The Japan Neurosurgical Database: Statistics Update 2018 and 2019

Koji IHIARA, Nobuhito SAITO, Michiyasu SUZUKI, Isao DATE, Yukihiro FUJII, Kiyohiro HOUKIN, Tooru INOUE, Toru IWAMA, Takakazu KAWAMATA, Phyo KIM, Hiroyuki KINOUCHI, Haruhioko KISHIMA, Nobuhiro MIKUNI, Susumu MIYAMOTO, Akio MORITA, Hiroyuki NAKASE, Yoshitaka NARITA, Ryo NISHIKAWA, Kazuhiro NOZAKI, Kuniaki OGASAWARA, Kenji OHATA, Nobuyuki SAKAI, Hiroaki SAKAMOTO, Yoshiaki SHIOKAWA, Jun C. TAKAHASHI, Keisuke UEKI, Toshihiko WAKABAYASHI, Koji YOSHIMOTO, Hajime ARAI, Teiji TOMINAGA, and on behalf of the Japan Neurosurgical Society

1Department of Neurosurgery, National Cerebral and Cardiovascular Center, Suita, Osaka, Japan
2Department of Neurosurgery, The University of Tokyo, Tokyo, Japan
3Department of Advanced ThermoNeuroBiology, Yamaguchi University Graduate School of Medicine, Ube, Yamaguchi, Japan
4Department of Neurological Surgery, Okayama University Graduate School of Medicine, Okayama, Okayama, Japan
5Department of Neurosurgery, Brain Research Institute, Niigata University, Niigata, Niigata, Japan
6Department of Neurosurgery, Hokkaido University Graduate School of Medicine, Sapporo, Hokkaido, Japan
7Department of Neurosurgery, Fukuoka University School of Medicine, Fukuoka, Fukuoka, Japan
8Department of Neurosurgery, Gifu University School of Medicine, Gifu, Gifu, Japan
9Department of Neurosurgery, Tokyo Women’s Medical University, Tokyo, Japan
10Department of Neurologic Surgery, Utsunomiya Neurospine Center, Utsunomiya, Tochigi, Japan
11Department of Neurosurgery, University of Yamanashi Interdisciplinary Graduate School of Medicine, Chuo, Yamanashi, Japan
12Department of Neurosurgery, Osaka University Graduate School of Medicine, Suita, Osaka, Japan
13Kinki Central Hospital of the Mutual Aid Association of Public School Teachers, Itami, Hyogo, Japan
14Department of Neurosurgery, Chugoku Rosai Hospital, Kure, Hiroshima, Japan
15Department of Neurosurgery, Kyorin University, School of Medicine, Mitaka, Tokyo, Japan
16Department of Neurosurgery, Faculty of Medicine, University of Tsukuba, Tsukuba, Ibaraki, Japan
17Department of Neurosurgery, Sapporo Medical University, Sapporo, Hokkaido, Japan
18Department of Neurosurgery, Sapporo Medical University, Sapporo, Hokkaido, Japan
19Department of Neurosurgical Science, Nippon Medical School, Tokyo, Japan
20Department of Neurosurgery, Nara Medical University, Kashiwara, Nara, Japan
21Department of Neurosurgery and Neuro-Oncology, National Cancer Center Hospital, Tokyo, Japan
22Department of Neuro-Oncology/Neurosurgery, Saitama Medical University International Medical Center, Hidaka, Saitama, Japan
23Department of Neurosurgery, Shiga University of Medical Science, Otsu, Shiga, Japan
24Department of Neurosurgery, Iwate Medical University, Morioka, Iwate, Japan
25Naniwa Ikuno Hospital, Osaka, Osaka, Japan
26Department of Neurosurgery, Kobe City Medical Center General Hospital, Kobe, Hyogo, Japan
27Department of Pediatric Neurosurgery, Osaka City General Hospital, Osaka, Osaka, Japan

Copyright © 2021 The Japan Neurosurgical Society
This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives International License.
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. Unlike the National Neurosurgery Quality and Outcomes Database in the US and the Neurosurgical National Audit Program in the UK, 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.

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. 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. 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 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. 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%)
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** | | | | |
| 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)** | | | | |
| 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)** | | | | |
| 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)** | | | | |
| 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)** | | | | |
| 6. Obey 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

| Route of admission | 2018 | 2019 |
|--------------------|------|------|
| 1. In-hospital referral from other department | 13531 | 2.6 |
| 2. Direct admission from patient home | 434591 | 83.1 |
| 3. Transfer from other hospital or clinic | 46440 | 8.9 |
| 4. Transfer from nursing home, welfare facility | 24263 | 4.6 |
| 5. In-hospital birth | 195 | 0.0 |
| 6. Others | 4263 | 0.8 |

#### Scheduled/emergent admission

| Scheduled/emergent admission | 2018 | 2019 |
|------------------------------|------|------|
| Scheduled | 165390 | 31.6 |
| Emergent admission | 357893 | 68.4 |

#### Ambulance use

| Ambulance use | 2018 | 2019 |
|---------------|------|------|
| No | 290089 | 55.4 |
| Yes | 233194 | 44.6 |

#### Destination of discharge

| Destination of discharge | 2018 | 2019 |
|--------------------------|------|------|
| 1. In-hospital other department | 20319 | 3.9 |
| 2. Home | 333169 | 63.7 |
| 3. Transfer to other hospital | 115249 | 22.0 |
| 4. Geriatric health services facility | 14836 | 2.8 |
| 5. Nursing home other than hospitals | 13482 | 2.6 |
| 6. In-hospital death | 25162 | 4.8 |
| 7. Others | 1066 | 0.2 |

#### mRS at discharge

| mRS at discharge | 2018 | 2019 |
|------------------|------|------|
| 0. No symptoms | 144947 | 27.7 |
| 1. No significant disability. Able to carry out all usual activities, despite some symptoms | 116821 | 22.3 |
| 2. Slight disability. Able to look after own affairs without assistance, but unable to carry out all previous activities | 77996 | 14.9 |
| 3. Moderate disability. Requires some help, but able to walk unassisted. | 59199 | 11.3 |
| 4. Moderately severe disability. Unable to attend to own bodily needs without assistance and unable to walk unassisted | 62737 | 12.0 |
| 5. Severe disability. Requires constant nursing care and attention, bedridden, incontinent | 36245 | 6.9 |
| 6. Dead | 25338 | 4.8 |

