Longitudinal survey of cranial case log entries during neurological surgery residency training

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OBJECTIVE The purpose of this study was to analyze national trends in adult cranial cases performed by neurological surgery residents as logged into the Accreditation Council for Graduate Medical Education (ACGME) system.

METHODS The ACGME resident case logs were retrospectively reviewed for the years 2009–2017. In these reports, the national average of cases performed by graduating residents is organized by year, type of procedure, and level of resident. These logs were analyzed in order to evaluate trends in residency experience with adult cranial procedures. The reported number of cranial procedures was compared to the ACGME neurosurgical minimum requirements for each surgical category. A linear regression analysis was conducted in order to identify changes in the average number of procedures performed by residents graduating during the study period. Additionally, a 1-sample t-test was performed to compare reported case volumes to the ACGME required minimums.

RESULTS An average of 577 total cranial procedures were performed throughout residency training for each of the 1631 residents graduating between 2009 and 2017. The total caseload for graduating residents upon completion of training increased by an average of 26.59 cases each year ($r^2 = 0.99$). Additionally, caseloads in most major procedural subspecialty categories increased; this excludes open vascular and extracranial vascular categories, which showed, respectively, a decrease and no change. The majority of cranial procedures performed throughout residency pertained to tumor (mean 158.38 operations), trauma (mean 102.17 operations), and CSF diversion (mean 76.12 operations). Cranial procedures pertaining to the subspecialties of trauma and functional neurosurgery showed the greatest rise in total procedures, increasing at 8.23 ($r^2 = 0.91$) and 6.44 ($r^2 = 0.95$) procedures per graduating year, respectively.

CONCLUSIONS Neurosurgical residents reported increasing case volumes for most cranial procedures between 2009 and 2017. This increase was observed despite work hour limitations set forth in 2003 and 2011. Of note, an inverse relationship between open vascular and endovascular procedures was observed, with a decrease in open vascular procedures and an increase in endovascular procedures performed during the study period. When compared to the ACGME required minimums, neurosurgery residents gained much more exposure to cranial procedures than was expected. Additionally, a larger caseload throughout training suggests that residents are graduating with greater competency and experience in cranial neurosurgery.

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KEYWORDS Accreditation Council for Graduate Medical Education; case logs; neurological surgery; cranial; residency

SURGICAL technical proficiency requires extensive and diverse patient-centered training. In order to ensure that residents are adequately equipped to operate independently, residents assume various roles, such as senior or lead surgeon, as their skill set matures. Monitoring of the type of case is considered one way to ensure a general level of experience and growing competence prior to beginning post-residency practice.

Previous reports have demonstrated a positive relationship between the volume of procedures performed and patient outcomes.^{3,9} This volume-outcome model is the method utilized by the Accreditation Council for Graduate Medical Education (ACGME) to track resident experience. The ACGME implemented minimum requirements for the number of cases performed in various surgical procedures, a goal in place to ensure that residents are sufficiently ex-

ABBREVIATIONS ACGME = Accreditation Council for Graduate Medical Education; CSF = cerebrospinal fluid.

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posed to the spectrum of current neurosurgical techniques (Table 1). Other studies suggest that this volume-outcome method may not apply in all circumstances.⁴ For example, only 50% of surgical program directors felt that residents were competent in performing hepatopancreaticobiliary surgery upon graduation.¹⁸

The resident's surgical experience during training is tracked by the ACGME case log system, which requires residents to record the surgical procedures in which they have one of several roles. The case log system only provides credit for cases wherein the resident is senior resident surgeon or lead resident surgeon. This study aims to evaluate trends in the national cranial surgery cases performed by residents who completed training between 2009 and 2017. Our purpose in this report is to determine whether graduating neurosurgical residents are obtaining a diverse surgical education and to evaluate how the resident surgical experience correlates with the required minimums set forth by the ACGME.

