; and release surgery for brachial plexus injury. Contrastingly, anterior decompression, other treatments for carpal tunnel syndrome, posterior fixation for other spinal and peripheral nerve disorders, partial removal and other treatment for spinal extramedullary tumors (intradural confined), anterior decompression and percutaneous vertebroplasty for other spinal trauma, anterior decompression for spinal trauma with dislocation fracture, anterior decompression for spinal infection with abscess formation, other treatments for carpal tunnel syndrome, and total/subtotal removal of primary vertebral tumor decreased by more than 20%.

6) Functional neurosurgery

In the overall cohort, the most common main diagnoses were epilepsy (70% of all cases in 2018).

In the neurosurgical subgroup, the total case volume of functional neurosurgery increased by 8% between 2018 and 2019, and the most common main diagnoses were hemifacial spasm, Parkinson's disease, trigeminal neuralgia, and epilepsy. Similar results were obtained in 2019. Regarding specific treatment (≥10 cases in 2018), there was a marked increase (≥20%) from 2018 to 2019 in other treatments for hemifacial spasm; implantation of intracranial electrodes; temporal lobectomy, focal resection for neocortical epilepsy, multilobar resection (functional or anatomical), and other treatments for epilepsy; stereotactic neurosurgery (ablation) for dystonia; stereotactic neurosurgery (deep brain stimulation, ablation, and focused ultrasound), implantation of other stimulation systems, and other functional surgeries for essential tremor; implantation of spinal cord stimulation system for other functional disorders; and other treatments for other functional neurosurgery. Contrastingly, other stereotactic neurosurgeries and implantation of other stimulation systems for Parkinson's disease,

Table 6 Case volume of DS and EVT or brain tumors in the JND in 2018 and 2019

Modality	Mode of Operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/EVT case)	Case no.	% (in all admission)	% (in DS/EVT case)
1101. Meningioma		**10383**			**10659**		
	Removal	5501	53.0	74.9	5596	53.9	74.1
	Biopsy	32	0.3	0.4	29	0.3	0.4
	Transnasal surgery	144	1.4	2.0	147	1.4	1.9
	Extensive skull base tumor resection reconstruction	184	1.8	2.5	225	2.2	3.0
EVT	Tumor embolization	1279	12.3	17.4	1376	13.3	18.2
	Others (e.g., Ommaya reservoir)	227	2.2	3.1	222	2.1	2.9
	Decompressive craniectomy	31	0.3	0.4	51	0.5	0.7
1116. Metastatic brain tumor		**17297**			**17082**		
	Removal	3025	17.5	84.6	3210	18.8	85.7
	Biopsy	157	0.9	4.4	165	1.0	4.4
	Transnasal surgery	17	0.1	0.5	16	0.1	0.4
	Extensive skull base tumor resection reconstruction	7	0.0	0.2	8	0.0	0.2
EVT	Tumor embolization	23	0.1	0.6	26	0.2	0.7
	Others (e.g., Ommaya reservoir)	365	2.1	10.2	368	2.2	9.8
	Decompressive craniectomy	25	0.1	0.7	22	0.1	0.6
1106. Pituitary adenoma		**4204**			**4571**		
	Removal	638	15.2	20.4	795	17.4	23.5
	Biopsy	13	0.3	0.4	4	0.1	0.1
	Transnasal surgery	2777	66.1	88.9	3039	66.5	89.7
	Extensive skull base tumor resection. reconstruction	27	0.6	0.9	34	0.7	1.0
EVT	Tumor embolization	2	0.0	0.1	0	0.0	0.0
	Others (e.g., Ommaya reservoir)	36	0.9	1.2	35	0.8	1.0
	Decompressive craniectomy	2	0.0	0.1	4	0.1	0.1
1104. Glioblastoma		**6924**			**7702**		
	Removal	2149	31.0	78.7	2325	30.2	79.3
	Biopsy	390	5.6	14.3	441	5.7	15.0
	Transnasal surgery	1	0.0	0.0	3	0.0	0.1
	Extensive skull base tumor resection reconstruction	2	0.0	0.1	0	0.0	0.0
EVT	Tumor embolization	25	0.4	0.9	16	0.2	0.5
	Others (e.g., Ommaya reservoir)	157	2.3	5.8	155	2.0	5.3
	Decompressive craniectomy	31	0.4	1.1	27	0.4	0.9
1107. Schwannoma		**2821**			**3077**		
	Removal	1419	50.3	91.7	1483	48.2	90.5
	Biopsy	13	0.5	0.8	9	0.3	0.5
	Transnasal surgery	13	0.5	0.8	12	0.4	0.7

Table 6 (Continued)

Modality	Mode of Operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/EVT case)	Case no.	% (in all admission)	% (in DS/EVT case)
	Extensive skull base tumor resection reconstruction	54	1.9	3.5	51	1.7	3.1
EVT	Tumor embolization	9	0.3	0.6	25	0.8	1.5
	Others (e.g., Ommaya reservoir)	37	1.3	2.4	44	1.4	2.7
	Decompressive craniectomy	11	0.4	0.7	12	0.4	0.7
1109. Malignant lymphoma		**2650**			**2843**		
	Removal	410	15.5	36.1	374	13.2	31.7
	Biopsy	669	25.2	58.8	761	26.8	64.5
	Transnasal surgery	5	0.2	0.4	7	0.2	0.6
	Extensive skull base tumor resection reconstruction	1	0.0	0.1	1	0.0	0.1
EVT	Tumor embolization	2	0.1	0.2	1	0.0	0.1
	Others (e.g., Ommaya reservoir)	68	2.6	6.0	58	2.0	4.9
	Decompressive craniectomy	8	0.3	0.7	9	0.3	0.8
1102. Astrocytoma		**2691**			**2615**		
	Removal	829	30.8	72.8	796	30.4	71.9
	Biopsy	234	8.7	20.5	258	9.9	23.3
	Transnasal surgery	4	0.1	0.4	4	0.2	0.4
	Extensive skull base tumor resection reconstruction	1	0.0	0.1	1	0.0	0.1
EVT	Tumor embolization	1	0.0	0.1	4	0.2	0.4
	Others (e.g., Ommaya reservoir)	63	2.3	5.5	48	1.8	4.3
	Decompressive craniectomy	2	0.1	0.2	5	0.2	0.5
1118. Other brain tumor		**1697**			**1906**		
	Removal	483	28.5	62.6	489	25.7	63.1
	Biopsy	107	6.3	13.9	124	6.5	16.0
	Transnasal surgery	54	3.2	7.0	46	2.4	5.9
	Extensive skull base tumor resection reconstruction	14	0.8	1.8	26	1.4	3.4
EVT	Tumor embolization	42	2.5	5.4	36	1.9	4.6
	Others (e.g., Ommaya reservoir)	68	4.0	8.8	62	3.3	8.0
	Decompressive craniectomy	9	0.5	1.2	9	0.5	1.2
1105. Other neuroepithelial tumor		**1286**			**1288**		
	Removal	449	34.9	74.8	435	33.8	76.3
	Biopsy	63	4.9	10.5	71	5.5	12.5
	Transnasal surgery	12	0.9	2.0	10	0.8	1.8
	Extensive skull base tumor resection reconstruction	5	0.4	0.8	2	0.2	0.4
EVT	Tumor embolization	12	0.9	2.0	5	0.4	0.9
	Others (e.g., Ommaya reservoir)	59	4.6	9.8	55	4.3	9.6
	Decompressive craniectomy	2	0.2	0.3	0	0.0	0.0
1110. Hemangioblastoma		**625**			**691**		
	Removal	378	60.5	82.2	422	61.1	76.9

