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Specialty Classifications of Physicians Who Provide Neurocritical Care in the United States

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Abstract

Objective: We sought to characterize the specialty classification of U.S. physicians who provide critical care for neurological/neurosurgical disease.

Design: Observational study.

Setting: Inpatient claims between 2009–2015 from a nationally representative 5% sample of Medicare beneficiaries.

Patients: We selected hospitalizations for neurological/neurosurgical diseases with potential to result in life-threatening manifestations requiring critical care.

Measurements and Main Results: Using *Current Procedural Terminology*[®] codes, we determined the medical specialty of providers submitting critical-care claims, and, using National

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Author contributions

- Andrew Martin made substantial contributions to the conception and design of the work, acquired, analyzed, and interpreted data for the work, drafted and revised the manuscript for intellectual content, and provided final approval of the version to be submitted.
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- Hooman Kamel made contributions to the conception and design of the work, acquired and analyzed the data, revised the work critically for intellectual content, provided study supervision, and provided final approval of the version to be submitted.

Statistical analyses performed by Hooman Kamel, Abhinaba Chatterjee, and Xian Wu of Weill Cornell Medical College.

Provider Identifier numbers, we merged in data from the United Council for Neurologic Subspecialties (UCNS) to determine whether the provider was a UCNS diplomate in neurocritical care. We defined providers with a clinical neuroscience background as neurologists, neurosurgeons, and/or UCNS diplomates in neurocritical care. We defined neurocritical care service as a critical care claim with a qualifying neurological/neurosurgical diagnosis in patients with a relevant primary hospital discharge diagnosis and ≥ 3 total critical care claims, excluding claims from the first day of hospitalization since these were mostly emergency-department claims. Our findings were reported using descriptive statistics with exact confidence intervals (CI). Among 1,952,305 Medicare beneficiaries, we identified 99,937 hospitalizations with at least one claim for neurocritical care. In our primary analysis, neurologists accounted for 28.0% (95% CI, 27.5–28.5%) of claims, neurosurgeons for 3.7% (95% CI, 3.5–3.9%), UCNS-certified neurointensivists for 25.8% (95% CI, 25.3–26.3%), and providers with any clinical neuroscience background for 42.8% (95% CI, 42.2–43.3%). The likelihood of management by physicians with a clinical neuroscience background increased proportionally with patients' county-level socioeconomic status and such providers were 3 times more likely to be based at an academic medical center than other physicians who billed for critical care in our sample (odds ratio, 2.9; 95% CI, 1.1–8.1).

Conclusions: Physicians with a dedicated clinical neuroscience background accounted for less than half of neurocritical care service in U.S. Medicare beneficiaries.

Keywords

critical care; medical care; health services research; specialty boards; administrative claims; healthcare; neurology; neurosurgery

The field of critical care medicine emerged in the mid-20th century with the advent of new technologies for mechanical ventilation to support patients with respiratory failure (1). Critical care medicine has always existed at the intersection of multiple medical specialties. Over the past several decades, the field's evolution has led to the development of critical care units specializing in the care of patients with medical, surgical, trauma-related, neurological, neurosurgical, burn-related, and coronary conditions. In this wider context, dedicated neurocritical care units have become increasingly common, first in academic medical centers and then at other types of hospitals. The founding of the Neurocritical Care Society in 2002 was both a reflection and driver of the evolution of neurocritical care as an organized specialty (1). Despite these significant organizational changes in the care of critically ill neurological/neurosurgical patients, little is known about the characteristics of neurocritical care providers at a national level. Neurocritical care is a multidisciplinary field and Neurocritical Care Society physician members have backgrounds in anesthesiology, emergency medicine, internal medicine, neurology, neurosurgery, and other fields. However, few data exist on the specialty classification of physicians who provide neurocritical care in the U.S. We therefore aimed to characterize the specialty classification of U.S. physicians who provide critical care services for neurological or neurosurgical disease.