Methods

ACGME resident case logs were retrospectively reviewed for the years 2009 to 2017. The national average of cases performed by graduating residents is provided in ACGME reports and is further categorized by year, type of procedure, and level of resident participation in the case. The ACGME neurosurgical case log classifies procedures into cranial and spinal procedures. This study included all adult cranial-based or related procedures as recorded in the case logs. Further classification of cranial procedures yields categories pertaining to tumor, open vascular, functional, trauma, extracranial vascular, radiosurgical, endovascular, transsphenoidal and sellar/parasellar tumor, and cerebrospinal fluid (CSF) diversion procedures. Of note, a small number of cases were excluded from the cranial subcategory analysis, as these could not be followed longitudinally given ACGME case log data reorganization in 2013. The reports from 2009 to 2012 included categories for craniosynostosis, craniofacial reconstruction, and infection/cyst/Chiari/other that were not seen in the reports from 2013 to 2017. Additionally, the reports from 2013 to 2017 had a craniotomy for pain category that was not present in the prior reports. Because of these inconsistencies in procedural categorization, these categories (207 total procedures) were excluded from the subcategory analysis. The mean number of cranial procedures performed throughout residency was determined. The reported number of cranial procedures was compared to the ACGME neurosurgical minimum requirements for each surgical category. A linear regression analysis was performed to identify changes in the mean number of procedures reported by residents graduating during the study period. IBM SPSS (IBM Corp.) software was utilized to perform a 1-sample t-test comparing reported case volumes to ACGME required minimums.

Results

A total of 5193 cranial procedures were performed throughout residency training by the 1631 residents gradu-

TABLE 1. Current neurological surgery case log defined case categories and required minimum numbers

Defined Case Category	Required Minimum Number
Adult Cranial	
DC1 Craniotomy for brain tumor	60
DC2 Craniotomy for trauma	40
Total vascular lesion (Combined DC3a and DC3b)	50
DC3a Craniotomy for intracranial vascular lesion	Must be reported
DC3b Endovascular therapy for tumor or vascular lesion	Must be reported
DC4 Craniotomy for pain	5
DC5 Transsphenoidal sellar/parasellar tumors (endoscopic and microsurgical)	15
DC6 Extracranial vascular procedures	5
DC7 Radiosurgery	10
DC8 Functional procedures	10
DC 9 VP shunt	10
Total Adult Cranial	205
Adult Spinal	
DC10 Anterior cervical approaches for decompression/stabilization	25
DC11 Posterior cervical approaches for decompression/stabilization	15
DC12 Lumbar discectomy	25
DC13 Thoracic/lumbar instrumentation fusion	20
DC14 Peripheral nerve procedures	10
Total Adult Spinal	95
Pediatric	
DC15 Brain tumor	5
DC16 Trauma (uses adult trauma codes)	10
DC17 Spinal procedures	5
DC18 VP shunt	10
Total Pediatric	30
DC19 Adult and Pediatric Epilepsy	10
Critical Care	
DC20 ICP monitor placement	5
DC21 External ventricular drain	10
DC22 VP shunt tap/programming	10
DC23 Cervical spine traction	5
DC25 CVP line placement	10
DC26 Airway management	10
DC27 Arterial line placement	10
Total Critical Care	60
Total All Defined Case Categories	400
Reportable but Non-Tracked Categories	
Arteriography	
Stereotactic frame placement	

CVP = central venous pressure; ICP = intracranial pressure; VP = ventriculoperitoneal.

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FIG. 1. National averages for the total number of cranial procedures performed by individual residents graduating from 2009 through 2017; $y = 26.587 + 444.11$ ($r^2 = 0.9888$). Figure is available in color online only.

ating between 2009 and 2017. For each resident, a mean of 577.04 cranial procedures were performed. Total case volume upon completed residency increased by a mean of 26.59 cases each year ($r^2 = 0.99$), peaking in 2017 with 668.5 cranial procedures (Fig. 1). Of note, 207 procedures were eliminated from the total of 5193 procedures when performing the cranial subcategory analysis due to changes in the way ACGME categorized data, precluding longitudinal analysis. As a result, 4986 cases were utilized as the study cohort for subcategory analysis. Trauma and functional operations showed the greatest rise, increas-

ing at 8.23 ($r^2 = 0.91$) and 6.44 ($r^2 = 0.95$) procedures per graduating year, respectively.

The majority of cranial procedures performed throughout residency pertained to tumor management (mean 158.38 operations), trauma surgery (mean 102.17 operations), and CSF diversion (mean 76.12 operations) (Fig. 2). These comprised 28.59%, 18.44%, and 13.74% of the total number of cranial procedures, respectively. The top tumor procedure was craniotomy for tumor resection, excluding transsphenoidal and sellar/parasellar tumors, which comprised 90.37% of tumor procedures. The most common trauma category performed was skull fracture/hematoma, which comprised 59.11% of trauma procedures.