Table 6 (Continued)

Modality	Mode of Operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/ EVT case)	Case no.	% (in all admission)	% (in DS/ EVT case)
	Biopsy	3	0.5	0.7	2	0.3	0.4
	Transnasal surgery	0	0.0	0.0	2	0.3	0.4
	Extensive skull base tumor resection reconstruction	3	0.5	0.7	3	0.4	0.5
EVT	Tumor embolization	53	8.5	11.5	86	12.4	15.7
	Others (e.g., Ommaya reservoir)	27	4.3	5.9	27	3.9	4.9
	Decompressive craniectomy	2	0.3	0.4	11	1.6	2.0
1108. Craniopharyngioma		**802**			**740**		
	Removal	242	30.2	49.9	243	32.8	54.6
	Biopsy	18	2.2	3.7	11	1.5	2.5
	Transnasal surgery	219	27.3	45.2	212	28.6	47.6
	Extensive skull base tumor resection reconstruction	20	2.5	4.1	15	2.0	3.4
EVT	Tumor embolization	1	0.1	0.2	0	0.0	0.0
	Others (e.g., Ommaya reservoir)	34	4.2	7.0	33	4.5	7.4
	Decompressive craniectomy	0	0.0	0.0	1	0.1	0.2
1103. Oligodendroglioma		**1165**			**1022**		
	Removal	440	37.8	88.5	243	23.8	55.1
	Biopsy	30	2.6	6.0	15	1.5	3.4
	Transnasal surgery	0	0.0	0.0	0	0.0	0.0
	Extensive skull base tumor resection reconstruction	1	0.1	0.2	0	0.0	0.0
EVT	Tumor embolization	1	0.1	0.2	1	0.1	0.2
	Others (e.g., Ommaya reservoir)	23	2.0	4.6	9	0.9	2.0
	Decompressive craniectomy	0	0.0	0.0	1	0.1	0.2
1113. Cystic lesion (other than dermoid, epidermoid, arachnoid cyst)		**431**			**553**		
	Removal	94	21.8	28.8	135	24.4	35.2
	Biopsy	6	1.4	1.8	7	1.3	1.8
	Transnasal surgery	215	49.9	66.0	253	45.8	66.1
	Extensive skull base tumor resection reconstruction	0	0.0	0.0	3	0.5	0.8
EVT	Tumor embolization	1	0.2	0.3	0	0.0	0.0
	Others (e.g., Ommaya reservoir)	31	7.2	9.5	21	3.8	5.5
	Decompressive craniectomy	1	0.2	0.3	1	0.2	0.3
1111. Germ cell tumor, pineal tumor		**654**			**709**		
	Removal	121	18.5	41.9	118	16.6	42.0
	Biopsy	131	20.0	45.3	121	17.1	43.1
	Transnasal surgery	17	2.6	5.9	23	3.2	8.2
	Extensive skull base tumor resection reconstruction	0	0.0	0.0	0	0.0	0.0
EVT	Tumor embolization	2	0.3	0.7	1	0.1	0.4
	Others (e.g., Ommaya reservoir)	36	5.5	12.5	49	6.9	17.4

Table 6 (Continued)

Modality	Mode of Operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/ EVT case)	Case no.	% (in all admission)	% (in DS/ EVT case)
	Decompressive craniectomy	0	0.0	0.0	0	0.0	0.0
1112. Dermoid, epidermoid		**257**			**227**		
	Removal	168	65.4	87.0	158	69.6	89.8
	Biopsy	5	1.9	2.6	4	1.8	2.3
	Transnasal surgery	1	0.4	0.5	1	0.4	0.6
	Extensive skull base tumor resection reconstruction	12	4.7	6.2	7	3.1	4.0
EVT	Tumor embolization	0	0.0	0.0	0	0.0	0.0
	Others (e.g., Ommaya reservoir)	8	3.1	4.1	5	2.2	2.8
	Decompressive craniectomy	0	0.0	0.0	0	0.0	0.0
1202. Benign skull tumor		**197**			**203**		
	Removal	152	77.2	89.4	154	75.9	91.7
	Biopsy	12	6.1	7.1	10	4.9	6.0
EVT	Tumor embolization	1	0.5	0.6	1	0.5	0.6
1114. Chordoma, chondrosarcoma		**246**			**289**		
	Removal	53	21.5	36.6	69	23.9	41.6
	Biopsy	2	0.8	1.4	2	0.7	1.2
	Transnasal surgery	99	40.2	68.3	103	35.6	62.0
	Extensive skull base tumor resection reconstruction	10	4.1	6.9	14	4.8	8.4
EVT	Tumor embolization	2	0.8	1.4	4	1.4	2.4
	Others (e.g., Ommaya reservoir)	5	2.0	3.4	4	1.4	2.4
	Decompressive craniectomy	0	0.0	0.0	0	0.0	0.0
1301. Intraorbital tumor		**235**			**210**		
	Removal	132	56.2	87.4	114	54.3	87.7
	Biopsy	10	4.3	6.6	7	3.3	5.4
EVT	Tumor embolization	1	0.4	0.7	5	2.4	3.8
1201. Malignant skull tumor		**170**			**175**		
	Removal	98	57.6	79.0	96	54.9	76.8
	Biopsy	18	10.6	14.5	19	10.9	15.2
EVT	Tumor embolization	6	3.5	4.8	8	4.6	6.4
1115. Primary skull base tumor (other than chordoma, chondrosarcoma including direct invasion to nasopharyngeal locations)		**212**			**204**		
	Removal	33	15.6	23.4	26	12.7	21.5
	Biopsy	2	0.9	1.4	3	1.5	2.5
	Transnasal surgery	30	14.2	21.3	17	8.3	14.0
	Extensive skull base tumor resection reconstruction	65	30.7	46.1	70	34.3	57.9
EVT	Tumor embolization	19	9.0	13.5	13	6.4	10.7
	Others (e.g., Ommaya reservoir)	2	0.9	1.4	3	1.5	2.5
	Decompressive craniectomy	1	0.5	0.7	1	0.5	0.8

Table 6 (Continued)

Modality	Mode of Operations	2018 Case no.	2018 % (in all admission)	2018 % (in DS/EVT case)	2019 Case no.	2019 % (in all admission)	2019 % (in DS/EVT case)
1303. Skull defect after decompression		**88**			**98**		
	Cranioplasty	82	93.2	95.3	111	113.3	96.5
1302. Scalp tumor		**139**			**124**		
	Removal	114	82.0	87.7	105	84.7	92.9
	Biopsy	3	2.2	2.3	2	1.6	1.8
EVT	Tumor embolization	7	5.0	5.4	2	1.6	1.8
1117. Embryonal brain tumor		**225**			**193**		
	Removal	59	26.2	75.6	59	30.6	69.4
	Biopsy	8	3.6	€	10	5.2	11.8
	Transnasal surgery	0	0.0	0.0	1	0.5	1.2
	Extensive skull base tumor resection reconstruction	0	0.0	0.0	1	0.5	1.2
EVT	Tumor embolization	0	0.0	0.0	0	0.0	0.0
	Others (e.g., Ommaya reservoir)	16	7.1	20.5	20	10.4	23.5
	Decompressive craniectomy	0	0.0	0.0	2	1.0	2.4
1203. Other skull tumor		**119**			**115**		
	Removal	49	41.2	69.0	39	33.9	72.2
	Biopsy	16	13.4	22.5	10	8.7	18.5
EVT	Tumor embolization	1	0.8	1.4	4	3.5	7.4

DS: direct surgery, EVT: endovascular treatment, JND: Japan Neurosurgical Database.