Methods

Design

We used data from inpatient and outpatient claims between 2009–2015 from a nationally representative 5% random sample of Medicare beneficiaries. The U.S. federal government's Centers for Medicare and Medicaid Services (CMS) provide health insurance to a large majority of U.S. residents once they reach 65 years of age. CMS makes available to researchers data on claims submitted by providers and hospitals in the course of Medicare beneficiaries' clinical care (2). Claims data from hospitals include *International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM)* diagnosis and procedure codes and dates of hospitalization. Physician claims include *ICD-9-CM* diagnosis codes, *Current Procedural Terminology*® (*CPT*®) codes, the dates of service, and physicians' specialty designation and National Provider Identifier (NPI) number. Beneficiaries are randomly selected for the 5% sample based on the last two digits of their health insurance claim number and information on all beneficiaries included in this 5% sample is provided for all years until death, disenrollment from Medicare, or the end of the study period covered in the data use agreement. All claims for a given patient can be linked via a unique, anonymous identifier code, thus allowing for a comprehensive and longitudinal analysis of each beneficiary's diagnoses over time. We adhered to the Report of Studies Conducted Using Observational Routinely Collected Health Data guidelines for studies using administrative claims data (3).

Patient Population

From among our 5% sample of beneficiaries, we included only those 65 years of age who had continuous coverage in traditional fee-for-service Medicare (both Parts A and B) for at least 1 year (or until death, if applicable) and no enrollment in a Medicare Advantage plan, as is standard in analysis of Medicare data (4). From this sample, we selected patients hospitalized between January 1, 2009 and September 30, 2015 for neurological/neurosurgical diseases that have the potential to result in life-threatening manifestations requiring critical care. Based on clinical experience, we defined this inclusion criterion as a composite of traumatic brain injury, stroke, cardiac arrest, seizure, central nervous system infection, coma, inflammatory disorder of the central or peripheral nervous system, disorder of the neuromuscular junction, or malignancy or structural lesion of the central nervous system. These conditions were defined based on the presence of an applicable *ICD-9-CM* code in any hospital discharge diagnosis code position (Table 1). The end date of September 30, 2015 was chosen because *ICD-10* went into effect on October 1, 2015, and we sought to maintain uniformity of coding across the study period. We included all eligible hospitalizations for a given patient, and for each eligible hospitalization, we included all physician claims dated from the day of admission through the day of discharge. Then, from this sample of eligible hospitalizations, we included only those hospitalizations with at least one physician claim for critical care service, defined as *CPT*® codes 99291 or 99292. These codes may be used for direct delivery of medical care to a patient with acute impairment of one or more vital organ system such that there is a high probability of imminent or life-threatening deterioration in the patient's condition. More than one provider can submit claims using these codes on any given day of hospitalization as long as the care is not

duplicative and the providers are of different specialties and not within the same group practice. Any provider participating in Medicare, regardless of specialty, can bill for these codes without the need for specific qualifications.

Measurements

Our exposure variable was neurocritical care service. We examined several definitions of neurocritical care. Our primary definition of neurocritical care was a critical care claim with a qualifying neurological/neurosurgical diagnosis (Table 1) in patients with a relevant primary hospital discharge diagnosis and ≥ 3 total critical care claims, excluding claims from the first day of hospitalization since these were mostly emergency-department claims. Secondary definitions of neurocritical care were (a) any physician claim with *CPT*® codes 99291 or 99292, and any critical care claim except (b) claims in which the provider did not specifically list one of our qualifying neurological/neurosurgical diagnoses (Table 1), (c) claims from hospitalizations for cardiac arrest, (d) claims from the first day of hospitalization, (e) claims from hospitalizations with <3 total critical care claims, and (f) claims from hospitalizations in which the primary hospital discharge diagnosis was not one of our qualifying neurological/neurosurgical diagnoses.

