Original Article

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Comparison of Cranial Procedure Exposure among Neurosurgery Residents Between E-Da Hospital and the United States

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Objective: The purpose of this study was to compare the quantity of adult cranial surgeries attended by neurosurgical residents before completion of their training between E-Da Hospital and their counterparts in the United States (US) according to the US national database.

Methods: The quantity and category of cranial surgery at E-Da Hospital were extracted from the hospital billing system between the year 2006 and 2017. The data were coded according to the Accreditation Council for Graduate Medical Education (ACGME) guidelines to enable a fair comparison with the US database. Linear regression analyses were conducted to identify changes in each surgical category during the study period.

Results: Each of the five neurosurgery residents at E-Da Hospital participated in an annual average of 566.80 total cranial procedures during the last four years of their residency training with the total caseloads decreasing by 37.84 cases each year (r^2 = 0.78). The national average in the US was 577.04 cranial procedures for each of the 1,631 residents over the same four-year period with an annual increase of 26.59 cases (r^2 = 0.99). Neurosurgery residents at E-Da Hospital participated in significantly more trauma (mean 229.00 ± 32.98) and tumor (mean 194.40 ± 48.65) procedures than those in the US (means 102.17 ± 7.87 and 158.38 ± 4.39, respectively), while the US offered their residents a significantly higher exposure to vascular (mean 84.37 ± 2.61), functional (mean 68.23 ± 6.01), radiosurgery (mean 17.64 ± 4.56), and extracranial (mean 14.01 ± 0.79) procedures than that at E-Da Hospital (means 37.60 ± 16.43, 11.60 ± 4.51, 1.60 ± 3.05 and 1.00 ± 1.22, respectively). E-Da Hospital and the US provided comparable exposure of cerebral spinal fluid (CSF) shunting procedures (means 60.00 ± 23.56 and 76.12 ± 2.15, respectively) and endoscopic transsphenoidal surgeries (ETSS) (means 27.40 ± 13.03 and 33.10 ± 1.85, respectively) for their residents.

Conclusions: The categories of cranial procedures to which neurosurgery residents were exposed were different between E-Da Hospital and the US. When resident case logs were evaluated in different settings (i.e., from regional, national, to international), valuable information regarding residency trainings could be obtained.

Key Words: Accreditation Council for Graduate Medical Education, resident surgical case logs, United States of America, E-Da Hospital, cranial

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Introduction

The Accreditation Council for Graduate Medical Education (ACGME) assesses residents' surgical experience in America by setting a required case minimum and mandating all residents to log in their case participations online.[1] Previously, a comparative study between E-Da Hospital, a medical center located in Southern Taiwan, and the United States was conducted for spinal case volumes.[2] Extrapolating the comparison methods, this study investigated the volumes of cranial procedures that had a higher diversity compared to that of spinal surgeries.

A previous study reviewed the national ACGME resident case log in the US and analyzed the national trends in neurosurgical resident exposure to adult cranial procedures before completion of their training from 2009 to 2017.[3] The report showed that each of the 1,631 US neurosurgical residents participated in an average of 577.04 cranial procedures at training completion with the mean number of procedures increased by 26.59 ($r^2 = 0.99$) cases per year.

This study aims at examining the case log compiled at E-Da Hospital similar to that of the US to gain an overview of E-Da neurosurgical training program. E-Da resident's case log was compared with that of the US over the corresponding study periods to evaluate the differences in cranial case volumes and trends. Finally, this study attempted to further elucidate the importance of setting up a national online case logging platform in Taiwan.

Materials and Methods

Study protocol and period

Information on adult cranial procedures defined by ACGME with participation of neurosurgical residents at E-Da Hospital between 2006 and 2017 was collected from the E-Da procedure billing system, generating an E-Da resident case log. The cranial procedures were then coded according to the ACGME case log guidelines.[4]

Study parameters

Although neurosurgical residency training in Taiwan is a six-year program, only surgical participations in the last four years of residency were included for assessing technical maturation. A previous study has reported the results of comparison regarding surgical exposure among neurosurgery residents between E-Da Hospital and the US in the spinal surgery setting.[2] Hence, the present study used the number of procedures that neurosurgical residents participated in during the last four years of their training.