Table 7 Case volume of DS and EVT for neurotrauma in the JND in 2018 and 2019

Modality	Mode of operations	2018 Case no.	2018 % (in all admission)	2018 % (in DS/EVT case)	2019 Case no.	2019 % (in all admission)	2019 % (in DS/EVT case)
3002. CSDH		**40889**			**42630**		
	Burr hole and irrigation	39291	96.1	97.3	40734	95.6	97.4
	Removal of hematoma (craniotomy)	531	1.3	1.3	551	1.3	1.3
	Others	304	0.7	0.8	378	0.9	0.9
3100. Traumatic intracranial hemorrhage group		**42233**			**45521**		
	Removal of hematoma (craniotomy)	5473	13.0	74.3	5620	12.3	74.8
	Decompressive craniectomy	1471	3.5	20.0	1487	3.3	19.8
	Burr hole surgery	963	2.3	13.1	1079	2.4	14.4
	Others	649	1.5	8.8	611	1.3	8.1
3016. Skull defect after external decompression		**1151**			**1219**		
	Cranioplasty	1137	98.8	98.1	1213	99.5	98.9

Table 7 (Continued)

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/ EVT case)	Case no.	% (in all admission)	% (in DS/ EVT case)
3090. Other head trauma		**1899**			**1971**		
	Others	437	23.0	93.8	521	26.4	95.4
3017. CSF leakage		**845**			**805**		
	Repair of CSF leakage	273	32.3	93.8	322	40.0	96.7
3004. Skull fracture		**4025**			**4114**		
	Cranioplasty	176	4.4	88.9	192	4.7	90.6
3010. Traumatic cerebrovascular diseases		**502**			**371**		
	Bypass surgery	3	0.6	2.8	1	0.3	0.8
EVT	Endovascular surgery	65	12.9	59.6	91	24.5	77.1
	Others	39	7.8	35.8	23	6.2	19.5
3007. Intraventricular hemorrhage		**490**			**370**		
	Ventricular drainage	51	10.4	72.9	34	9.2	65.4
3006. Diffuse axonal injury		**531**			**549**		
	Placement of ICP monitor	21	4.0	65.6	21	3.8	65.6
	Ventricular drainage	10	1.9	31.3	10	1.8	31.3
3014. Facial injury (facial bone fracture)		**620**			**653**		
	Facial fracture reduction	24	3.9	88.9	21	3.2	91.3
3008. Cranial nerve injury (optic canal fracture)		**29**			**32**		
	Optic nerve decompression	14	48.3	100.0	17	53.1	85.0
	Others	0	0.0	0.0	1	3.1	5.0
3018. Penetrating brain injury		**18**			**28**		
	Removal of foreign material	13	72.2	92.9	15	53.6	88.2
3013. Facial injury (orbital fracture)		**412**			**398**		
	Open reduction of orbital fracture	10	2.4	100.0	5	1.3	100.0

DS: direct surgery, EVT: endovascular treatment, JND: Japan Neurosurgical Database, CSDH: chronic subdural hematoma, CSF: cerebrospinal fluid, ICP: intracranial pressure.

and multiple hippocampal transection for epilepsy decreased by more than 20%.

7) Encephalopathy/infection/inflammatory/miscellaneous diseases

In the overall cohort, the most common main diagnoses were miscellaneous diseases (registered as others) (61.2% of all cases in 2018).

In the neurosurgical subgroup, the total case volume of functional neurosurgery increased by 20.2% between 2018 and 2019, and the most common main diagnoses were miscellaneous diseases (registered as others) and bacterial infection (other bacterial infection) (37.0%, 17.4%, 16.9%, and 10.9%, respectively, in 2018). Similar results were obtained in 2019. Regarding specific treatment (≥10 cases in 2018), there was a marked increase (≥20%) from 2018 to 2019 in treatments (e.g., tracheostomy) for other diseases, drainage for bacterial cerebral abscess, removal of subdural empyema, and biopsy for inflammatory diseases (angiitis). Contrastingly, the number of cases of biopsy for inflammatory degenerative diseases decreased by more than 20%.

Discussion

The JND has succeeded in creating a comprehensive database with 1,093,917 cases admitted to

Table 8 Case volume of DS for hydrocephalus and developmental anomalies in the JND in 2018 and 2019

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS case)	Case no.	% (in all admission)	% (in DS case)
4002. Acquired (secondary) hydrocephalus		**10268**			**10951**		
	VP shunt	4650	45.3	41.5	4896	44.7	40.9
	LP shunt	1641	16.0	14.6	1745	15.9	14.6
	VA shunt	151	1.5	1.3	122	1.1	1.0
	Shunt revision	493	4.8	4.4	559	5.1	4.7
	Third ventriculostomy	424	4.1	3.8	468	4.3	3.9
	Ventricular drainage	3051	29.7	27.2	3394	31.0	28.3
	Shunt removal	488	4.8	4.4	584	5.3	4.9
	Others	640	6.2	5.7	639	5.8	5.3
4003. Idiopathic normal pressure hydrocephalus		**7673**			**8962**		
	VP shunt	1921	25.0	43.7	2221	24.8	43.7
	LP shunt	1871	24.4	42.5	2084	23.3	41.0
	VA shunt	140	1.8	3.2	190	2.1	3.7
	Shunt revision	168	2.2	3.8	229	2.6	4.5
	Third ventriculostomy	26	0.3	0.6	44	0.5	0.9
	Ventricular drainage	101	1.3	2.3	113	1.3	2.2
	Shunt removal	145	1.9	3.3	165	1.8	3.2
	Others	75	1.0	1.7	110	1.2	2.2
4001. Congenital hydrocephalus		**1051**			**1012**		
	VP shunt	383	36.4	38.6	340	33.6	39.5
	LP shunt	10	1.0	1.0	6	0.6	0.7
	VA shunt	27	2.6	2.7	18	1.8	2.1
	Shunt revision	209	19.9	21.1	185	18.3	21.5
	Third ventriculostomy	148	14.1	14.9	131	12.9	15.2
	Ventricular drainage	127	12.1	12.8	101	10.0	11.7
	Shunt removal	105	10.0	10.6	95	9.4	11.0
	Others	133	12.7	13.4	83	8.2	9.7
4202. Spinal lipoma		**624**			**671**		
	Untethering	342	54.8	91.2	367	54.7	95.1
	Others	37	5.9	9.9	39	5.8	10.1
4004. Craniosynostosis		**490**			**543**		
	Cranioplasty (without distraction)	99	20.2	27.4	105	19.3	27.3
	Cranioplasty (with distraction)	109	22.2	30.2	106	19.5	27.5
	Suturectomy	40	8.2	11.1	34	6.3	8.8
	Others (e.g., removal of devices)	112	22.9	31.0	137	25.2	35.6
4290. Other spinal cord/spinal anomaly		**400**			**535**		
	Untethering	155	38.8	79.1	166	31.0	74.8
	Others	39	9.8	19.9	50	9.3	22.5
4101. Chiari malformation (Type I)		**332**			**336**		
	Foramen magnum decompression	212	63.9	93.0	185	55.1	91.1

Table 8 (Continued)