#### GOS at discharge

| GOS at discharge | 2018 | 2019 |
|------------------|------|------|
| 1. Dead | 3492 | 5.5 |
| 2. Vegetative state | 1194 | 1.9 |
| 3. Severely disabled | 13757 | 21.7 |
| 4. Moderately disabled | 7839 | 12.4 |
| 5. Good recovery | 35025 | 55.3 |

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

| Purpose of admission                  | Case no. | %   | Case no. | %   |
|--------------------------------------|----------|-----|----------|-----|
| Overall cohort                       | 523283   |     | 571423   |     |
| 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    |          |     |          |     |
| 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                   |          |     |          |     |
| 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                         |          |     |          |     |
| 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                                  |          |     |          |     |
| 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 |
| Whole brain | 1416 | 0.3 |
| Whole spinal | 67   | 0.0 |
| Others (proton, heavy particle radiotherapy) | 54   | 0.0 |

Other adjuvant therapy for brain tumors

| 2018 | 2019 |
|------|------|
| Immunotherapy | 56   | 0.0 |
| Optune | 19   | 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 chordrosarcoma, 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%.
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).
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, 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                      |
|--------------------------------|------------------------------------------------|---------------------------|---------------------------|
| 2001. Cerebral aneurysm        | DS Neck clipping                               | 52292 case no.            | 56466 case no.            |
|                                | For ruptured                                   | 15426 Case no.            | 15305 Case no.            |
|                                | For ruptured                                   | 7819 % (in all admission) | 7551 % (in all admission) |
|                                | For ruptured                                   | 388 % (in DS/EVT case)    | 362 % (in DS/EVT case)    |
|                                | For ruptured                                   | 116 % (in DS/EVT case)    | 132 % (in DS/EVT case)    |
|                                | For ruptured                                   | 228 % (in DS/EVT case)    | 238 % (in DS/EVT case)    |
|                                | For ruptured                                   | 111 % (in DS/EVT case)    | 113 % (in DS/EVT case)    |
|                                | DS Trapping                                    | 325 Case no.              | 278 Case no.              |
|                                | For ruptured                                   | 238 % (in DS/EVT case)    | 182 % (in DS/EVT case)    |
|                                | For ruptured                                   | 378 % (in DS/EVT case)    | 362 % (in DS/EVT case)    |
|                                | For ruptured                                   | 186 % (in DS/EVT case)    | 158 % (in DS/EVT case)    |
|                                | For ruptured                                   | 1028 Case no.             | 1013 Case no.             |
|                                | For ruptured                                   | 228 % (in DS/EVT case)    | 32.0 % (in DS/EVT case)   |
|                                | For ruptured                                   | 922 % (in DS/EVT case)    | 917 % (in DS/EVT case)    |
|                                | DS Bypass (combined)                           | 3496 Case no.             | 4166 Case no.             |
|                                | For ruptured                                   | 724 % (in DS/EVT case)    | 820 % (in DS/EVT case)    |
|                                | For ruptured                                   | 423 % (in DS/EVT case)    | 543 % (in DS/EVT case)    |
|                                | For ruptured                                   | 4 % (in DS/EVT case)      | 14 % (in DS/EVT case)     |
|                                | For ruptured                                   | 283 Case no.              | 308 Case no.              |
|                                | For ruptured                                   | 205 % (in DS/EVT case)    | 227 % (in DS/EVT case)    |
|                                | EVT Coil embolization (w/o stent)              | 9794 Case no.             | 10671 Case no.            |
|                                | For ruptured                                   | 5210 % (in DS/EVT case)   | 5653 % (in DS/EVT case)   |
|                                | EVT Coil embolization (with stent)             | 3496 Case no.             | 4166 Case no.             |
|                                | For ruptured                                   | 724 % (in DS/EVT case)    | 820 % (in DS/EVT case)    |
|                                | EVT Flow diverter                               | 423 % (in DS/EVT case)    | 543 % (in DS/EVT case)    |
|                                | For ruptured                                   | 4 % (in DS/EVT case)      | 14 % (in DS/EVT case)     |
|                                | EVT Others                                      | 283 % (in DS/EVT case)    | 308 % (in DS/EVT case)    |
|                                | For ruptured                                   | 205 % (in DS/EVT case)    | 227 % (in DS/EVT case)    |
|                                | EVT Endovascular therapy for cerebral           | 1178 Case no.             | 1278 Case no.             |
|                                | vasospasm (ruptured cases only)                | 2.3 % (in all admission)  | 2.3 % (in all admission)  |
| 2012. Ischemic stroke/transient| Magnetic resonance angiography                  | 127361 case no.           | 144999 case no.           |
| ischemic attack                | Intravenous t-PA infusion                      | 6832 % (in all admission) | 8830 % (in all admission) |
|                                | EVT Acute reperfusion therapy                  | 9740 % (in all admission) | 12493 % (in all admission)|
|                                | DS Decompression craniectomy                   | 1304 % (in all admission) | 1456 % (in all admission) |
|                                | Others                                         | 769 % (in all admission)  | 748 % (in all admission)  |
| 2005. Carotid stenosis (cervical) | DS Endarterectomy                             | 3766 % (in all admission) | 4053 % (in all admission) |
|                                | DS STA–MCA bypass                              | 314 % (in all admission)  | 373 % (in all admission)  |
|                                | DS Other bypass surgery                        | 25 % (in all admission)   | 24 % (in all admission)   |
|                                | EVT Carotid stenting                           | 7595 % (in all admission) | 8471 % (in all admission) |
|                                | EVT Percutaneous angioplasty (w/o stenting)    | 585 % (in all admission)  | 679 % (in all admission)  |
|                                | EVT Percutaneous angioplasty (w/o stenting)    | 129 % (in all admission)  | 101 % (in all admission)  |
| 2009. Hypertensive intracerebral hemorrhage | DS Removal of hematoma                      | 7312 % (in all admission) | 7900 % (in all admission) |
| 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          | 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          | 1165     | 21.7                 | 53.4                   | 1345     | 22.3                 | 54.1                   |
| DS          | 8        | 0.1                  | 0.4                    | 8        | 0.1                  | 0.3                    |
| DS          | 32       | 0.6                  | 1.5                    | 32       | 0.5                  | 1.3                    |
| EVT         | 343      | 6.4                  | 15.7                   | 436      | 7.2                  | 17.5                   |