Our outcome was the specialty classification of the physician submitting a critical care claim. We used two methods to classify the background of physicians performing neurocritical care. In the primary approach, we used the CMS provider specialty code associated with the critical care claim. These codes reflect the medical specialty self-designated by providers at the time of their enrollment as participating providers in Medicare (5). Previously, we have found outstanding agreement between these CMS provider specialty codes and the medical specialty designated by physicians in their NPI files (6) (agreement rate, 89.0%; kappa, 0.81), and between the CMS specialty codes and physician backgrounds as determined by review of public online records (agreement rate, 91.5%; kappa, 0.85) (7). To further assess the reliability of CMS provider specialty codes in the neurocritical care population, we randomly selected 100 providers who billed for critical care in our sample. An investigator blinded to their CMS specialty codes reviewed their public online profiles and ascertained whether they had a reported history of training in neurology, neurosurgery, or neurocritical care. We also assessed whether they practiced at an academic medical center, and performed a case-control analysis of whether physicians with a clinical neuroscience background were more likely to be based at an academic medical center. In our secondary approach, we determined whether the physician submitting a critical care claim was a diplomate certified in Neurocritical Care by the United Council for Neurologic Subspecialties (UCNS). To do so, we used a Python software script to look up the NPI numbers of physicians listed in the public UCNS directory of Neurocritical Care diplomates (8). We then used these NPI numbers to determine which critical care claims in our sample had been submitted by UCNS diplomates.

Standard Protocol Approval

This study was approved by the Weill Cornell Medical College institutional review board. The need for human subject consent was waived.

Statistical Analysis

We used descriptive statistics to report proportions along with exact 95% confidence intervals (CI). Since we were interested in whether neurocritical care is evolving towards greater numbers of providers who have both neurological/neurosurgical expertise and critical care expertise, we specifically calculated the proportion of critical care claims submitted by neurologists and neurosurgeons, as well as by UCNS diplomates, who may have trained in a variety of fields but received specific training in neurological/neurosurgical aspects of neurocritical care. We also calculated the proportion of providers with clinical neuroscience training, defined as physicians who trained in neurology and/or neurosurgery and/or were UCNS diplomates. In addition, we created tabular lists of the top 10 physician specialties providing neurocritical care. We also reported subgroup analyses stratified by discharge diagnosis and by receipt of mechanical ventilation, a proxy for illness severity. We used the χ^2 test to compare trends across calendar years 2009–2015. An unadjusted odds ratio (OR) was used to calculate the likelihood of practice at an academic medical center among physicians with a dedicated clinical neuroscience background versus those without. For the above analyses, the unit of analysis was each individual critical care claim. For the analyses below, the unit of analysis was each patient day on which at least one critical care claim was submitted. We used the χ^2 test to compare the proportion of neurologists, neurosurgeons, and UCNS diplomates providing neurocritical care during days when only one physician submitted a critical care claim for a given patient (single-team approach) versus days when multiple different physicians submitted a critical care claim for a given patient (multi-team approach). Lastly, in a post hoc exploratory analysis, we examined the association between management by a provider with a clinical neuroscience background and the risk of mortality during patients' index hospitalization. We adjusted for age, sex, race, Charlson comorbidity index, socioeconomic advantage score, year of hospitalization, diagnosis, and, as a proxy for illness severity, mechanical ventilation. Statistical analyses were performed using Stata/MP (version 14, StataCorp). The threshold of statistical significance for comparisons was set at $\alpha = 0.05$.

Results

Among the 1,952,305 Medicare beneficiaries in our sample, we identified 82,725 patients with 99,937 separate hospitalizations comprising at least one claim for neurocritical care services (Table 2). The most common conditions resulting in neurocritical care were stroke (32.5%), cardiac arrest (31.3%), seizure (14.7%), inflammatory disease (11.6%), and traumatic brain injury (10.9%) (Table 2). During these 99,937 hospitalizations, at least one critical care claim was submitted on 207,782 days, resulting in 346,651 total critical care claims.

Under our primary definition of neurocritical care, neurologists accounted for 28.0% (95% CI, 27.5–28.5%) of claims and neurosurgeons accounted for 3.7% (95% CI, 3.5–3.9%). The remaining claims were most commonly submitted by physicians trained in pulmonary medicine (23.2%), internal medicine (19.5%), emergency medicine (18.4%), critical care medicine (11.2%), cardiology (4.2%), general surgery (3.7%), family medicine (2.8%), or anesthesiology (2.4%) (Figure 1, Definition A). Regardless of specialty, UCNS diplomates