The total numbers of cranial procedures in each of the nine ACGME-defined case categories were evaluated using linear regression analysis to determine trends in residency case exposures. The mean numbers of cranial procedures and changes in the average total numbers of cranial procedures with resident participation at E-Da and the US during the study period were compared. Besides, a com-

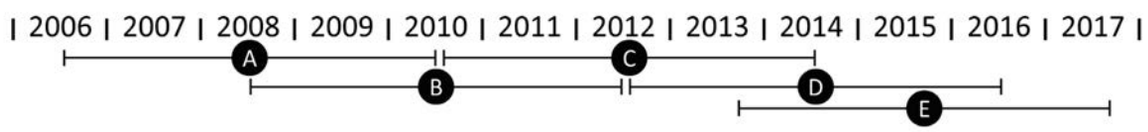

Fig. 1 Timeline representing the month and year of neurosurgical residents graduating from E-Da Hospital from 2010 to 2017. By default, only the procedures operated by graduating residents during the last four years before graduation were included in this study. For example, for "Resident A", only cases participated by him from 1st July 2006 to 30th June 2010 were included.

Table 1. Linear regression analysis of E-Da Hospital neurosurgery resident participation in the nine categories of Accreditation Council for Graduate Medical Education (ACGME)-defined cranial procedures.

Category	Mean number of procedures	Change (procedures/year)	r^2	*p*-value
Tumor	194.40	-13.34	0.63	0.11
Trauma	229.00	-10.06	0.76	0.05
Vascular	37.60	-4.22	0.54	0.16
Pain relief	4.20	-0.94	0.94	0.01
ETSS	27.40	-2.34	0.028	0.36
Extracranial	1.00	NA	NA	NA
RS	1.60	0.63	0.35	0.03
Functional	11.60	-0.59	0.14	0.53
CSF diversion	60.00	-6.80	0.68	0.08
Total	566.80	-37.84	0.78	0.05

NA = not applicable

parison of the proportions of ACGME-defined cranial case categories was made between E-Da Hospital and the US.

Statistical analysis

The mean numbers of neurosurgical procedures at E-Da Hospital were compared with those in the US as described in a previous study[3] using unpaired Student's t-test. All analyses were performed using Microsoft Excel 365 (Microsoft; Redmond, WA). Data collection required neither interaction with study participants nor collection of private information. A *p* value less than 0.05 was considered statistically significant.

Results

Comparison of numbers of cranial procedure exposure of neurosurgery residents in between E-Da Hospital and United States

The five neurosurgery residents at E-Da Hospital participated in a mean of 566.80 total cranial procedures upon completion of their training between 2006 and 2017 with the total numbers of Accreditation Council for Graduate Medical Education (ACGME)-defined cranial procedures being 760, 551, 565, 540, and 418, respectively (Fig. 1).

General trends during the study period

As shown in Table 1, the total number of cranial procedures that neurosurgery residents participated in decreased by 37.84 per year (r^2 = 0.78) at E-Da Hospital (Table 1). The number at E-Da Hospital and that in the US3 intersected around the year 2013 (Fig. 2). Comparison of the mean numbers of cranial procedures attended by neurosurgery residents between E-Da Hospital and those in the US reported in a previous study[3] revealed more tumor (36.02 more; 95% CI: 31.62 to 40.42) and trauma (126.83 more; 95% CI: 119.77 to133.89) procedures at E-Da Hospital compared to those in the US.