| EVT         | 491      | 9.1                  | 22.5                   | 567      | 9.4                  | 22.8                   |
| EVT         | 92       | 1.7                  | 4.2                    | 75       | 1.2                  | 3.0                    |
| **2003. Dural arteriovenous fistula** | **4184** |                      |                        | **4735** |                      |                        |
| DS          | 258      | 6.2                  | 12.3                   | 273      | 5.8                  | 12.2                   |
| EVT         | 1752     | 41.9                 | 83.2                   | 1914     | 40.4                 | 85.4                   |
| DS          | 56       | 1.3                  | 2.7                    | 51       | 1.1                  | 2.3                    |
| DS          | 57       | 1.4                  | 2.7                    | 42       | 0.9                  | 1.9                    |
| **2002. Cerebral arteriovenous malformation** | **3647** |                      |                        | **4080** |                      |                        |
| DS          | 842      | 23.1                 | 44.1                   | 909      | 22.3                 | 43.3                   |
| EVT         | 772      | 21.2                 | 40.4                   | 890      | 21.8                 | 42.4                   |
| DS          | 297      | 8.1                  | 15.5                   | 305      | 7.5                  | 14.5                   |
| DS          | 132      | 3.6                  | 6.9                    | 136      | 3.3                  | 6.5                    |
| **2008. Moyamoya disease** | **4274** |                      |                        | **4837** |                      |                        |
| DS          | 1301     | 30.4                 | 70.1                   | 1378     | 28.5                 | 69.0                   |
| DS          | 974      | 22.8                 | 52.5                   | 1023     | 21.1                 | 51.2                   |
| DS          | 138      | 3.2                  | 7.4                    | 151      | 3.1                  | 7.6                    |
| DS          | 133      | 3.1                  | 7.2                    | 135      | 2.8                  | 6.8                    |
| DS          | 73       | 1.7                  | 3.9                    | 67       | 1.4                  | 3.4                    |
| **2010. Nonhypertensive intracerebral hemorrhage (excluding moyamoya disease and vascular malformation)** | **6797** |                      |                        | **7012** |                      |                        |
| DS          | 1198     | 17.6                 | 76.3                   | 1250     | 17.8                 | 81.3                   |
| DS          | 219      | 3.2                  | 13.9                   | 185      | 2.6                  | 12.0                   |
| DS          | 148      | 2.2                  | 9.4                    | 124      | 1.8                  | 8.1                    |
| **2014. Skull defect (after external decompression)** | **1149** |                      |                        | **1419** |                      |                        |
| DS          | 1125     | 97.9                 | 97.8                   | 1398     | 98.5                 | 98.3                   |
| **2006. Extracranial arterial occlusive disease (excluding cervical carotid stenosis)** | **2084** |                      |                        | **2177** |                      |                        |
| DS          | 37       | 1.8                  | 2.0                    | 41       | 1.9                  | 4.0                    |
| DS          | 257      | 12.3                 | 13.8                   | 303      | 13.9                 | 29.7                   |
| DS          | 1        | 0.0                  | 0.1                    | 1        | 0.0                  | 0.1                    |
| DS          | 42       | 2.0                  | 2.3                    | 46       | 2.1                  | 4.5                    |
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                | Removal                                         | 10383 | 53.0 | 74.9 | 5596 | 53.9 | 74.1 |
|                                 | Biopsy                                          | 5501 | 0.3 | 0.4 | 5965 | 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    | Removal                                         | 17297 | 17.5 | 84.6 | 3210 | 18.8 | 85.7 |
|                                 | Biopsy                                          | 3025 | 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         | Removal                                         | 4204 | 15.2 | 20.4 | 795 | 17.4 | 23.5 |
|                                 | Biopsy                                          | 638 | 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              | Removal                                         | 6924 | 31.0 | 78.7 | 2325 | 30.2 | 79.3 |
|                                 | Biopsy                                          | 2149 | 5.6 | 14.3 | 441 | 5.7 | 15.0 |
|                                 | Transnasal surgery                              | 390 | 0.0 | 0.0 | 3 | 0.0 | 0.1 |
|                                 | Extensive skull base tumor resection reconstruction | 1 | 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                | Removal                                         | 2821 | 50.3 | 91.7 | 1483 | 48.2 | 90.5 |
|                                 | Biopsy                                          | 1419 | 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 | Case no. | % (in all admission) | % (in DS/EVT case) | 2019 | 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 |
| 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 | 0 | 0.0 | 0.0 |
| 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 |
| 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 | 2019 |
|----------|--------------------|------|------|
|          | Case no. | % (in all admission) | % (in DS/EVT case) | Case no. | % (in all admission) | % (in DS/EVT case) |
| 1303. Skull defect after decompression | 88 | 93.2 | 95.3 | 98 | 111 | 113.3 | 96.5 |
| 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 | 1 | 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 | 2019 |
|----------|--------------------|------|------|
|          | Case no. | % (in all admission) | % (in DS/EVT case) | Case no. | % (in all admission) | % (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 |
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 (angitis). Contrastingy, 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 | 2018 | 2019 |
|---------------------------------|-------------------|------|------|------|------|
|                                 | Case no. | % (in all admission) | % (in DS case) | Case no. | % (in all admission) | % (in DS case) |
| 4002. Acquired (secondary) hydrocephalus | 10268 | 45.3 | 41.5 | 10951 | 44.7 | 40.9 |
| VP shunt                        | 4650     | 1.5 | 1.3 | 4122 | 1.5 | 1.3 |
| LP shunt                        | 1641     | 4.8 | 4.4 | 1745 | 5.1 | 4.7 |
| VA shunt                        | 424      | 4.1 | 3.8 | 468  | 4.3 | 3.9 |
| Shunt revision                  | 3051     | 29.7 | 27.2 | 3394 | 31.0 | 28.3 |
| Third ventriculostomy           | 488      | 4.8 | 4.4 | 584  | 5.3 | 4.9 |
| Ventricular drainage            | 140      | 1.8 | 1.2 | 250  | 1.8 | 1.2 |
| Shunt removal                   | 27       | 1.0 | 1.0 | 639  | 1.8 | 1.2 |
| Others                          | 133      | 12.7 | 13.4 | 83   | 8.2 | 9.7 |
| 4003. Idiopathic normal pressure hydrocephalus | 7673 | 25.0 | 43.7 | 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 | 36.4 | 38.6 | 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 | 54.8 | 91.2 | 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 | 20.2 | 27.4 | 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 | 38.8 | 79.1 | 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 | 63.9 | 93.0 | 336  | |
| Foramen magnum decompression    | 212      | 63.9 | 93.0 | 185  | 55.1 | 91.1 |
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 neurological 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