accounted for 25.8% (95% CI, 25.3–26.3%) of claims. Providers with any type of dedicated clinical neuroscience background (i.e., a neurologist, neurosurgeon, or UCNS-certified neurointensivist) submitted 42.8% (95% CI, 42.2–43.3%) of all claims. Providers with a clinical neuroscience background were responsible for a larger proportion of neurocritical care claims in counties with higher socioeconomic advantage (Figure 2) (9). There was some variation in this proportion across diagnoses, with the lowest proportion seen in traumatic brain injury (28.2%) and the highest in central nervous system tumors (61.7%) (Table 3). There was no significant variation between those with and without mechanical ventilation (Table 4). The proportion of patients cared for by providers with a dedicated clinical neuroscience background increased significantly from 39.7% in 2009 to 45.1% in 2015 ($P < 0.001$). We found a 95% agreement rate (kappa, 0.85) between our dataset and physicians' online profiles. Among providers who were not classified as having a clinical neuroscience background in our dataset, only 1% (95% CI, 0–5.4%) listed a training background in neurology, neurosurgery, and/or neurocritical care in their online profile. Physicians with a clinical neuroscience background were approximately 3 times more likely to be based at an academic medical center than other physicians who billed for critical care in our sample (OR, 2.9; 95% CI, 1.1–8.1).

Under our secondary definitions of neurocritical care, the proportion of critical care claims submitted by neurologists ranged from 7.5% (95% CI, 7.4–7.6%) in the scenario excluding cardiac arrest hospitalizations to 14.8% (95% CI, 14.6–15.0%) in the scenario which required a primary neurological hospital discharge diagnosis (Figure 1, Definitions B-G). The proportion of critical care claims submitted by neurosurgeons ranged from 0.8% (95% CI, 0.8–0.9%) in the scenario requiring at least three critical care bills during the hospitalization to 2.0% (95% CI, 1.9–2.1%) in the scenario which required a primary neurological hospital discharge diagnosis. The proportion of critical care claims submitted by UCNS diplomates ranged from 7.3% (95% CI, 7.2–7.4%) in the scenario excluding cardiac arrest hospitalizations to 12.7% (95% CI, 12.5–12.9%) in the scenario which required a primary neurological hospital discharge diagnosis. The proportion of critical care claims submitted by providers with a dedicated clinical neuroscience background ranged from 12.7% (95% CI, 12.6–12.8%) when excluding cardiac arrest hospitalizations to 22.8% (95% CI, 22.5–23.0%) in the scenario which required a primary neurological hospital discharge diagnosis.

Among all hospitalization days with at least one critical care claim, claims were submitted by multiple different providers on 34.2% of days. Such a multi-team approach was more common on days when a critical care claim was submitted by neurologists (49.0% versus 33.0%; $P < 0.001$), neurosurgeons (49.2% versus 34.1%; $P < 0.001$), UCNS diplomates (41.2% versus 33.6%; $P < 0.001$), or any clinical-neuroscience trained physician (44.5% versus 32.7%; $P < 0.001$).

In a post hoc exploratory analysis, we found that management by a provider with a clinical neuroscience background was associated with a lower likelihood of mortality after adjustment for age, sex, race, Charlson comorbidity index, socioeconomic advantage score, year of hospitalization, diagnosis, and mechanical ventilation (OR, 0.86; 95% CI, 0.78–0.94).

Discussion

Among a large, nationally representative sample of Medicare beneficiaries, we found that physicians submitting claims for neurocritical care services had a wide variety of training backgrounds. We found that neurocritical care in the U.S. is delivered predominantly by physicians with a specialty classification in pulmonary medicine, internal medicine, critical care medicine, emergency medicine, and neurology. Physicians with a dedicated clinical neuroscience background accounted for approximately 10–40% of neurocritical care claims, depending on the criteria used to define neurocritical care.