Another notable trend was seen in endovascular procedures, which had a gross increase of over 6-fold from 2009 to 2017 and rose at a rate of 4.85 operations per year ($r^2 = 0.93$) per graduating class. The greatest increase seen within the endovascular category was in endovascular treatment of aneurysms, which rose 1.58 cases per year ($r^2 = 0.78$). In contrast, open vascular procedures demonstrated a decline during the study period and decreased by 2.85 procedures per year ($r^2 = 0.53$).

Functional, open vascular, transsphenoidal and sellar/parasellar tumor, endovascular, radiosurgery, and extracranial vascular procedures comprised 12.32%, 10.92%, 5.97%, 4.31%, 3.18%, and 2.53% of cranial operations performed throughout residency, respectively. The most prevalent operations in the functional and open vascular categories included deep brain stimulation (34.07%) and craniotomy for aneurysm (61.23%).

The mean number of procedures performed during res-

FIG. 2. Mean numbers of procedures performed nationally by graduating residents (mean total per resident), plotted with the standard error of the mean (error bars), compared to the required minimum for each surgical category. One-sample t-test significance indicated by * ($p < 0.001$) and ** ($p < 0.0001$). Tumor procedures had a mean of 158.38 ± 4.39 and a required minimum of 60. Trauma procedures had a mean of 102.17 ± 7.87 and a required minimum of 40. Vascular category combined "open vascular" and "endovascular" for comparison to the ACGME requirement of a total of 50 procedures between the 2 groups. The national average for vascular procedures was 84.37 ± 2.61 . CSF diversion procedures had a mean of 76.12 ± 2.15 and a required minimum of 10. Functional procedures had a mean of 68.23 ± 6.01 with a required minimum of 10. Transsphenoidal and sellar/parasellar tumor procedures had a mean of 33.10 ± 1.85 and a required minimum of 10. Radiosurgery procedures had a mean of 17.64 ± 4.56 and a required minimum of 10. Extracranial vascular procedures had a mean of 14.01 ± 0.79 and a required minimum of 5. RS = radiosurgery; transsphen = transsphenoidal. Figure is available in color online only.

FIG. 3. Mean number of total cranial cases performed by graduating residents (mean total per resident) for each level of involvement. Figure is available in color online only.

idency was compared to the required minimums set forth by the ACGME by surgical category. It was found that graduating residents performed significantly more procedures in each surgical category than required by the ACGME. The greatest differences between the required minimums and the mean numbers of procedures performed were in CSF diversion, functional, and extracranial vascular procedures. On average, in these categories, residents performed 7.12, 6.82, and 2.80 times the required minimum procedures, respectively. The mean number of procedures performed compared to the required minimums is illustrated in Fig. 2.

Trends in operative volume were also analyzed based on resident level: senior resident surgeon, lead resident surgeon, and assistant resident surgeon (Fig. 3). The greatest increase was found to be among lead resident surgeons. Within this group, there was a mean increase of 70.82 procedures per year ($r^2 = 0.96$). The number of procedures increased among assistant resident surgeons by 2.15 cases per year ($r^2 = 0.94$). Finally, the number of cases performed by senior resident surgeons declined by 10.47 cases per year ($r^2 = 0.94$).

To account for a potentially large degree of variability in cases performed by residents at different residency programs, the mean and median values for total procedures performed were compared (Fig. 4). The mean number of procedures increased by 27.52 operations per year ($r^2 = 0.93$), and the median values demonstrated an increase of 28.10 operations per year ($r^2 = 0.86$).

Discussion

Trends in US Cranial Surgery

This study has demonstrated that from 2009 to 2017 neurosurgery residents' cranial surgery caseload on average increased every year. It also reports that on average, the numbers of procedures residents performed for most reported surgical categories increased during this period. The exceptions to this trend were open vascular and extracranial vascular procedures, which demonstrated a decline and no significant change, respectively. Overall trends demonstrate an increase among lead resident surgeons, rising by over 70 cases per year between 2013 and

2017. These findings are consistent with studies published in other surgical specialties, such as general surgery¹⁴ and orthopedic surgery.¹⁰ Quantifying changes in resident caseloads is important in tracking changes in surgical training. Advancing technology, ACGME guidelines, and a myriad of other factors influence the residency experience.^{1,7,15,21}