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS case)	Case no.	% (in all admission)	% (in DS case)
	Syringo–subarachnoid shunt	5	1.5	2.2	13	3.9	6.4
	Fixation	3	0.9	1.3	2	0.6	1.0
	Others	23	6.9	10.1	17	5.1	8.4
4006. Arachnoid cyst		**348**			**327**		
	Fenestration (craniotomy)	60	17.2	29.3	52	15.9	26.7
	Fenestration (endoscopic)	86	24.7	42.0	85	26.0	43.6
	Cyst-peritoneal shunt	20	5.7	9.8	22	6.7	11.3
	Others	38	10.9	18.5	36	11.0	18.5
4201. Myelomeningocele/myeloschisis		**276**			**311**		
	Repair	87	31.5	65.4	101	32.5	77.1
	Others	42	15.2	31.6	30	9.6	22.9
4090. Other cranial/cerebral anomaly		**153**			**157**		
	Surgery	41	26.8	70.7	45	28.7	76.3
	Others	18	11.8	31.0	26	16.6	44.1
4005. Encephalocele		**81**			**93**		
	Repair	46	56.8	85.2	40	43.0	76.9
	Others	7	8.6	13.0	10	10.8	19.2
4190. Other anomaly of craniocervical junction		**77**			**72**		
	Foramen magnum decompression	19	24.7	52.8	19	26.4	59.4
	Syringo–subarachnoid shunt	2	2.6	5.6	0	0.0	0.0
	Fixation	9	11.7	25.0	9	12.5	28.1
	Others	9	11.7	25.0	10	13.9	31.3
4102. Chiari malformation (Type II)		**75**			**71**		
	Foramen magnum decompression	16	21.3	69.6	11	15.5	78.6
	Syringo–subarachnoid shunt	2	2.7	8.7	1	1.4	7.1
	Fixation	0	0.0	0.0	0	0.0	0.0
	Others	8	10.7	34.8	4	5.6	28.6

DS: direct surgery, JND: Japan Neurosurgical Database, VP: ventriculoperitoneal, LP: lumboperitoneal, VA: ventriculoatrial.

more than 1300 training institutions of the JNS between January 2018 and December 2019. The number of participating hospitals in this project increased by approximately 7.0%, with a corresponding increase in the registered patients (9.2% in the overall cohort). Overall, the demographics and clinical outcomes of the registered patients remained almost unchanged between 2018 and 2019. This JND Statistical Update 2018–2019 provides us with the largest-ever, clinical epidemiology statistics of real-world neurosurgical practices in Japan.

Basic clinical information and patient management in 2018 and 2019

Data on the purposes of admission to neurosurgical departments demonstrated that neurosurgeons in Japan are involved in not only operations but a wide range of clinical practices such as diagnosis, medical management, and rehabilitation.[1] Regarding medical treatment in neurosurgical admission, antiplatelet and anticoagulation treatment and neuroprotective therapy (e.g., edaravone[4]) are performed mainly for cerebrovascular diseases, whereas other medical treatments such as anti-edema therapy and

Table 9 Case volume of DS and EVT for spinal and peripheral nerve disorders in the JND in 2018 and 2019

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS/EVT case)	Case no.	% (in all admission)	% (in DS/EVT case)
5100. Spinal degenerative disorders		**15734**			**19045**		
	Anterior decompression	904	5.7	7.1	902	4.7	5.8
	Anterior fixation	1533	9.7	12.0	1710	9.0	11.0
	Posterior decompression	7654	48.6	59.9	9342	49.1	60.3
	Posterior fixation	2209	14.0	17.3	2622	13.8	16.9
	Discectomy	2194	13.9	17.2	2354	12.4	15.2
	Simultaneous anterior and posterior decompression	264	1.7	2.1	257	1.3	1.7
	Others	756	4.8	5.9	1045	5.5	6.8
5503. Spinal trauma – vertebral compression fracture		**3309**			**4020**		
	Anterior decompression	18	0.5	1.3	13	0.3	0.7
	Posterior decompression	103	3.1	7.2	120	3.0	6.7
	Fixation	354	10.7	24.9	442	11.0	24.7
	Percutaneous vertebroplasty	959	29.0	67.4	1283	31.9	71.7
	Others	108	3.3	7.6	121	3.0	6.8
5701. Peripheral nerve disorders – carpal tunnel syndrome		**528**			**564**		
	Release surgery	358	67.8	66.4	403	71.5	71.2
	Others	177	33.5	32.8	137	24.3	24.2
5890. Other spinal and peripheral nerve disorders		**1395**			**1306**		
	Posterior fixation	117	8.4	17.0	66	5.1	12.6
	Simultaneous anterior and posterior decompression	5	0.4	0.7	3	0.2	0.6
	Others	535	38.4	77.8	440	33.7	84.3
5202. Spinal tumor – extramedullary tumor (intradural confined)		**510**			**565**		
	Total/subtotal removal	390	76.5	85.3	429	75.9	91.3
	Partial removal	36	7.1	7.9	28	5.0	6.0
	Biopsy	2	0.4	0.4	0	0.0	0.0
	Others	15	2.9	3.3	6	1.1	1.3
5590. Spinal trauma – other spinal trauma		**897**			**1137**		
	Anterior decompression	28	3.1	8.1	22	1.9	5.5
	Posterior decompression	134	14.9	38.8	158	13.9	39.8
	Fixation	179	20.0	51.9	217	19.1	54.7
	Percutaneous vertebroplasty	27	3.0	7.8	18	1.6	4.5
	Others	70	7.8	20.3	83	7.3	20.9
5201. Spinal tumor – intramedullary tumor		**452**			**563**		
	Total/subtotal removal	184	40.7	68.4	197	35.0	59.7
	Partial removal	47	10.4	17.5	72	12.8	21.8
	Biopsy	20	4.4	7.4	38	6.7	11.5
	Others	10	2.2	3.7	17	3.0	5.2

Table 9 (Continued)

Modality	Mode of operations	2018 Case no.	2018 % (in all admission)	2018 % (in DS/EVT case)	2019 Case no.	2019 % (in all admission)	2019 % (in DS/EVT case)
5501. Spinal trauma – without bone injury		**1151**			**1225**		
	Anterior decompression	38	3.3	12.9	28	2.3	9.2
	Posterior decompression	199	17.3	67.5	214	17.5	70.4
	Fixation	79	6.9	26.8	82	6.7	27.0
	Percutaneous vertebroplasty	6	0.5	2.0	10	0.8	3.3
	Others	22	1.9	7.5	28	2.3	9.2
5801. Spinal deformity		**491**			**392**		
	Posterior fixation	163	33.2	43.1	86	21.9	33.2
	Simultaneous anterior and posterior decompression	21	4.3	5.6	5	1.3	1.9
	Others	185	37.7	48.9	160	40.8	61.8
5502. Spinal trauma – dislocation fracture		**362**			**367**		
	Anterior decompression	23	6.4	9.2	17	4.6	6.7
	Posterior decompression	57	15.7	22.8	57	15.5	22.4
	Fixation	189	52.2	75.6	190	51.8	74.8
	Percutaneous vertebroplasty	5	1.4	2.0	15	4.1	5.9
	Others	41	11.3	16.4	42	11.4	16.5
5203. Spinal tumor – extramedullary tumor (extradural and paraspinal extension)		**222**			**297**		
	Total/subtotal removal	141	63.5	75.0	171	57.6	71.8
	Partial removal	34	15.3	18.1	45	15.2	18.9
	Biopsy	3	1.4	1.6	5	1.7	2.1
	Others	6	2.7	3.2	10	3.4	4.2
5401. Spinal vascular diseases – dural arteriovenous fistula		**333**			**392**		
	Arteriovenous fistula obliteration	97	29.1	50.8	106	27.0	45.3
	Removal	9	2.7	4.7	23	5.9	9.8
	Others	6	1.8	3.1	8	2.0	3.4
EVT	Endovascular obliteration	91	27.3	47.6	111	28.3	47.4
5790. Peripheral nerve disorders – other peripheral nerve disorders		**688**			**756**		
	Release surgery	134	19.5	67.3	138	18.3	69.0
	Others	63	9.2	31.7	59	7.8	29.5
5406. Spinal vascular diseases – extradural hematoma		**210**			**276**		
	Arteriovenous fistula obliteration	1	0.5	1.0	0	0.0	0.0
	Removal	58	27.6	56.9	90	32.6	57.3
	Others	39	18.6	38.2	59	21.4	37.6
EVT	Endovascular obliteration	1	0.5	1.0	0	0.0	0.0
5601. Spinal infection – with abscess formation		**158**			**216**		
	Anterior decompression	12	7.6	9.3	8	3.7	5.1
	Posterior decompression	48	30.4	37.2	51	23.6	32.5