There are few published data on the characteristics of physicians caring for patients with neurological/neurosurgical critical illness in the U.S. This issue is relevant because of ongoing discussions about the optimal organization of neurocritical care. In one model, the care of critically ill neurological/neurosurgical patients is shared between an intensivist who manages common systemic issues such as respiratory failure, hemodynamic instability, acute kidney injury, and infection, and a neurologist or neurosurgeon who manages the nervous system-specific issues that resulted in neurocritical care admission. In recent years, organizations such as the Neurocritical Care Society have advocated for, and many hospitals have adopted, an alternative model in which physicians who have received dedicated training in both the clinical neurosciences and critical care take primary responsibility for all aspects of management for a patient requiring neurocritical care. Recent observational studies have suggested that specialized neurocritical care may reduce mortality and improve outcomes (10). There are few nationwide data on the prevalence of these two approaches. In this context, our findings provide novel insights into the organization of neurocritical care as currently practiced in the U.S. Our results suggest that the shared-responsibility model remains the prevalent approach, with neurologists, neurosurgeons, and UCNS-certified neurointensivists providing critical care services to a minority of patients. We found that dedicated neurocritical care services are more common in academic medical centers and in more socioeconomically advantaged regions. The latter finding is consistent with studies of other diseases which generally find greater access to specialty care in higher-income regions in the U.S. (11)

Our findings should be interpreted in the context of our study's limitations. First, our analysis involved only patients ≥ 65 years of age, and thus our findings may not be generalizable to all patients in the U.S. For instance, the proportion of certain neurocritical care diagnoses within our cohort may be different compared to those within a younger patient population. On the other hand, half of all patients in the U.S. who meet the inclusion criteria of our study are ≥ 65 years of age, (12) supporting the generalizability of our results. Second, we used our clinical judgment and experience to create a composite of diseases by which to identify patients receiving critical care. To mitigate the inherent subjectivity of this approach, we performed numerous secondary analyses using different definitions of neurocritical care and presented the full range of plausible estimates instead of making overly precise claims. Third, our results have limited applicability outside the U.S. given its unique organization of healthcare delivery. Fourth, we relied on CMS provider specialty codes to classify critical care providers' specialty backgrounds. Training paths leading to a role as a critical care provider vary and generally require residency training followed by

fellowship training. CMS specialty classifications are self-reported and therefore may not accurately reflect physicians' training backgrounds. We could not further delineate the training backgrounds of those physicians with a self-identified specialty of "critical care." Likewise, a physician providing critical care services while identifying their specialty as "internal medicine" may or may not have undergone additional subspecialty training in critical care. With the heterogeneity of residency and fellowship training pathways among critical care physicians, there is likely to be some overlap in the physician specialty categories when reported as a single designation. However, in both our previous work and in this study, we have found that the CMS specialty designations are generally highly reliable, so it is unlikely that there was enough imprecision in our estimates to fundamentally change our finding that the majority of physicians providing neurocritical care services to U.S. Medicare beneficiaries do not have formal clinical neuroscience training. Lastly, although we found a lower risk of mortality in patients managed by providers with clinical neuroscience backgrounds, this analysis was subject to many potential biases that cannot be accounted for and thus should be seen as an exploratory analysis only.

Conclusion

The field of neurocritical care has rapidly grown and evolved over the past several decades. An increasing number of physicians in the U.S. have received dedicated neurocritical care training intended to allow them to supervise all aspects of medical care for critically ill neurological and neurosurgical patients. However, based on self-reported specialty classification and UCNS diplomate status, we found that the majority of physicians providing neurocritical care service to Medicare beneficiaries in the United States from 2009–2015 do not have a dedicated clinical neuroscience background.

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Figure 1:

Distribution of Specialties of Physicians Submitting Critical Care Claims During Hospitalizations for Neurological or Neurosurgical Disease.

Caption:

- Definition A: Critical care claims with a qualifying neurological/neurosurgical diagnosis in patients with a relevant primary hospital discharge diagnosis and ≥ 3 total critical care claims, excluding claims from the first day of hospitalization.
- Definition B: Critical care claims from hospitalizations with a primary hospital discharge diagnosis of neurological/neurosurgical disease.
- Definition C: Critical care claims with an associated neurological diagnosis.
- Definition D: Critical care claims excluding the first day of hospitalization.
- Definition E: Critical care claims excluding hospitalizations for cardiac arrest.
- Definition F: Critical care claims from hospitalizations with at least 3 critical care claims.
- Definition G: Any critical care claim..

Figure 2:

Proportion of Neurocritical Care Provided by Physicians with a Dedicated Clinical Neuroscience Background Based on County Socioeconomic Advantage Score.