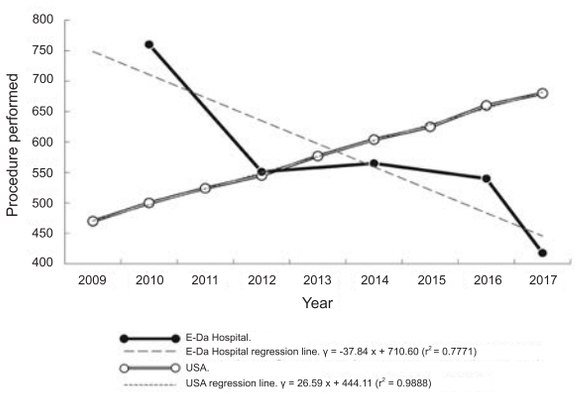

Fig. 2 Regression analysis for identifying the trends of changes in the total number of cranial procedures performed by neurosurgical residents at E-Da Hospital and the United States (USA) during the study period.

Comparison of exposures in defined case categories

Figure 3 shows the resuts of a comparison of cranial procedure exposures between neurosurgery residents at E-Da Hospital and those in the US using unpaired Student's t-test. Figure 3A demonstrates a higher exposure to tumor (difference: 36.02, 95% CI: 40.42 – 31.62) and trauma (difference: 126.83, 95% CI: 133.89 – 119.77) procedures among residents at E-Da Hospital compared to their US counterparts. Figure 3B shows a lower exposure to vascular (difference: 46.77, 95% CI: 44.37 – 49.17), functional (difference: 56.63, 95% CI: 51.34 – 61.62), radiosurgery (difference: 16.04, 95% CI: 12.03 – 20.05), and extracranial vascular (difference: 13.01, 95% CI: 12.31 – 13.71) procedures among residents at E-Da Hospital than those in the US. Figure 3C showed similar resident case exposure between E-Da Hospital and the US.

Division of cranial procedures attended by residents at E-Da Hospital into the nine ACGME-defined cranial case categories (Fig. 3) showed a strong emphasis on trauma (mean 299.00 ± 32.98) and tumor (mean 194.40 ± 48.65) procedures that comprised 40.40% and 34.30% of the total cranial procedures, respectively (Fig. 4). Comparison with their American counterparts revealed similar findings with the majority of cranial procedures pertaining to trauma-related (mean 102.17 ± 7.87) and tumor-related (mean 158.38 ± 4.39) operations that accounted for 18.44% and 28.59% of the total number of cranial procedures, respectively (Fig. 4). Nevertheless, the percentages of procedures in these two categories in the US were lower than those at E-Da Hospital.

Regarding the rest of the ACGME-defined cranial case categories, cerebral spinal fluid