Table 9 (Continued)

Modality	Mode of operations	2018 Case no.	2018 % (in all admission)	2018 % (in DS/EVT case)	2019 Case no.	2019 % (in all admission)	2019 % (in DS/EVT case)
	Fixation	33	20.9	25.6	45	20.8	28.7
	Others	52	32.9	40.3	71	32.9	45.2
5205. Spinal tumor – metastatic vertebral tumor		**309**			**300**		
	Total/subtotal removal	44	14.2	29.1	37	12.3	27.6
	Partial removal	63	20.4	41.7	62	20.7	46.3
	Biopsy	11	3.6	7.3	10	3.3	7.5
	Others	25	8.1	16.6	25	8.3	18.7
5301. Syringomyelia – tonsillar descent (chiari Type I)		**157**			**199**		
	Syringo shunt	10	6.4	10.2	11	5.5	9.6
	Foramen magnum decompression	79	50.3	80.6	96	48.2	83.5
	Lysis of adhesion	2	1.3	2.0	6	3.0	5.2
	Others	10	6.4	10.2	13	6.5	11.3
5703. Peripheral nerve disorders – tarsal tunnel syndrome		**75**			**105**		
	Release surgery	72	96.0	87.8	105	100.0	92.1
	Others	10	13.3	12.2	4	3.8	3.5
5290. Spinal tumor – other spinal tumor		**101**			**121**		
	Total/subtotal removal	39	38.6	62.9	36	29.8	52.2
	Partial removal	8	7.9	12.9	10	8.3	14.5
	Biopsy	4	4.0	6.5	11	9.1	15.9
	Others	5	5.0	8.1	11	9.1	15.9
5704. Peripheral nerve disorders – brachial plexus injury		**64**			**77**		
	Release surgery	37	57.8	82.2	50	64.9	82.0
	Others	12	18.8	26.7	11	14.3	18.0
5602. Spinal infection – without abscess formation		**121**			**137**		
	Anterior decompression	6	5.0	14.3	0	0.0	0.0
	Posterior decompression	11	9.1	26.2	13	9.5	22.8
	Fixation	16	13.2	38.1	19	13.9	33.3
	Others	20	16.5	47.6	30	21.9	52.6
5302. Syringomyelia – adhesive arachnoiditis		**97**			**67**		
	Syringo shunt	28	28.9	47.5	24	35.8	44.4
	Foramen magnum decompression	2	2.1	3.4	4	6.0	7.4
	Lysis of adhesion	24	24.7	40.7	24	35.8	44.4
	Others	13	13.4	22.0	11	16.4	20.4
5403. Spinal vascular diseases – extradural arteriovenous fistula		**51**			**58**		
	Arteriovenous fistula obliteration	15	29.4	48.4	13	22.4	34.2
	Removal	2	3.9	6.5	0	0.0	0.0
	Others	0	0.0	0.0	2	3.4	5.3
EVT	Endovascular obliteration	17	33.3	54.8	28	48.3	73.7

Table 9 (Continued)

Modality	Mode of operations	2018 Case no.	2018 % (in all admission)	2018 % (in DS/EVT case)	2019 Case no.	2019 % (in all admission)	2019 % (in DS/EVT case)
5490. Spinal vascular diseases – other spinal vascular disorders		**174**			**208**		
	Arteriovenous fistula obliteration	0	0.0	0.0	1	0.5	2.7
	Removal	6	3.4	26.1	13	6.3	35.1
	Others	12	6.9	52.2	12	5.8	32.4
EVT	Endovascular obliteration	4	2.3	17.4	10	4.8	27.0
5702. Peripheral nerve disorders – cubital tunnel syndrome		**59**			**50**		
	Release surgery	34	57.6	64.2	34	68.0	91.9
	Others	19	32.2	35.8	5	10.0	13.5
5204. Spinal tumor – primary vertebral tumor		**66**			**60**		
	Total/subtotal removal	20	30.3	52.6	9	15.0	25.7
	Partial removal	9	13.6	23.7	16	26.7	45.7
	Biopsy	5	7.6	13.2	3	5.0	8.6
	Others	4	6.1	10.5	5	8.3	14.3
5390. Syringomyelia – others		**61**			**59**		
	Syringo shunt	19	31.1	63.3	13	22.0	43.3
	Foramen magnum decompression	1	1.6	3.3	6	10.2	20.0
	Lysis of adhesion	4	6.6	13.3	1	1.7	3.3
	Others	9	14.8	30.0	13	22.0	43.3
5404. Spinal vascular diseases – intramedullary arteriovenous malformation		**59**			**71**		
	Arteriovenous fistula obliteration	5	8.5	22.7	1	1.4	4.0
	Removal	4	6.8	18.2	7	9.9	28.0
	Others	3	5.1	13.6	2	2.8	8.0
EVT	Endovascular obliteration	12	20.3	54.5	14	19.7	56.0
5402. Spinal vascular diseases – perimedullary arteriovenous malformation		**63**			**48**		
	Arteriovenous fistula obliteration	21	33.3	53.8	10	20.8	43.5
	Removal	4	6.3	10.3	2	4.2	8.7
	Others	3	4.8	7.7	1	2.1	4.3
EVT	Endovascular obliteration	12	19.0	54.5	10	20.8	43.5
5405. Spinal vascular diseases – cavernous malformation		**37**			**30**		
	Arteriovenous fistula obliteration	1	2.7	7.1	1	3.3	7.7
	Removal	11	29.7	78.6	12	40.0	92.3
	Others	0	0.0	0.0	0	0.0	0.0
EVT	Endovascular obliteration	0	0.0	0.0	1	3.3	7.7
5303. Syringomyelia –traumatic		**21**			**12**		
	Syringo shunt	7	33.3	63.6	5	41.7	62.5
	Foramen magnum decompression	0	0.0	0.0	0	0.0	0.0
	Lysis of adhesion	2	9.5	18.2	1	8.3	12.5
	Others	2	9.5	18.2	2	16.7	25.0

DS: direct surgery, EVT: endovascular treatment, JND: Japan Neurosurgical Database.