Caption: Each county's socioeconomic advantage score was calculated based on six variables representing wealth and income, education, and occupation (9). Socioeconomic data was obtained from the American Communities Survey (13). The resulting quantity represents the z-score, or the number of standard deviations from the mean socioeconomic score.

Table 1.*ICD-9-CM* Diagnosis Codes Used to Define Conditions Requiring Neurocritical Care.

Condition	<i>ICD-9-CM</i> codes
Stroke	430, 432.1, 431, 433.x1, 434.x1, 436
Traumatic brain injury	800.0–801.9, 803.0–804.9, 850.0–854.1, 959.01
Cardiac arrest	427.1, 427.4, 427.41, 427.42, 427.5, 798, 798.1, 798.2
Seizure	345
Central nervous system infection	003.21, 013, 036, 036.1, 047, 049.0, 049.1, 053.0, 054.72, 072.1, 072.2, 091.81, 094.2, 098.82, 100.81, 320–322, 049.8, 049.9, 054.3, 058.2, 062–065, 094.81, 323.0–323.42, 324.0, 324.9
Coma	780.01
Inflammatory disorder	340, 341, 357
Disease of neuromuscular junction	358
Central nervous system malignancy	191–192, 198.3, 198.4, 194.3, 237.0, 237.5, 237.6, 225
Central nervous system structural lesion	331.3–331.5, 348.4, 348.5

Abbreviations: ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.

Table 2.

Characteristics of Medicare Beneficiaries Receiving Critical Care for Neurological or Neurosurgical Conditions, 2009–2015.

Characteristic	No. of beneficiaries ^a (N = 97,980)
Age, mean, y	78.1
Female	49,588(50.6)
Race	
White	80,489 (82.2)
Black	11,639 (11.9)
Other	5,852 (6.0)
Diagnosis ^b	
Stroke	31,862 (32.5)
Traumatic brain injury	10,714 (10.9)
Cardiac arrest	30,683 (31.3)
Seizure	14,426 (14.7)
CNS Infection	905 (0.9)
Coma	4,141 (4.2)
Inflammatory disorder	11,390 (11.6)
Disease of neuromuscular junction	973 (1.0)
CNS Malignancy	4,372 (4.5)
Structural lesion of CNS	2,383 (2.4)
Charlson comorbidities, mean, no.	3.7

Abbreviations: CNS, central nervous system; SD, standard deviation.

^aData represent numbers (%) unless otherwise indicated.

^bPercentages sum to more than 100 because some patients had multiple diagnoses during a given hospitalization.

Table 3.

Proportions of Neurocritical Care Service by Clinical Neuroscience Providers, Stratified by Diagnosis.

Diagnosis	Neurologist	Neurosurgeon	UCNS Diplomate	Any Clinical Neuroscience Background
Ischemic stroke	30.4%	1.6%	19.8%	40.6%
ICH	30.3%	5.8%	31.6%	49.9%
SAH	31.2%	4.9%	40.9%	53.3%
TBI	12.7%	7.1%	17.9%	28.2%
Seizure	43.8%	1.5%	28.2%	53.0%
CNS infection	39.8%	3.1%	22.5%	47.1%
Coma	22.3%	1.4%	19.1%	30.5%
Inflammatory disorder	42.5%	3.5%	20.4%	53.1%
Myoneural disorder	48.05	0%	32.7%	60.9%
CNS tumor	43.2%	10.4%	39.8%	61.7%
CNS structural lesion	25.0%	2.8%	40.3%	48.6%

Abbreviations: CNS, central nervous system; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage; TBI, traumatic brain injury; UCNS, United Council for Neurologic Subspecialties.

Table 4.

Proportions of Neurocritical Care Service by Clinical Neuroscience Providers, Stratified by Mechanical Ventilation Status.

Diagnosis	Neurologist	Neurosurgeon	UCNS Diplomate	Any Clinical Neuroscience Background
Mechanical ventilation	26.1%	3.3%	28.7%	41.8%
No ventilation	30.7%	4.3%	21.9%	44.1%

Abbreviations: UCNS, United Council for Neurologic Subspecialties.