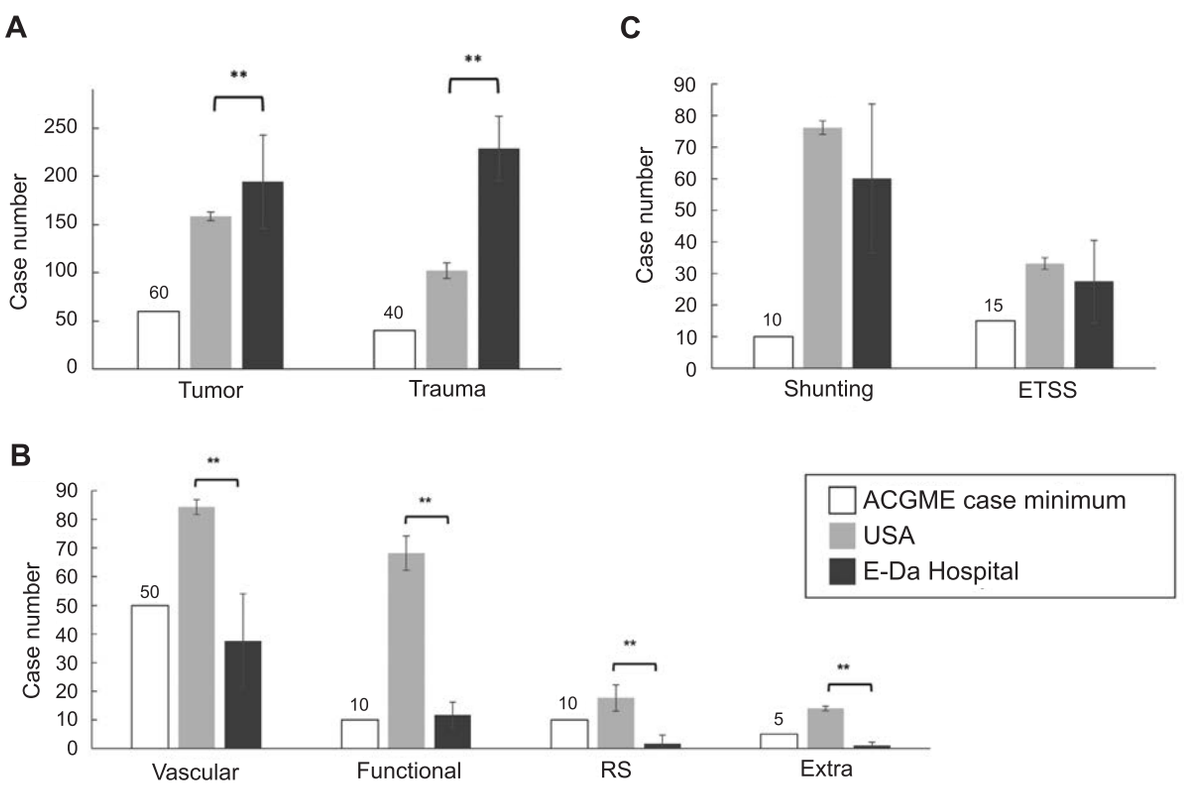

*Fig. 3 Difference in mean numbers of cranial procedures, plotted with standard errors, attended by neurosurgical residents between E-Da Hospital and the United State (USA). (A) Tumor and trauma procedures. (B) Vascular, functional, radiosurgery (RS), and extracranial vascular (Extra) procedures. (C) Cerebrospinal fluid (CSF) shunting and endoscopic transsphenoidal and sellar/parasellar surgery (ETSS). CI: confidence interval; **p < 0.0001 with unpaired Student's t-test:.*