Table 10 Case volume of direct surgery (DS) for functional neurosurgery in the JND in 2018 and 2019

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS Case)	Case no.	% (in all admission)	% (in DS case)
6102. Hemifacial spasm		**1919**			**2017**		
	Microvascular decompression	1739	90.6	98.7	1815	90.0	98.6
	Others	14	0.7	0.8	22	1.1	1.2
6201. Parkinson's disease		**2717**			**2839**		
	Stereotactic neurosurgery (deep brain stimulation)	606	22.3	38.9	523	18.4	35.0
	Stereotactic neurosurgery (ablation)	24	0.9	1.5	26	0.9	1.7
	Stereotactic neurosurgery (focused ultrasound)	0	0.0	0.0	0	0.0	0.0
	Stereotactic neurosurgery (others)	25	0.9	1.6	12	0.4	0.8
	Implantation of spinal cord stimulation system	38	1.4	2.4	19	0.7	1.3
	Implantation of other stimulation system	374	13.8	24.0	357	12.6	23.9
	Implantation of drug delivery infusion pump	1	0.0	0.1	1	0.0	0.1
	Neurotomy (selective)	0	0.0	0.0	0	0.0	0.0
	Dorsal rhizotomy (selective)	0	0.0	0.0	0	0.0	0.0
	Other functional neurosurgery	474	17.4	30.4	546	19.2	36.5
6001. Epilepsy		**26121**			**28608**		
	Implantation of intracranial electrodes	187	0.7	15.4	246	0.9	18.0
	Temporal lobectomy (for TLE)	144	0.6	11.8	173	0.6	12.6
	Selective amygdalohippocampectomy	76	0.3	6.3	83	0.3	6.1
	Multiple hippocampal transection	24	0.1	2.0	14	0.0	1.0
	Lobectomy (excluding for TLE, functional or anatomical)	25	0.1	2.1	37	0.1	2.7
	Multilober resection (functional or anatomical)	16	0.1	1.3	37	0.1	2.7
	Lesionectomy (structural lesion)	122	0.5	10.0	141	0.5	10.3
	Focus resection (for neocortical epilepsy)	59	0.2	4.9	76	0.3	5.6
	Hemispherectomy (functional or anatomical)	25	0.1	2.1	30	0.1	2.2
	Callosotomy	150	0.6	12.3	151	0.5	11.0
	MST	11	0.0	0.9	5	0.0	0.4
	Stereotactic ablation (including laser or MRI guided)	17	0.1	1.4	1	0.0	0.1
	Implantation of vagus nerve stimulation system	274	1.0	22.5	247	0.9	18.0
	Others	161	0.6	13.2	195	0.7	14.2
6101. Trigeminal neuralgia		**1656**			**1834**		
	Microvascular decompression	1196	72.2	97.9	1330	72.5	97.9
	Others	20	1.2	1.6	21	1.1	1.5
6206. Pain		**1038**			**1230**		
	Stereotactic neurosurgery (deep brain stimulation)	2	0.2	0.4	0	0.0	0.0
	Stereotactic neurosurgery (ablation)	0	0.0	0.0	1	0.1	0.2
	Stereotactic neurosurgery (focused ultrasound)	0	0.0	0.0	0	0.0	0.0
	Stereotactic neurosurgery (others)	1	0.1	0.2	0	0.0	0.0

Table 10 (Continued)

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS Case)	Case no.	% (in all admission)	% (in DS case)
	Implantation of spinal cord stimulation system	398	38.3	72.8	456	37.1	80.0
	Implantation of other stimulation system	14	1.3	2.6	14	1.1	2.5
	Implantation of drug delivery infusion pump	2	0.2	0.4	4	0.3	0.7
	Neurotomy (selective)	2	0.2	0.4	3	0.2	0.5
	Dorsal rhizotomy (selective)	7	0.7	1.3	3	0.2	0.5
	Other functional neurosurgery	117	11.3	21.4	87	7.1	15.3
6203. Dystonia		**337**			**427**		
	Stereotactic neurosurgery (deep brain stimulation)	65	19.3	22.3	55	12.9	15.5
	Stereotactic neurosurgery (ablation)	90	26.7	30.8	163	38.2	46.0
	Stereotactic neurosurgery (focused ultrasound)	2	0.6	0.7	0	0.0	0.0
	Stereotactic neurosurgery (others)	4	1.2	1.4	5	1.2	1.4
	Implantation of spinal cord stimulation system	5	1.5	1.7	5	1.2	1.4
	Implantation of other stimulation system	50	14.8	17.1	48	11.2	13.6
	Implantation of drug delivery infusion pump	4	1.2	1.4	10	2.3	2.8
	Neurotomy (selective)	0	0.0	0.0	4	0.9	1.1
	Dorsal rhizotomy (selective)	0	0.0	0.0	0	0.0	0.0
	Other functional neurosurgery	70	20.8	24.0	64	15.0	18.1
6205. Spasticity		**829**			**1070**		
	Stereotactic neurosurgery (deep brain stimulation)	0	0.0	0.0	1	0.1	0.3
	Stereotactic neurosurgery (ablation)	2	0.2	0.6	2	0.2	0.6
	Stereotactic neurosurgery (focused ultrasound)	0	0.0	0.0	0	0.0	0.0
	Stereotactic neurosurgery (others)	0	0.0	0.0	0	0.0	0.0
	Implantation of spinal cord stimulation system	7	0.8	2.3	3	0.3	0.9
	Implantation of other stimulation system	2	0.2	0.6	1	0.1	0.3
	Implantation of drug delivery infusion pump	217	26.2	70.0	234	21.9	70.1
	Neurotomy (selective)	6	0.7	1.9	12	1.1	3.6
	Dorsal rhizotomy (selective)	9	1.1	2.9	11	1.0	3.3
	Other functional neurosurgery	63	7.6	20.3	67	6.3	20.1
6202. Essential tremor		**277**			**426**		
	Stereotactic neurosurgery (deep brain stimulation)	39	14.1	18.8	51	12.0	15.3
	Stereotactic neurosurgery (ablation)	75	27.1	36.2	116	27.2	34.8
	Stereotactic neurosurgery (focused ultrasound)	34	12.3	16.4	84	19.7	25.2
	Stereotactic neurosurgery (others)	1	0.4	0.5	3	0.7	0.9
	Implantation of spinal cord stimulation system	0	0.0	0.0	1	0.2	0.3
	Implantation of other stimulation system	26	9.4	12.6	33	7.7	9.9
	Implantation of drug delivery infusion pump	0	0.0	0.0	0	0.0	0.0
	Neurotomy (selective)	0	0.0	0.0	0	0.0	0.0
	Dorsal rhizotomy (selective)	0	0.0	0.0	0	0.0	0.0

Table 10 (Continued)