Advances in technology play a key role in shifting the types of procedures residents invest more time in. For example, one study demonstrated how advancing techniques in laparoscopic surgery led to a decline in general surgery residents' case volume of open abdominal procedures from 2000 to 2011.¹⁵ Another study found that the introduction of robotic hysterectomy surgery resulted in a lower case volume of abdominal hysterectomies during their residency.²¹ In neurosurgery residencies, there was a mean increase in radiosurgery procedures of 1.67 cases per year. This rise in radiosurgery procedures could be associated with the installation of new radiosurgical technologies at various institutions or the need for all programs to meet the ACGME minimum case experience in this category.

FIG. 4. The mean and median values for total procedures performed by graduating residents from 2013 to 2016. Mean number of total procedures, $y = 28.10 + 533.00$ ($r^2 = 0.86834$). Median number of total procedures, $y = 27.52 + 52.95$ ($r^2 = 0.98054$). Figure is available in color online only.

The advanced technology and improved ability to treat patients using stereotactic radiosurgery have resulted in a higher number of procedures for residents. The introduction of new procedures or improvement of surgical techniques alters the competencies of graduating residents. The shifting focus of residents toward different surgical procedures is illustrated in the changing caseloads. These changing trends in surgical caseload, along with the types of procedures performed, provide insight into the surgical experience found in US residency programs.

A significant increase in endovascular procedures was observed during the study period: endovascular procedures increased over 6-fold. Endovascular treatment has emerged as a safe and effective treatment modality, correlating with the significant rise in endovascular cases residents are performing. The increase in endovascular cases is met with a corresponding decline in open vascular procedures seen in this study. This suggests that endovascular treatment may be taking over the treatment of cerebral vascular disease in some cases. Because of this noticeable shift in vascular treatment, the ACGME changed the required minimum for vascular operations in 2016 to 50 total procedures combined, between endovascular and open vascular. This change will help programs that may have struggled to meet the required minimums for either endovascular or open vascular procedures when they were separate categories. Further analysis of vascular caseloads before and after this change cannot be currently analyzed, given the recent change; however, the effects of this change on residents' ability to meet vascular minimums should be analyzed in future studies.

Impact of Duty Hour Restrictions

Implementation of new residency duty hours led to concern that resident surgical experience might suffer. Recent duty hour restrictions include the restrictions employed in 2003 and those instituted in 2011 regarding 16-hour shifts for interns. The present study found that reported case experience has increased during these years despite duty hour restrictions. In a study on education and productivity following implementation of the 80-hour workweek, residents reported significant decreases in abstracts presented at conferences and self-assessment ABNS (American Board of Neurological Surgery) examination scores.¹¹ Additionally, 96% of responding program directors believed these duty hour restrictions compromised patient safety. Another study found that duty hour restrictions did not lead to any change in patient outcomes or resident education but were associated with declining performance on certification examinations and a perception of worsened education and patient safety among residents.¹ Few studies have examined how case volumes have changed following 2011. The current study shows that despite duty hour restrictions, case volume has increased during the interval we studied.

Variability in Case Experience

In comparing the total number of procedures performed in each surgical category, there appears to be a large discrepancy with respect to which surgeries residents are spending the most time on. The total number of tumor-

related surgeries was found to be more than 60% higher than the second most common surgical category, trauma, and more than twice as high as the third most common category, CSF diversions. However, with the increasing complexity of the neurosurgical oncology field and the accompanying technological advances, more exposure may be needed for residents to master these types of cranial procedures.⁵ Additionally, the numbers of operations reported for residents and the required minimum for procedures, as defined by the ACGME, indicates an incongruity. For example, the ACGME requirement for craniotomy for brain tumor is 60 procedures; however, we found that the mean number of these procedures performed by a graduating neurosurgery resident was 158.38. A similar discrepancy can be seen in trauma and functional procedures as well. The requirement for total trauma procedures is 40 procedures, and the mean number performed by a graduating resident was 102.17. Similarly in the functional neurosurgery category, graduating residents perform an average of 68.23 procedures compared to the requirement of only 10. The higher reported caseloads of residents compared to the required minimums indicate that the average resident is gaining much more exposure to cranial neurosurgery than is expected. Nevertheless, the range varies significantly. For example, the reported number of craniotomies for tumor performed by 2014 graduates ranged between 73 and 633. This wide range of logged cases may partly be a consequence of inherent differences among programs, such as a higher operative output based on location, program size, number of faculty members, etc. Whatever the cause may be, the high degree of variance could indicate an incongruity in the competency of graduating residents. Residents not meeting the minimum, or barely meeting the minimum, may not be getting the same experience as the average graduating chief. The case minimum for selected categories may warrant reexamination in order to reduce the wide varied caseload among graduating residents.