---

| 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.
| Modality                                      | Mode of operations                                      | 2018 Case no. | % (in all admission) | % (in DS/EVT case) | 2019 Case no. | % (in all admission) | % (in DS/EVT case) |
|----------------------------------------------|---------------------------------------------------------|---------------|----------------------|---------------------|---------------|----------------------|---------------------|
| 5100. Spinal degenerative disorders          | Anterior decompression                                  | 15734         | 904                  | 5.7                 | 902           | 4.7                  | 5.8                 |
|                                              | Anterior fixation                                      | 1533          | 1533                 | 9.7                 | 1710          | 9.0                  | 11.0                |
|                                              | Posterior decompression                                | 7654          | 7654                 | 48.6                | 9342          | 49.1                 | 60.3                |
|                                              | Posterior fixation                                     | 2209          | 2209                 | 14.0                | 2622          | 13.8                 | 16.9                |
|                                              | Discectomy                                              | 2194          | 2194                 | 13.9                | 2354          | 12.4                 | 15.2                |
|                                              | Simultaneous anterior and posterior decompression       | 264           | 264                  | 1.7                 | 257           | 1.3                  | 1.7                 |
|                                              | Others                                                  | 756           | 756                  | 4.8                 | 1045          | 5.5                  | 6.8                 |
| 5503. Spinal trauma – vertebral compression  | Anterior decompression                                  | 3309          | 18                   | 0.5                 | 13            | 0.3                  | 0.7                 |
| fracture                                     | Posterior decompression                                | 103           | 103                  | 3.1                 | 120           | 3.0                  | 6.7                 |
|                                              | Fixation                                                | 354           | 354                  | 10.7                | 442           | 11.0                 | 24.7                |
|                                              | Percutaneous vertebroplasty                             | 959           | 959                  | 29.0                | 1283          | 31.9                 | 71.7                |
|                                              | Others                                                  | 108           | 108                  | 3.3                 | 121           | 3.0                  | 6.8                 |
| 5701. Peripheral nerve disorders – carpal    | Release surgery                                         | 528           | 358                  | 67.8                | 403           | 71.5                 | 71.2                |
| tunnel syndrome                              | Others                                                  | 177           | 177                  | 33.5                | 137           | 24.3                 | 24.2                |
| 5890. Other spinal and peripheral nerve      | Posterior fixation                                      | 1395          | 117                  | 8.4                 | 66            | 5.1                  | 12.6                |
| disorders                                    | Simultaneous anterior and posterior decompression       |               | 5                    | 0.4                 | 3             | 0.2                  | 0.6                 |
|                                              | Others                                                  | 535           | 535                  | 38.4                | 440           | 33.7                 | 84.3                |
| 5202. Spinal tumor – extramedullary tumor    | Total/subtotal removal                                  | 510           | 390                  | 76.5                | 429           | 75.9                 | 91.3                |
| (intradural confined)                        | Partial removal                                         | 36            | 36                   | 7.1                 | 28            | 5.0                  | 6.0                 |
|                                              | Biopsy                                                  | 2             | 2                    | 0.4                 | 0             | 0.0                  | 0.0                 |
|                                              | Others                                                  | 15            | 15                   | 2.9                 | 6             | 1.1                  | 1.3                 |
| 5590. Spinal trauma – other spinal trauma    | Anterior decompression                                  | 897           | 28                   | 3.1                 | 22            | 1.9                  | 5.5                 |
|                                              | Posterior decompression                                 | 134           | 134                  | 14.9                | 158           | 13.9                 | 39.8                |
|                                              | Fixation                                                | 179           | 179                  | 20.0                | 217           | 19.1                 | 54.7                |
|                                              | Percutaneous vertebroplasty                             | 27            | 27                   | 3.0                 | 18            | 1.6                  | 4.5                 |
|                                              | Others                                                  | 70            | 70                   | 7.8                 | 83            | 7.3                  | 20.9                |
| 5201. Spinal tumor – intramedullary tumor    | Total/subtotal removal                                  | 452           | 184                  | 40.7                | 197           | 35.0                 | 59.7                |
|                                              | Partial removal                                         | 47            | 47                   | 10.4                | 72            | 12.8                 | 21.8                |
|                                              | Biopsy                                                  | 20            | 20                   | 4.4                 | 38            | 6.7                  | 11.5                |
|                                              | Others                                                  | 10            | 10                   | 2.2                 | 17            | 3.0                  | 5.2                 |
| Modality | Mode of operations | 2018 |  | 2019 |  |
|----------|-------------------|------|---|------|---|
|          | Case no. | % (in all admission) | % (in DS/ EVT case) | Case no. | % (in all admission) | % (in DS/ EVT case) |
| 5501. Spinal trauma – without bone injury | 1151 | 1225 |
| Anterior decompression | 38 | 12.9 | 28 | 9.2 |
| Posterior decompression | 199 | 67.5 | 214 | 70.4 |
| Fixation | 79 | 26.8 | 82 | 27.0 |
| Percutaneous vertebroplasty | 6 | 2.0 | 10 | 3.3 |
| Others | 22 | 7.5 | 28 | 9.2 |
| 5801. Spinal deformity | 491 | 392 |
| Posterior fixation | 163 | 43.1 | 86 | 33.2 |
| Simultaneous anterior and posterior decompression | 21 | 5.6 | 5 | 1.9 |
| Others | 185 | 48.9 | 160 | 40.8 |
| 5502. Spinal trauma – dislocation fracture | 362 | 367 |
| Anterior decompression | 23 | 9.2 | 17 | 6.7 |
| Posterior decompression | 57 | 22.8 | 57 | 22.4 |
| Fixation | 189 | 75.6 | 190 | 74.8 |
| Percutaneous vertebroplasty | 5 | 2.0 | 15 | 5.9 |
| Others | 41 | 16.4 | 42 | 16.5 |
| 5203. Spinal tumor – extramedullary tumor (extradural and paraspinal extension) | 222 | 297 |
| Total/subtotal removal | 141 | 75.0 | 171 | 71.8 |
| Partial removal | 34 | 18.1 | 45 | 18.9 |
| Biopsy | 3 | 1.6 | 5 | 2.1 |
| Others | 6 | 3.2 | 10 | 4.2 |
| 5401. Spinal vascular diseases – dural arteriovenous fistula | 333 | 392 |
| Arteriovenous fistula obliteration | 97 | 50.8 | 106 | 45.3 |
| Removal | 9 | 4.7 | 23 | 9.8 |
| Others | 6 | 3.1 | 8 | 3.4 |
| EVT Endovascular obliteration | 91 | 47.6 | 111 | 47.4 |
| 5790. Peripheral nerve disorders – other peripheral nerve disorders | 688 | 756 |
| Release surgery | 134 | 67.3 | 138 | 69.0 |
| Others | 63 | 31.7 | 59 | 29.5 |
| 5406. Spinal vascular diseases – extradural hematoma | 210 | 276 |
| Arteriovenous fistula obliteration | 1 | 1.0 | 0 | 0.0 |
| Removal | 58 | 56.9 | 90 | 57.3 |
| Others | 39 | 38.2 | 59 | 37.6 |
| EVT Endovascular obliteration | 1 | 1.0 | 0 | 0.0 |