Modality	Mode of operations	2018 Case no.	2018 % (in all admission)	2018 % (in DS Case)	2019 Case no.	2019 % (in all admission)	2019 % (in DS case)
	Other functional neurosurgery	32	11.6	15.5	45	10.6	13.5
6290. Other functional disorders		**2009**			**2440**		
	Stereotactic neurosurgery (deep brain stimulation)	1	0.0	1.1	1	0.0	0.7
	Stereotactic neurosurgery (ablation)	3	0.1	3.2	11	0.5	8.1
	Stereotactic neurosurgery (focused ultrasound)	0	0.0	0.0	0	0.0	0.0
	Stereotactic neurosurgery (others)	1	0.0	1.1	0	0.0	0.0
	Implantation of spinal cord stimulation system	21	1.0	22.1	39	1.6	28.9
	Implantation of other stimulation system	2	0.1	2.1	1	0.0	0.7
	Implantation of drug delivery infusion pump	16	0.8	16.8	14	0.6	10.4
	Neurotomy (selective)	0	0.0	0.0	0	0.0	0.0
	Dorsal rhizotomy (selective)	2	0.1	2.1	0	0.0	0.0
	Other functional neurosurgery	49	2.4	51.6	67	2.7	49.6
6204. Other involuntary movement disorders		**273**			**262**		
	Stereotactic neurosurgery (deep brain stimulation)	17	6.2	32.1	14	5.3	22.6
	Stereotactic neurosurgery (ablation)	7	2.6	13.2	13	5.0	21.0
	Stereotactic neurosurgery (focused ultrasound)	1	0.4	1.9	0	0.0	0.0
	Stereotactic neurosurgery (others)	0	0.0	0.0	0	0.0	0.0
	Implantation of spinal cord stimulation system	2	0.7	3.8	3	1.1	4.8
	Implantation of other stimulation system	8	2.9	15.1	14	5.3	22.6
	Implantation of drug delivery infusion pump	7	2.6	13.2	1	0.4	1.6
	Neurotomy (selective)	0	0.0	0.0	1	0.4	1.6
	Dorsal rhizotomy (selective)	0	0.0	0.0	0	0.0	0.0
	Other functional neurosurgery	11	4.0	20.8	16	6.1	25.8
6190. Other neurovascular compression syndrome		**142**			**145**		
	Other neurovascular compression syndrome	56	39.4	91.8	55	37.9	90.2
	Others	4	2.8	6.6	6	4.1	9.8

DS: direct surgery, JND: Japan Neurosurgical Database, TLE: temporal lobe epilepsy, MST: multiple subpial transection, MRI: magnetic resonance imaging.

seizure and epilepsy control are used for a wider range of the major classifications. Although individual drug names are not included in this database, such information may be useful for designing clinical research and market research for new drug development. Notably, neurointensive treatment under monitoring (6.5% of all cases in 2019) is performed mainly for cerebrovascular diseases and neurotrauma. Various studies involving 40,000 patients have suggested that outcomes are improved when patients who have neurocritical conditions (e.g., stroke and traumatic brain injury) are cared for in specialized neurointensive care units, especially with the involvement of neurointensivists.[5] A previous study using data from the Japan Neurotrauma Data Bank showed that the management and monitoring of intracranial pressure are both important for the management and care of severe brain injury.[6] Further studies are required to investigate the effect of neurocritical care and quality assessment on patient outcomes, especially after stroke and neurotrauma.

Neurosurgical emergencies are an important cause of disability and mortality. In the JND, direct admission from home comprised the largest proportion

Table 11 Case volume of DS for encephalopathy/infection/inflammatory/miscellaneous diseases in the JND in 2018 and 2019

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS case)	Case no.	% (in all admission)	% (in DS case)
7901. Others		**11713**			**13897**		
	Others (e.g., tracheostomy)	1430	12.2	84.5	2059	14.8	88.4
7304. Bacterial infection – other bacterial infection		**1759**			**1809**		
	Removal	209	11.9	26.2	227	12.5	25.3
	Drainage	75	4.3	9.4	92	5.1	10.2
	Others	495	28.1	62.1	571	31.6	63.5
7302. Bacterial infection – cerebral abscess		**822**			**890**		
	Removal	241	29.3	31.3	311	34.9	35.8
	Drainage	423	51.5	54.9	447	50.2	51.4
	Others	97	11.8	12.6	104	11.7	12.0
7303. Bacterial infection – subdural empyema		**493**			**514**		
	Removal	173	35.1	34.6	210	40.9	39.0
	Drainage	214	43.4	42.8	213	41.4	39.6
	Others	104	21.1	20.8	111	21.6	20.6
7601. Other infectious diseases		**884**			**1081**		
	Biopsy	8	0.9	2.5	15	1.4	4.1
	Others	281	31.8	89.5	317	29.3	87.3
7301. Bacterial infection – meningitis		**626**			**677**		
	Removal	9	1.4	4.4	11	1.6	5.8
	Drainage	24	3.8	11.8	44	6.5	23.2
	Others	162	25.9	79.4	131	19.4	68.9
7703. Inflammatory diseases – angiitis		**100**			**125**		
	Biopsy	72	72.0	96.0	100	80.0	98.0
	Others	2	2.0	2.7	2	1.6	2.0
7705. Inflammatory diseases – other inflammatory diseases		**400**			**406**		
	Biopsy	66	16.5	64.7	67	16.5	67.0
	Others	29	7.3	28.4	31	7.6	31.0
7701. Inflammatory diseases – degenerative diseases		**202**			**220**		
	Biopsy	35	17.3	83.3	27	12.3	84.4
	Others	6	3.0	14.3	4	1.8	12.5
7202. Viral infection – encephalitis		**248**			**254**		
	Biopsy	7	2.8	50.0	11	4.3	68.8
	Others	7	2.8	50.0	4	1.6	25.0
7702. Inflammatory diseases – collagen diseases		**50**			**34**		
	Biopsy	13	26.0	81.3	13	38.2	92.9
	Others	0	0.0	0.0	1	2.9	7.1

Table 11 (Continued)

Modality	Mode of operations	2018			2019		
		Case no.	% (in all admission)	% (in DS case)	Case no.	% (in all admission)	% (in DS case)
7201. Viral infection – meningitis		**667**			**815**		
	Biopsy	2	0.3	18.2	2	0.2	18.2
	Others	9	1.3	81.8	9	1.1	81.8
7704. Inflammatory diseases – sarcoidosis		**21**			**17**		
	Biopsy	4	19.0	50.0	10	58.8	100.0
	Others	3	14.3	37.5	0	0.0	0.0
7204. Viral infection – other virus infection		**236**			**246**		
	Biopsy	4		66.7	3	1.2	33.3
	Others	2		33.3	6	2.4	66.7
7501. Neurosyphilis		**5**			**6**		
	Biopsy	0	0.0	0.0	0	0.0	0.0
	Others	1	20.0	100.0	2	33.3	100.0
7401. Tuberculosis		**21**			**16**		
	Biopsy	3	14.3	33.3	1	6.3	50.0
	Others	6	28.6	66.7	1	6.3	50.0
7203. Viral infection – slow virus infection		**13**			**9**		
	Biopsy	2		100.0	0		0.0
	Others	0		0.0	2		100.0

DS: direct surgery, JND: Japan Neurosurgical Database.

regarding the route of admission, and a high proportion of emergency admission and ambulance use suggest the significant involvement of acute care in neurosurgery, as seen in other countries.[7] A previous study from the US showed that acute cerebrovascular diseases, intracranial injury, spinal cord injury, and occlusion/stenosis of precerebral arteries requiring emergency neurosurgery carry an important nationwide burden in terms of complications, deaths, charges, and length of stay.[8] Further studies are necessary to examine the national burden of neurosurgical conditions requiring neurosurgical procedures in Japan.

The JND as an infrastructure of multicenter clinical research

With the ongoing transition from a fee-for-service to a quality-based healthcare system, the use of "big data" in neurosurgical clinical research has become increasingly popular.[9–16] One method of capturing outcomes has been through the use of administrative databases. A previous study in 2018 from the US showed that a total of 324 articles were identified since 2000 with an exponential increase since 2011.[17] In the US, the National Inpatient Sample was the most commonly used database with an average study size of 114841 subjects.[17] When categorizing study objectives, "outcomes" was the most common one.[17] Between quality-based reimbursement policies and outcomes reporting on a national scale in the US, it appears that the efforts of clinical researchers are directed at using this nationwide data for population-level analysis worldwide.