The mean values for the number of cases performed were used in this study to analyze trends in case volume. Because of the variability described above, the mean versus median values were graphed to determine if the data were skewed. As seen in Fig. 4, the mean values for total procedures performed did not vary greatly from the median values: mean values showed an increase of 27.52 operations per year compared to 28.10 for the median values. The mean and median values did not vary greatly and demonstrated the same increasing trend in operations. This suggests that although the minimum and maximum number of procedures performed by graduating residents are vastly different, the mean values reported in this study are not skewed by the numbers of procedures performed by residents from high-output programs.

To address the disparity in exposure to different cranial operations, various additions to the curriculum may provide residents an opportunity to gain skills in selected procedures that are not performed often at their training institution. Recent studies have demonstrated that utilizing surgical simulation can improve surgical skills before entering the operating room.^{12,17} Interest in surgical simulation is growing due to increased emphasis on patient safety and operating room efficiency as well as increasing

complexity of procedures and work hour limitations.^{13,16} Developing a resident's technique and surgical skill outside of the operating room can allow the resident to be more prepared and take full advantage of time in the OR. Surgical simulation training may help augment residents' competency in surgical procedures that are performed less frequently during residency training. Residents with poor case diversity may also seek training at sites that can fill the training/experience gap. Each medical center may not have an adequate volume of cases for each neurosurgical procedure. Facilitating resident exchanges with other sites will give residents access to a greater array of surgical cases in all aspects of neurosurgery.

The increased size of caseloads among residents suggests that residency training is improving. Previous studies have demonstrated a strong relationship between operative volume and outcomes in many surgical fields, including bariatric, spine, and cranial surgery.^{2,6,8,19,20} This volume-outcome relationship suggests that residents who are gaining increased exposure to cranial operations will graduate with greater competency and experience in performing cranial operations.

Limitations

This study is limited by its retrospective nature. Further analysis with a prospective study would provide additional insight regarding changes in neurosurgery residents' caseloads. Additionally, the categories provided in the ACGME case logs were inconsistent throughout the years and certain procedures were reassigned to different procedural categories for consistency. Also, in this study we were unable to track procedural caseloads for residents throughout each individual year of residency. It should be noted that the data analyzed in this study were retrieved from a plethora of different residency programs that vary in size and output, as well as having different case logging policies. This study cannot account for the inherent variability among logging practices and surgical output of different residency programs.

Conclusions

Neurosurgical residents reported increasing case volumes for cranial procedures between 2009 and 2017. This increase was observed despite work hour limitations set forth in 2003 and 2011. Although an increase was observed in most major cranial surgery categories, there was also considerable variance in the caseloads. An inverse relationship between open vascular and endovascular procedures was also observed; there was a trend of decreasing open vascular procedures and increasing endovascular procedures during the study period. Craniotomy for tumor comprised a disproportionately large percentage of cranial cases. Alternative educational methods or inter-departmental resident exchanges may reduce the variation in case experience between programs and support broader competence in some of the less commonly performed procedures. Neurosurgery residents gained much more exposure to cranial procedures than was expected based on the ACGME required minimums. Additionally, the increasing number of caseloads throughout training suggests

that residents are graduating with greater competency and experience in cranial neurosurgery.

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Disclosures

Dr. Lunsford reports a consultant relationship with Insightec DSMB and direct stock ownership in Elekta.

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Conception and design: Agarwal, Lunsford, Hamilton. Acquisition of data: Agarwal, Cohen. Analysis and interpretation of data: Agarwal, White, Cohen, Hamilton. Drafting the article: Agarwal, White, Cohen. Critically revising the article: Agarwal, Lunsford, Hamilton. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Agarwal. Statistical analysis: White, Hamilton. Administrative/technical/material support: Lunsford, Hamilton. Study supervision: Hamilton.

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