| 5601. Spinal infection – with abscess formation | 158 | 216 |
| Anterior decompression | 12 | 9.3 | 8 | 5.1 |
| Posterior decompression | 48 | 37.2 | 51 | 32.5 |
| Modality                                | Mode of operations                  | 2018                  | 2019                  |
|-----------------------------------------|-------------------------------------|-----------------------|-----------------------|
|                                         | Case no. | % (in all admission) | % (in DS/EVT case)  | Case no. | % (in all admission) | % (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      |                      |                      |          |                      |                      |
| 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 | | |
| 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 | | |
| 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      |                      |                      |          |                      |                      |
| 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 | | |
| 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 | | |
| 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      |                      |                      |          |                      |                      |
| 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 | | |
| 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                                     | 17       | 33.3                | 54.8                 | 28       | 48.3                | 73.7                 |
| Modality | Mode of operations | 2018 | 2019 |
|----------|-------------------|------|------|
|          | Case no. | % (in all admission) | % (in DS/EVT case) | Case no. | % (in all admission) | % (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 Case no. | % (in all admission) | % (in DS Case) | 2019 Case no. | % (in all admission) | % (in DS Case) |
|------------------------------|----------------------------------------------------------|---------------|----------------------|----------------|---------------|----------------------|----------------|
| 6102. Hemifacial spasm       | Microvascular decompression                              | 1919          | 1739                 | 90.6           | 1815          | 90.0                 | 98.6           |
|                              | Others                                                   | 6101          | 14                   | 0.7            | 22            | 1.1                  | 1.2            |
| 6201. Parkinson’s disease    | Stereotactic neurosurgery (deep brain stimulation)      | 2717          | 606                  | 22.3           | 523           | 18.4                 | 35.0           |
|                              | Stereotactic neurosurgery (ablation)                     |               | 24                   | 0.9            | 26            | 0.9                  | 1.7            |
|                              | Stereotactic neurosurgery (focused ultrasound)           |               | 0                    | 0.0            | 0             | 0.0                  | 0.0            |
|                              | Stereotactic neurosurgery (others)                       |               | 25                   | 0.9            | 12            | 0.4                  | 0.8            |
|                              | Implantation of spinal cord stimulation system           |               | 38                   | 1.4            | 19            | 0.7                  | 1.3            |
|                              | Implantation of other stimulation system                 |               | 374                  | 13.8           | 357           | 12.6                 | 23.9           |
|                              | Implantation of drug delivery infusion pump              |               | 1                    | 0.0            | 1             | 0.0                  | 0.1            |
|                              | Neurotomy (selective)                                   |               | 0                    | 0.0            | 0             | 0.0                  | 0.0            |
|                              | Dorsal rhizotomy (selective)                            |               | 0                    | 0.0            | 0             | 0.0                  | 0.0            |
|                              | Other functional neurosurgery                            |               | 474                  | 17.4           | 546           | 19.2                 | 36.5           |
| 6001. Epilepsy               | Implantation of intracranial electrodes                  | 26121         | 187                  | 0.7            | 246           | 0.9                  | 18.0           |
|                              | Temporal lobectomy (for TLE)                            |               | 144                  | 0.6            | 173           | 0.6                  | 12.6           |
|                              | Selective amygdalohippocampectomy                        |               | 76                   | 0.3            | 83            | 0.3                  | 6.1            |
|                              | Multiple hippocampal transection                         |               | 24                   | 0.1            | 14            | 0.0                  | 1.0            |
|                              | Lobectomy (excluding for TLE, functional or anatomical)  |               | 25                   | 0.1            | 37            | 0.1                  | 2.7            |
|                              | Multilobere resection (functional or anatomical)         |               | 16                   | 0.1            | 37            | 0.1                  | 2.7            |
|                              | Lesionectomy (structural lesion)                         |               | 122                  | 0.5            | 141           | 0.5                  | 10.3           |
|                              | Focus resection (for neocortical epilepsy)               |               | 59                   | 0.2            | 76            | 0.3                  | 5.6            |
|                              | Hemispherectomy (functional or anatomical)              |               | 25                   | 0.1            | 30            | 0.1                  | 2.2            |
|                              | Callosotomy                                              |               | 150                  | 0.6            | 151           | 0.5                  | 11.0           |
|                              | MST                                                      |               | 11                   | 0.0            | 5             | 0.0                  | 0.4            |
|                              | Stereotactic ablation (including laser or MRI guided)    |               | 17                   | 0.1            | 1             | 0.0                  | 0.1            |
|                              | Implantation of vagus nerve stimulation system           |               | 274                  | 1.0            | 247           | 0.9                  | 18.0           |
|                              | Others                                                   |               | 161                  | 0.6            | 195           | 0.7                  | 14.2           |
| 6101. Trigeminal neuralgia   | Microvascular decompression                              | 1656          | 1196                 | 72.2           | 1330          | 72.5                 | 97.9           |
|                              | Others                                                   |               | 20                   | 1.2            | 21            | 1.1                  | 1.5            |
| 6206. Pain                   | Stereotactic neurosurgery (deep brain stimulation)      | 1038          | 2                    | 0.2            | 0             | 0.0                  | 0.0            |
|                              | Stereotactic neurosurgery (ablation)                     |               | 0                    | 0.0            | 1             | 0.1                  | 0.2            |
|                              | Stereotactic neurosurgery (focused ultrasound)          |               | 0                    | 0.0            | 0             | 0.0                  | 0.0            |
|                              | Stereotactic neurosurgery (others)                       |               | 1                    | 0.1            | 0             | 0.0                  | 0.0            |
| 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) |
|--------------------------------------------|---------------------------------------------------------|---------------|---------------------------|---------------------|---------------|---------------------------|---------------------|
| 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                             | 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                           | 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                     | 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                 |
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 10 (Continued)