In Japan, the Diagnosis Procedure Combination (DPC), a mixed-case patient classification system, was launched in 2002 by the Japanese Ministry of Health, Labour and Welfare and is linked with a hospital financing system.[14] By 2015, the DPC system had been adopted by an estimated 1580 acute care hospitals, representing approximately half of all Japanese hospital beds and encompassing a wide variety of centers, including rural and urban, academic and nonacademic, and small and large hospitals. Since 2014, several study groups in collaboration with the JNS and other relevant societies have published papers on various aspects of real-world neurosurgical and stroke practices.[9–11,13,15,16,18]

Unlike such administrative databases, the JND data are unique in that this database was created

by the database committee of the JNS for specific purposes as reported previously.[1] Although no central review of the registered data has been conducted, the registered data are validated by neurosurgeons. Overall, the patient demographics and short-term clinical outcomes based on the major classifications remained unchanged in 2018 and 2019. Considering the high proportion of participating hospitals in the JND among the training institutions of the JNS, these findings suggest that the JND data may be useful to calculate the crude incidence of neurosurgical diseases and procedures in Japan. Some of the emerging trends in this paper, however, such as the increased use of intravenous recombinant tissue plasminogen activator administration and mechanical thrombectomy for acute ischemic stroke are consistent with previous reports in response to the movement toward nationwide implementation of primary stroke centers in Japan.[11,19] Notably, we found that in the modern endovascular era, endovascular treatment comprised approximately half of all neurosurgical procedures in Japan.[20] The increased use of flow diverters for cerebral aneurysms is also compatible with recent reports worldwide.[21]

Due to the limited data sources of the current form of the JND, the granularity and specificity of the data related to neurosurgical procedures and practices are limited. Therefore, the types of clinical research that could be performed are limited to practice patterns, utilization, and broad assessments of safety or outcomes for a class of procedures.[22,23] For example, the higher proportion of neurotrauma in the neurosurgical subgroup observed among patients aged 80–89 years is consistent with the result of a previous nationwide study on CSDH in Japan using the DPC database.[16] In this paper, the authors estimated that the annual incidence of newly diagnosed CSDH is approximately 24000 cases/year and enrolled 63000 CSDH for a 3-year (2010–2013) study period. However, the JND database showed that burr hole irrigation for CSDH was performed in approximately 40000 cases in Japan. Even though the recurrence rate is estimated to be approximately 13%,[16] the actual incidence of newly diagnosed CSDH in Japan might be higher than that reported previously. This may be partly because aging of the Japanese population has accelerated in the last 10 years. Thus, the JND data are useful to examine clinical epidemiology of neurosurgical diseases and discuss selection bias in future studies in Japan.

The JND was originally designed to have a multi-layered database, and the statistics of the first-layer database, covering all fields of subspecialties, is described in this paper.[1] Relevant societies of the subspecialties of the JNS published the paper using clinical registries such as the Japanese Registry of Neuroendovascular Therapy,[19,20,24] the Brain Tumor Registry of Japan,[25,26] the Japan Neurotrauma Data Bank,[6,27] and registries of pediatric neurosurgery,[28,29] functional neurosurgery,[30,31] unruptured aneurysms and cerebrovascular surgery,[32,33] moyamoya diseases,[34–36] and stereotactic radiosurgery.

The Launching Effectiveness Research to Guide Practice in Neurosurgery Workshop was held in 2015 by the National Institute of Neurological Disorders and Stroke.[37] The workshop concluded that in the future, advances in information technology such as electronic health records could lead to creation of a massive database where clinical data from all neurosurgeons are integrated and analyzed, ending the separation of clinical research and practice and leading to a new "science of principle."[37,38] Recently, a novel method of measuring the quality of stroke care was developed (the Close The Gap-Stroke) by combining health insurance claim data with data from electronic health records.[13] Further efforts are necessary to promote clinical research using the JND, in collaboration with relevant stakeholders and experts all over Japan.

Neurosurgical registries for advancing quality and device surveillance

The improvement of quality and outcomes of neurosurgery depends primarily on persuading neurosurgeons to change their practice for the better. The Society of Cardiothoracic Surgeons of Great Britain and Ireland, in response to the reports of the public inquiry into children's heart surgery at the British Royal Infirmary, launched the national quality improvement initiatives in cardiovascular surgery. The Society of British Neurological Surgeons established the Neurosurgical National Audit Programme in 2013 as part of a major quality improvement initiative to support neurosurgical units in the UK and Ireland.[39] Similarly, the Quality Outcomes Database, formerly known as the National Neurosurgery Quality and Outcomes Database, was established in the US by the NeuroPoint Alliance in collaboration with relevant national stakeholders and experts to collect, measure, and analyze practice patterns and neurosurgical outcomes, and the Quality and Outcomes Database's spine modules have evolved into the largest North American spine registries.[40–42] The JND will provide the national benchmark on the quality of neurosurgical practices and make international comparison possible in all kinds of neurosurgical procedures.

Apart from the collection of data for performance of surgeons and institutions, registries have a major

and important capacity to provide information about medical devices and, in particular, about implants that are an integral part of surgical care.[43] In 2018, as the second tier of the JND database, the JNS launched two multicenter prospective observation studies focusing on neurosurgical devices with monitoring systems that ensure data reliability. These registrations have been developed for the use of clinical researches on cervical artificial disc replacement surgery (study name: a multicenter study on the efficacy and safety of a cervical artificial disc replacement) and pediatric ventriculoperitoneal shunt (study name: an evaluation of the therapeutic effect of a ventricular peritoneal shunt on pediatric hydrocephalus). Highly reliable registrations are carried out by the committee on medical device registries of the JNS, using the REDCap electron data capture system under the standard operating procedures. Some data of cervical artificial disc replacement surgery will be used for post-marketing surveillance. The initial registration for cervical artificial disc replacement with one intervertebral level surgery has been completed in 54 cases throughout 17 institutions as post-marketing surveillance following government regulations, and an additional 27 cases registered for a JNS initiative study. Regarding the registration of pediatric ventriculoperitoneal shunts, 114 cases have been registered throughout 42 institutions. These registries include detailed device-specific information, clinical demographics, outcomes, and key imaging studies from DICOM data. In the future, the JNS will increase the number of such medical device registries complying with Good Clinical Practice and ministerial ordinance on Good Post-marketing Study Practice in collaboration with industries.

Limitations of the JND Data

Although the JND data from hospital records comprise an important part of the available sources of information of epidemiologic studies on neurosurgical practices, some limitations exist. First, hospital admissions are selective in relation to personal characteristics, severity of diseases, associated conditions, and admission policies. Second, the JND data are not designed for specific research, so they may be incomplete or missing and variable with respect to the diagnostic quality of records. Thus, if we wish to combine data from different hospitals, problems of comparability may be encountered. Third, the population at risk (denominator) is generally not defined. Although all hospitals in Japan belong to the secondary medical area, the catchment area of neurosurgical practice may differ based on the subspeciality and necessity of emergent medical services (e.g., ruptured aneurysm and epilepsy). Further, patients with some diseases related to neurosurgical practices (e.g., stroke, spinal diseases, and epilepsy) may also be admitted to and treated by other medical departments.

Conclusions

The JND statistical update 2018–2019 represents a critical resource for the lay public, policy makers, media professionals, neurosurgeons, healthcare administrators, researchers, health advocates, and others seeking the best available data on neurosurgical practices. The findings of the JND may provide important insights into achieving better treatment outcomes, quality of care, patient safety, education, and research and development activities for Japanese neurosurgeons in the future.

Supplementary Material

The participating institutions are listed in Supplementary Table 1 (available online).

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Conflicts of Interest Disclosure

The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication. All authors have no conflicts of interest.

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