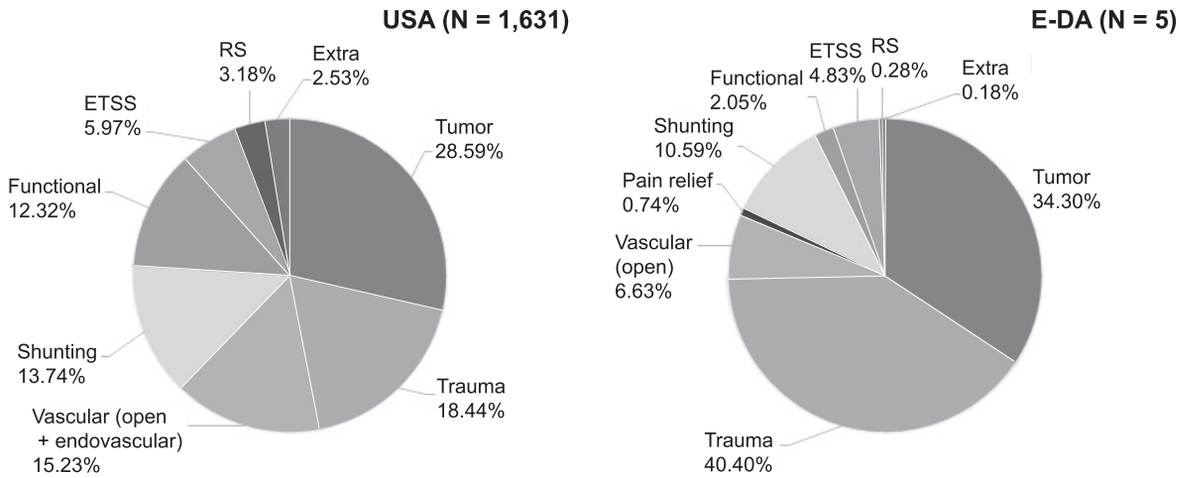

Fig. 4 Proportions of the nine categories of Accreditation Council for Graduate Medical Education (ACGME)-defined cranial procedures in which neurosurgical residents at E-Da Hospital and in the United States (USA) participated upon completion of their training. No data on pain relief procedure was available from USA. Shunting: cerebrospinal fluid shunting; ETSS: endoscopic transsphenoidal and sellar/parasellar surgery; RS: radiosurgery; Extra: extracranial vascular procedures.

(CSF) shunting, open vascular, endoscopic transsphenoidal surgery (ETSS), functional, radiosurgery, extracranial vascular and pain relief procedures comprised 10.59%, 6.63%, 4.83%, 2.05%, 0.28%, 0.18% and 0.74%, respectively, of cranial operations that the residents at E-Da Hospital were exposed to (Fig. 4). In contrast, CSF shunting, vascular (including open and endovascular), ETSS, functional, radiosurgery, and extracranial vascular procedures comprised 13.74%, 15.23% (including 10.92% open and 4.31% endovascular), 5.97%, 12.32%, 3.18%, and 2.53%, respectively, of cranial operations in which the residents participated in the US (Fig. 4). Therefore, the results demonstrated a lower exposure of residents at E-Da Hospital to these procedures compared with that of their US counterparts. No data for pain relief procedure was available from the US.

Comparison of trends in defined case categories

Changes in the number of cranial procedures participated by neurosurgery residents at E-Da Hospital were analyzed (Table 1) to identify the main areas of reduction. Trauma and tumor operations showed the greatest decline with reductions of 10.06 ($r^2 = 0.76$) and 13.43 ($r^2 = 0.63$) procedures per year, respectively. CSF diversion, open vascular, and pain relief procedures also showed slight decreases by 6.80 ($r^2 = 0.68$), 4.22 ($r^2 = 0.54$), and 0.94 ($r^2 = 0.94$) procedures per year, respectively.

The study by Agarwal N et al.[3] showed a general increase in all cranial case volumes in USA, with trauma showing the greatest rise at 8.23 ($r^2 = 0.91$) procedures per graduating year. The only decrease in USA was open vascular procedures, which demonstrated a decline by 2.85 procedures per year ($r^2 = 0.53$). However, this phenomenon was explained by the shift in treatment strategies for aneurysms, from open vascular to endovascular procedures, which increased by 1.58 procedures per year ($r^2 = 0.78$) in USA.

Discussion

Generally, the mean number of total cranial procedures participated by residents steadily decreased at E-Da Hospital, while consistently increased in the US (Fig. 2). The decline in tumor and trauma case volumes could largely account for the decrease in cranial procedures at E-Da Hospital (Table 1).

The increase in total cranial procedures in

the US could be explained by a growing familiarity among residents with the ACGME online case logging system over the study period, resulting in less under-reporting. This trend was observed and explained in the previous study comparing spinal case logs between E-Da Hospital and the US.[2]

The volume of cranial trauma-related procedures at E-Da Hospital was more than twice that of the US (Fig. 3A). The main indications for cranial trauma procedures were falls in the elderly, blunt head trauma by objects, traffic accidents and hemorrhagic/ischemic strokes.[5,6]

As a trauma center, E-Da Hospital is in a position to manage a large number of traffic accidents due to the high proportion of motorcyclists in Taiwan, which has been shown to significantly correlated with the incidence of traumatic brain injury in various studies.[7] In contrast, motorcycle is not a popular mode of transportation in the US.[8] In Taiwan, the decrease in trauma procedures (Table 1) could be explained by the enforcement of the regulation of wearing helmets for all motorcyclists as well as the implementation of stricter traffic laws that directly reduced the incidence of road accident-associated head injuries in Taiwan.[9]