| Modality | Mode of operations | 2018 | 2019 |
|----------|-------------------|------|------|
|          | Case no. | % (in all admission) | % in DS Case | Case no. | % (in all admission) | % in DS case |
| Other functional neurosurgery | 32 | 11.6 | 15.5 | 45 | 10.6 | 13.5 |
| 6290. Other functional disorders | | | | | | |
| 2009 | | | | | | |
| 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 |
| 2009 | | | | | | |
| 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 |
| 2009 | | | | | | |
| 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.
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 | Others (e.g., tracheostomy) | 11713 | 13897 |
| 7304. Bacterial infection – other bacterial infection | Removal | 1430 | 2059 |
|          | Drainage | 75 | 92 |
|          | Others | 495 | 571 |
| 7302. Bacterial infection – cerebral abscess | Removal | 1759 | 1809 |
|          | Drainage | 129 | 195 |
|          | Others | 80 | 104 |
| 7303. Bacterial infection – subdural empyema | Removal | 247 | 227 |
|          | Drainage | 423 | 447 |
|          | Others | 97 | 104 |
| 7601. Other infectious diseases | Biopsy | 281 | 317 |
|          | Others | 281 | 317 |
| 7301. Bacterial infection – meningitis | Removal | 429 | 227 |
|          | Drainage | 423 | 447 |
|          | Others | 97 | 104 |
| 7703. Inflammatory diseases – angiitis | Biopsy | 100 | 125 |
|          | Others | 2 | 2 |
| 7705. Inflammatory diseases – other inflammatory diseases | Biopsy | 400 | 406 |
|          | Others | 29 | 31 |
| 7701. Inflammatory diseases – degenerative diseases | Biopsy | 202 | 220 |
|          | Others | 7 | 6 |
| 7202. Viral infection – encephalitis | Biopsy | 248 | 254 |
|          | Others | 7 | 4 |
| 7702. Inflammatory diseases – collagen diseases | Biopsy | 50 | 34 |
|          | Others | 0 | 1 |
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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{17} In the US, the National Inpatient Sample was the most commonly used database with an average study size of 114841 subjects.\textsuperscript{17} When categorizing study objectives, “outcomes” was the most common one.\textsuperscript{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.\textsuperscript{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.\textsuperscript{9–11,13,15,16,18}

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

| Table 11 (Continued) |
|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Modality                  | Mode of operations | Case no. | % (in all admission) | % (in DS case) | Case no. | % (in all admission) | % (in DS case) |
|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 7201. Viral infection – meningitis | Biopsy | 667 | 2 | 0.3 | 18.2 | 815 | 2 | 0.2 | 18.2 |
| | Others | 9 | 1.3 | 81.8 | 9 | 1.1 | 81.8 |
| 7704. Inflammatory diseases – sarcoidosis | Biopsy | 21 | 4 | 19.0 | 50.0 | 17 | 10 | 58.8 | 100.0 |
| | Others | 3 | 14.3 | 37.5 | 0 | 0.0 | 0.0 |
| 7204. Viral infection – other virus infection | Biopsy | 236 | 4 | 66.7 | 3 | 1.2 | 100.0 |
| | Others | 2 | 33.3 | 6 | 2.4 | 66.7 |
| 7501. Neurosyphilis | Biopsy | 5 | 0 | 0.0 | 0.0 | 6 | 0 | 0.0 | 0.0 |
| | Others | 1 | 20.0 | 100.0 | 2 | 33.3 | 100.0 |
| 7401. Tuberculosis | Biopsy | 21 | 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 | Biopsy | 13 | 2 | 100.0 | 0 | 9 | 0 | 0.0 | 0.0 |
| | Others | 0 | 0.0 | 2 | 100.0 |

DS: direct surgery, JND: Japan Neurosurgical Database.
by the database committee of the JNS for specific purposes as reported previously.\textsuperscript{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.\textsuperscript{11,19} Notably, we found that in the modern endovascular era, endovascular treatment comprised approximately half of all neurosurgical procedures in Japan.\textsuperscript{20} The increased use of flow diverters for cerebral aneurysms is also compatible with recent reports worldwide.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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\%,\textsuperscript{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.\textsuperscript{11} Relevant societies of the subspecialties of the JNS published the paper using clinical registries such as the Japanese Registry of Neuroendovascular Therapy,\textsuperscript{19,20,24} the Brain Tumor Registry of Japan,\textsuperscript{25,26} the Japan Neurotrauma Data Bank,\textsuperscript{6,27} and registries of pediatric neurosurgery,\textsuperscript{28,29} functional neurosurgery,\textsuperscript{30,31} unruptured aneurysms and cerebrovascular surgery,\textsuperscript{32,33} moyamoya diseases,\textsuperscript{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.\textsuperscript{37} The workshop concluded that in the future, advances in information technology such as electronic health records could lead to the 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.”\textsuperscript{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.\textsuperscript{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 neurological units in the UK and Ireland.\textsuperscript{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.\textsuperscript{40–43} 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. 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).

**Acknowledgments**

Creation of the JND was supported by the Practical Research Project for Life-Style related Diseases including Cardiovascular Diseases and Diabetes Mellitus managed by the Japan Agency for Medical Research and Development (16hk0102037h0001, 17hk0102037h0002, 18hk0102037h0003). We also thank all the collaborators of the 1360 participating hospitals in the JND, Ms. Misa Takegami and Dr. Kunihiro Nishimura (National Cerebral and Cardiovascular Center) for preparing the manuscript, and the secretarial assistance provided by Ms. Kei Watanabe of the JNS.

**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.

**References**

1) Anderson IA, Kailaya-Vasan A, Nelson RJ, Tolias CM: Clipping aneurysms improves outcomes for patients undergoing coiling. *J Neurosurg* 1–7, 2018, ahead of print.
2) Asher AL, McCormick PC, Selden NR, Ghogawala Z, McGirt MJ: The National Neurosurgery Quality and Outcomes Database and NeuroPoint Alliance: rationale, development, and implementation. Neurosurg Focus 34: E2, 2013

3) Asher AL, Speroff T, Dittus RS, et al.: The National Neurosurgery Quality and Outcomes Database (N2QOD): a collaborative North American outcomes registry to advance value-based spine care. Spine (Phila Pa 1976) 39: S106–116, 2014

4) Busl KM, Bleck TP, Varelas PN: Neurocritical care outcomes, research, and technology: a review. JAMA Neurol 76: 612–618, 2019

5) Clark S, Boyle L, Matthews P, Schweder P, Deng C, Campbell D: Development and validation of a multivariate prediction model of perioperative mortality in neurosurgery: The New Zealand neurosurgical risk tool (NZRISK-NEURO). Neurosurgery 87: E313–E320, 2020

6) GBD 2017 US Neurological Disorders Collaborators, Feigin VL, Vos T, et al.: Burden of neurological disorders across the US From 1990-2017: a global burden of disease study. JAMA Neurol 78: 165–176, 2021

7) De la Garza Ramos R, Goodwin CR, Nakhla J, et al.: The nationwide burden of neurological conditions requiring emergency neurosurgery. Neurosurgery 81: 422–431, 2017

8) Edaravone Acute Infarction Study Group: Effect of a novel free radical scavenger, edaravone (MCI-186), on acute brain infarction. Randomized, placebo-controlled, double-blind study at multicenters. Cerebrovasc Dis 15: 222–229, 2003

9) Fiorella D, Gache L, Frame D, Arthur AS: How safe and effective are flow diveters for the treatment of unruptured small/medium intracranial aneurysms of the internal carotid artery? Meta-analysis for evidence-based performance goals. J Neurointerv Surg 12: 869–873, 2020

10) Funakoshi Y, Hata N, Kuga D, et al.: Current trend in treatment of glioblastoma in Japan: a national survey using the diagnostic procedure combination database (J-ASPECT study-glioblastoma). Int J Clin Oncol 26: 1441–1449, 2021

11) Hayakawa M, Matsumaru Y, Yamagami H, et al.: Trends in endovascular reperfusion therapy for acute stroke after introduction of mechanical thrombectomy devices: Japanese registry of neuroendovascular therapy (JR-NET)3. Neurol Med Chir (Tokyo) 60: 191–201, 2020

12) Hiramatsu M, Sugiu K, Hishikawa T, et al.: Results of 1940 embolizations for dural arteriovenous fistulas: Japanese Registry of Neuroendovascular Therapy (JR-NET3). J Neurosurg 1–8, 2019, ahead of print

13) Hosomi K, Shimokawa T, Ikoma K, et al.: Daily repetitive transcranial magnetic stimulation of primary motor cortex for neuropathic pain: a randomized, multicenter, double-blind, crossover, sham-controlled trial. Pain 154: 1065–1072, 2013

14) Hosomi K, Sugiyama K, Nakamura Y, et al.: A randomized controlled trial of 5 daily sessions and continuous trial of 4 weekly sessions of repetitive transcranial magnetic stimulation for neuropathic pain. Pain 161: 351–360, 2020

15) Iihara K, Nishimura K, Kada A, et al.: Effects of comprehensive stroke care capabilities on in-hospital mortality of patients with ischemic and hemorrhagic stroke: J-ASPECT study. PLoS One 9: e96819, 2014

16) Iihara K, Tominaga T, Saito N, et al.: The Japan Neurosurgical Database: overview and results of the first-year survey. Neurol Med Chir (Tokyo) 60: 165–190, 2020

17) Ikawa F, Morita A, Nakayama T, et al.: A register-based SAH study in Japan: high incidence rate and recent decline trend based on lifestyle. J Neurosurg 134: 983–991, 2020

18) Kada A, Ogasawara K, Kitazono T, et al.: National trends in outcomes of ischemic stroke and prognostic influence of stroke center capability in Japan, 2010–2016. Int J Stroke 1747493019884526, 2019, ahead of print