Besides traffic accidents, the incidence of hypertensive intracranial hemorrhage in Taiwan was higher than that in the US. Genetic factors have been found to play a role.[10] In the US, the incidence of ischemic stroke was higher than in Taiwan,[11] but the number of patients indicated for emergent craniectomy for malignant hemispheric infarction was lower than that for intracranial hemorrhage.[12,13]

The affordable and accessible medical care system in Taiwan, which is governed by National Health Insurance (NHI), contributed to the high operation volumes; patients and families were subjected to minimal financial pressure when deciding on such life-saving cranial operations.[14] All these factors contributed significantly to more cranial trauma-related procedures at E-Da Hospital than in the US.

The other ACGME-defined case category to which E-Da Hospital neurosurgical residents had a greater exposure was tumor procedures. This could also be explained by the NHI-governed medical environment in Taiwan that provides coverage for over 99% of the population.[14] Patients in the US might refrain from brain surgery due to an uninsured status that prompted patients to choose observation over surgical management.[15] This could partly explain the higher volume of brain tumor-related procedures in Taiwan.

Although patients in Taiwan were more willing to accept brain surgery, studies have shown a higher brain and central nervous tumor incidence rate in the US than in Taiwan.[16] Furthermore, a study demonstrated a slight decrease in primary malignant brain tumors in Taiwan.[17] In addition, the substantial increase in the use of non-operative strategies, such as radiosurgery, targeted therapy, and immunotherapy, in Taiwan[18] could account for the decreasing trend in brain tumor procedures at E-Da Hospital during the study period (Table 1).

The ACGME criteria for case inclusion in the category of pain relief were restricted to microvascular decompression and suboccipital/subtemporal craniectomy. Following the global trend, radiosurgery at E-Da Hospital has been gaining popularity over microvascular decompression as the preferred treatment for trigeminal neuralgia after failure of oral medications.[19] Thus, the choices of pain relief procedures at E-Da Hospital were limited (Table 1), barely reaching the case minimum of five required by ACGME. No comparison was made in Figure 3 because no data was available from the US.

As mentioned in the previous study comparing spinal case volumes between E-Da Hospital and the US, residents at E-Da Hospital seldom participated in extra-operation room (extra-OR) procedures like peripheral nerve neurolysis.[2] Similar trends were identified in the current study, suggesting that residents at

E-Da Hospital may be in this area.

Another area seldom participated by residents at E-Da Hospital was radiosurgery, which were performed in the Gamma knife center located in a separate building of E-Da Hospital. Similarly, endovascular procedures were routinely performed by radiologists. Because neurosurgical residents at E-Da Hospital never participated in the interventional procedures performed by radiologists, open vascular procedures constituted the entirety of their vascular surgical training (Fig. 4). If residents at E-Da Hospital had participated in the endovascular procedures performed by radiologists, the total number of vascular cases would most likely have exceeded the ACGME case minimum and might even be comparable to the national average in the US.

Another glaring difference between E-Da Hospital and the US was in the number of functional procedures (Fig. 4). E-Da participated in very few functional procedures compared to their US counterparts (Fig. 3B). It was important to note that neuromodulation with spinal cord stimulation for chronic pain management (e.g., RFA) is classified under functional procedures according to the ACGME case log guidelines.[4] Recently, ACGME announced a new sub-category named "Extracranial Functional" in 2019 to differentiate extracranial (e.g., RFA of spine) from intracranial functional procedures.[20] However, in the study by Agarwal N et al.,[3] extracranial functional procedures for spinal stimulation was still categorized under functional procedures. This could account for the significantly higher case volume in the US when compared to that at E-Da Hospital. Neurosurgical residents at E-Da Hospital seldom participated in routine RFA spinal procedures in an outpatient setting.

Finally, the limited numbers of functional procedures including rhizotomy, sympathectomy and deep brain stimulation at E-Da Hospital together with the lack of other functional operations such as seizure-control, intrathecal pumps placement or vagal nerve stimulation resulted in the overall small case volume at E-Da Hospital, which barely reached the ACGME case minimum requirement of ten (Fig. 3B).

Resident case volumes in CSF diversion and ETSS were similar between E-Da Hospital and the US (Fig. 3C & 4). This study showed no difference in the average volumes of CSF shunting procedure participation between the two groups. As for ETSS, because E-Da Hospital had one neurosurgeon specialized in pituitary operations, resident participations stayed fairly consistent over the study period (Table 1).

Taken together, residents at E-Da Hospital were generally adequately trained in trauma, tumor, open vascular, CSF diversion and ETSS operations. However, subspecialty training such as functional, pain relief and extra-cranial vascular procedures were insufficient, suggesting that reinforcement measures should be implemented to enhance residents' competency in these areas. From a medical education point of view, this imbalance in cranial procedures training would result in a lack of certain sets of essential surgical skills among neurosurgery residents at the completion of their training. After being promoted to attending surgeons, those residents who have completed their training at E-Da Hospital would transfer patients to other facilities with the technical capabilities of those procedures, thereby perpetuating the vicious cycle. A possible solution to this problem would be the participation of residents in training programs at other tertiary referral centers that can provide adequate training opportunities to fill the gap between ACGME requirements and clinical practice.

Limitations

The results of this study from analyzing neurosurgery resident case volumes of a single tertiary referral center in Taiwan were not representative of the whole country. To date,

there were a total of 19 neurosurgical training programs in Taiwan. Inter-hospital data transference and collaboration were unable to be carried out at this stage due to patient information confidentiality issues. Furthermore, because widely varied coding systems were used in different hospitals, a unified case logging system needs to be installed before nationwide data could be collated and analyzed.

The case log at E-Da Hospital was underreported despite its accuracy because only the cases participated by neurosurgery residents in their last four years were included. The present study adopted the approach from a previous study comparing spinal case logs among residents between E-Da Hospital and the US.[2] This method balanced the under-reporting nature of resident-managed case logs in the US with the role-definition rules of the ACGME case log system wherein only senior and leading residents were credited. The comparable case volumes in CSF diversion and ETSS participated by residents between E-Da Hospital and the US supported the fairness of this method.

Future directions

This study advocated the establishment of a case coding system resembling that of ACGME for all surgical training programs in Taiwan to enable more comprehensive evaluation of individual training. Residents could apply for training programs at other hospitals to compensate for their own inadequacy. Moreover, a national case logging platform could allow residents to scrutinize their own case participation rates to ensure adequate training and competence in different categories of procedures prior to beginning post-residency practice upon completion of residency training.

Literature studies have demonstrated a positive relationship between the volume of procedures performed and patient outcomes.[21] However, this volume-outcome method may not apply in all circumstances.[22] This may be particularly true in cranial operations, where a high level of technical competency is demanded due to their complexities. Therefore, case volume alone may not suffice to assess a neurosurgery resident's competency. Tracking of patient outcomes and complication rates with a multi-faceted evaluation system may be necessary to develop an all-round neurosurgical training program.

Conclusions

This study evaluated the cranial case volumes and trends participated by graduated neurosurgical residents in E-Da Hospital and compared them against America's national means. E-Da residents were generally well-trained in trauma management with abundant case exposures. E-Da residents were adequately trained in tumor, open vascular, CSF diversion and ETSS procedures. E-Da residents were ill-trained in functional, pain relief and extra-cranial vascular procedures. Particularly, E-Da residents were under-trained in extra-OR procedures such as extra-cranial functional, radiosurgery and endovascular procedures. An immediate adjustment to E-Da's neurosurgical program to include residents in extra-OR procedures was imperative.

Most importantly, the establishment of a national online case logging platform in Taiwan could not be emphasized enough, so that improvements to medical education on surgical trainings could be strengthened.

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