19) Kawada T, Hishikawa T, Date I, Tominari S, Morita A: Risk of rupture of unruptured cerebral aneurysms in elderly patients. Neurology 86: 1650, 2016

20) Kuroda S; AMORE Study Group: Asymptomatic moyamoya disease: literature review and ongoing AMORE study. Neurol Med Chir (Tokyo) 55: 194–198, 2015

21) McGirt MJ, Speroff T, Dittus RS, Harrell FE, Jr., Asher AL: The National Neurosurgery Quality and Outcomes Database (N2QOD): general overview and pilot-year project description. Neurosurg Focus 34: E6, 2013

22) Miyamoto S, Yoshimoto T, Hashimoto N, et al.: Effects of extracranial-intracranial bypass for patients with hemorrhagic moyamoya disease: results of the Japan Adult Moyamoya Trial. Stroke 45: 1415–1421, 2014

23) UCAS Japan Investigators, Morita A, Kirino T, et al.: The natural course of unruptured cerebral aneurysms in a Japanese cohort. N Engl J Med 366: 2474–2482, 2012

24) Narita Y, Shibui S, Committee of Brain Tumor Registry of Japan Supported by the Japan Neurosurgical S: Trends and outcomes in the treatment of gliomas based on data during 2001-2004 from the Brain Tumor Registry of Japan. Neurol Med Chir (Tokyo) 55: 286–295, 2015

25) Nishimura A, Nishimura K, Kada A, Iihara K; J-ASPECT Study GROUP: status and future perspectives of utilizing big data in neurosurgical and stroke research. Neurol Med Chir (Tokyo) 56: 655–663, 2016

26) Oi S, Inagaki T, Shinoda M, et al.: Guideline for management and treatment of fetal and congenital hydrocephalus: Center of Excellence-Fetal and Congenital Hydrocephalus Top 10 Japan Guideline 2011. Childs Nerv Syst 27: 1563–1570, 2011

27) Oi S, Nomura S, Nagasaka M, et al.: Embryopathogenetic surgicanoanatomical classification of dysraphism and surgical outcome of spinal lipoma: a nationwide multicenter cooperative study in Japan. J Neurosurg Pediatr 3: 412–419, 2009
28) Oravec CS, Motiwalla M, Reed K, et al.: Big data research in neurosurgery: a critical look at this popular new study design. Neurosurgery 82: 728–746, 2018
29) Oya S, Ikawa F, Ichihara N, et al.: Nation-wide brain tumor registry-based study of intracranial meningioma in Japan: analysis of surgery-related risks. Neurol Med Chir (Tokyo) 61: 98–106, 2021
30) Parker SL, McGirt MJ, Bekelis K, et al.: The National Neurosurgery Quality and Outcomes Database Qualified Clinical Data Registry: 2015 measure specifications and rationale. Neurosurg Focus 39: E4, 2015
31) Pittman CA, Miranpuri AS: Neurosurgery clinical registry data collection utilizing informatics for integrating biology and the bedside and electronic health records at the University of Rochester. Neurosurg Focus 39: E16, 2015
32) Ren N, Nishimura A, Kurogi A, et al.: Measuring quality of care for ischemic stroke treated with acute reperfusion therapy in Japan - the close the gap-stroke. Circ J 85: 201–209, 2021
33) Reponen E, Tuominen H, Korja M: Quality of British and American nationwide quality of care and patient safety benchmarking programs: case neurosurgery. Neurosurgery 85: 500–507, 2019
34) Sakai N, Uchida K, Iihara K, et al.: Japanese surveillance of neuroendovascular therapy in JR-NET - Part II. Japanese Registry of neuroendovascular treatment 3. Main report. Neurol Med Chir (Tokyo) 59: 106–115, 2019
35) Schuhmann MU, Rickels E, Rosahl SK, Schneekloth CG, Samii M: Acute care in neurosurgery: quantity, quality, and challenges. J Neurol Neurosurg Psychiatry 71: 182–187, 2001
36) Sodrakyan A, Campbell B, Graves S, Cronenwett JL: Surgical registries for advancing quality and device surveillance. The Lancet 388: 1358–1360, 2016
37) Sherrod BA, Johnston JM, Rocque BG: Risk factors for unplanned readmission within 30 days after pediatric neurosurgery: a nationwide analysis of 9799 procedures from the American College of Surgeons National Surgical Quality Improvement Program. J Neurosurg Pediatr 18: 350–362, 2016
38) Shimoda K, Maeda T, Tado M, Yoshino A, Katayama Y, Bullock MR: Outcome and surgical management for geriatric traumatic brain injury: analysis of 888 cases registered in the Japan Neurotrauma Data Bank. World Neurosurg 82: 1300–1306, 2014
39) Suehiro E, Fujiyama Y, Koizumi H, Suzuki M: Directions for use of intracranial pressure monitoring in the treatment of severe traumatic brain injury using data from The Japan Neurotrauma Data Bank. J Neurotrauma 34: 2230–2234, 2017
40) Takahashi JC, Funaki T, Houkin K, et al.: Significance of the hemorrhagic site for recurrent bleeding: prespecified analysis in the Japan Adult Moyamoya Trial. Stroke 47: 37–43, 2016
41) Toi H, Kinoshita K, Hirai S, et al.: Present epidemiology of chronic subdural hematoma in Japan: analysis of 63,358 cases recorded in a national administrative database. J Neurosurg 128: 222–228, 2018
42) Walicke P, Abosch A, Asher A, et al.: Launching effectiveness research to guide practice in neurosurgery: a National Institute Neurological Disorders and Stroke Workshop Report. Neurosurgery 80: 505–514, 2017
43) Wilde HW, Reese JC, Azab MA, Karsy M, Guan J, Rolston JD: Evaluating the landscape of clinical research in neurosurgery. Neurosurgery 85: E485–E493, 2019

Corresponding author: Koji Iihara, MD, PhD
Department of Neurosurgery, National Cerebral and Cardiovascular Center, 6-1 Kishibeshinmachi, Suita, Osaka 564-8565, Japan
e-mail: kiihara@ncvc.go.jp