An analysis of cross-continental scholarship requirements during neurosurgical training and national research productivity

Michael S. Rallo, BS, Omar Ashraf, BA, Fareed Jumah, MD, Gaurav Gupta, MD, and Anil Nanda, MD, MPH

Department of Neurosurgery, Rutgers Robert Wood Johnson Medical School, New Brunswick, New Jersey

OBJECTIVE Engagement in research and scholarship is considered a hallmark of neurosurgical training. However, the participation of neurosurgical trainees in this experience has only recently been analyzed and described in the United States, with little, if any, data available regarding the research environment in neurosurgical training programs across the globe. Here, the authors set out to identify requirements for research involvement and to quantify publication rates in leading neurosurgical journals throughout various nations across the globe.

METHODS The first aim was to identify the research requirements set by relevant program-accrediting and/or board-certifying agencies via query of the literature and published guidelines. For the second part of the study, the authors attempted to determine each country’s neurosurgical research productivity by quantifying publications in the various large international neurosurgical journals—World Neurosurgery, Journal of Neurosurgery, and Neurosurgery—via a structured search of PubMed.

RESULTS Data on neurosurgical training requirements addressing research were available for 54 (28.1%) of 192 countries. Specific research requirements were identified for 39 countries, partial requirements for 8, and no requirements for 7. Surprisingly, the authors observed a trend of increased average research productivity with the absence of designated research requirements, although this finding is not unprecedented in the literature.

CONCLUSIONS A variety of countries of various sizes and neurosurgical workforce densities across the globe have instituted research requirements during training and/or prior to board certification in neurosurgery. These requirements range in intensity from 1 publication or presentation to the completion of a thesis or dissertation and occur at various time points throughout training. While these requirements do not correlate directly to national research productivity, they may provide a foundation for developing countries to establish a culture of excellence in research.

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presented by the National Resident Match Program, neurosurgery ranked as the highest in mean number of abstracts, presentations, and publications among allopathic seniors who matched into the specialty in 2018. One of the most significant factors in determining the productivity of these trainees is the extent of support offered by their institutions. Institutions can foster supporting educational environments via the provision of protected research time, funding, medical editorial assistance, and travel stipends. In fact, the lack of protected time and institutional resources, including training in research design and conduct, has been identified as one of the greatest barriers to research involvement among physicians in various specialties. Notably, however, a program’s designation of a “research requirement” was not shown to have a significant impact on departmental productivity in the large neurosurgery resident cohort mentioned above. Authors of that study reasoned that research is engrained in the culture of many of the highly productive programs and does not require formal designation, while programs with an explicit requirement may be in the early stages of such a culture change.

The translation of these findings to the global arena of neurosurgery is unclear and likely influenced by various country- or region-specific factors including socioeconomic status, density of neurosurgeons, and research infrastructure and support. At present, there is limited literature on identifying and evaluating research requirements during neurosurgical training in nations outside of North America. In an important study focused on identifying and evaluating research requirements in several nations, Gasco et al. reported that 3.8% of responding international societies require involvement in a research project, with publication, prior to oral examination eligibility. However, this analysis was limited to member societies of the World Federation of Neurosurgical Societies (WFNS) and did not explore in depth the impact of the requirement, nor other factors on research productivity in the responding countries. In appreciation of the great value of participation in the pursuit of knowledge via research and/or scholarship, our group has set out to identify research requirements established by relevant accrediting and/or certifying bodies across the globe. Additionally, we seek to understand how these requirements correspond to productivity.

Methods

Data Extraction

A list of countries was compiled from the WFNS Global Neurosurgical Workforce Map (https://www wfns org/ menu/61/global-neurosurgical-workforce-map). Our first aim was to identify research requirements set by relevant program-accrediting and/or board-certifying agencies within each country. This search was conducted using a general query of Google and the PubMed database to obtain the above described information from agency/society guidelines and previously reported literature. Search terms for these queries included various combinations of the country name AND “neurosurgery” AND “residency” OR “training” OR “education” AND “research.” These queries returned results including websites of national/regional neurosurgical certification organizations and previously published scholarly literature, which facilitated our determination of research requirements during training. Required research was defined as any compulsory research activity during residency, such as mandatory publications, presentations, thesis/dissertation, or research time. Explicit requirements including number of publications and/or presentations, when listed, were recorded for analysis. Undefined scholarly requirements were excluded from our analysis.

For the second part of the study, we aimed to determine each country’s neurosurgical research productivity, which was assessed by quantifying a given country’s publications in the various large international neurosurgical journals: World Neurosurgery, Journal of Neurosurgery, and Neurosurgery. These data were collected by performing a query of the PubMed database using the name of each country as the term in the “affiliation” search field in combination with the title of each journal in the “journal” search field. Our final PubMed query was as follows: “<journal->[Journal] AND “<country>”[Affiliation] with no restriction on time.

Data Analysis

We performed a descriptive analysis of the research requirements and productivity across the countries for which data were available. These countries were grouped into 3 categories based on the nature of their requirements: 1) no stated requirement; 2) partial requirement, defined as a guideline lacking explicit details and/or only requiring education on research methodology; and 3) specific requirement, defined as a guideline with details on the type of research required and/or number of publications/presentations. The number of publications for countries within each group was averaged, with descriptive statistics reported as the mean and range.

Results

We identified a total of 192 countries from the WFNS Global Neurosurgery Workforce Map. A complete list of countries and research output is included in Table 1, which displays each country along with information regarding that country’s continent and geographic region as well as its number of publications in the aforementioned journals. Data regarding neurosurgical training requirements for research were available for 54 (28.1%) of the 192 countries. Specific research requirements, as defined above, were identified for 39 countries, partial requirements for 8, and no requirements for 7 (Table 2). The most frequently occurring reporting body was the College of Surgeons of East, Central and Southern Africa (COSECSA), which oversees surgical training in 14 African countries. In Europe, such data were primarily reported by the Joint Residency Advisory and Accreditation Committee (JRAAC), which is an agency that accredits residency programs throughout the various countries in the European Union. Finally, requirements in several nations were set by board-certifying agencies, such as the Japan Neurosurgical Society, making research obligatory in order to be board certified, although
TABLE 1. Summary of countries, with information regarding their geographic location and research output in three neurosurgical journals

| Country                  | Continent | Region                  | World Neurosurg | Neurosurg | J Neurosurg |
|--------------------------|-----------|-------------------------|-----------------|-----------|-------------|
| Afghanistan              | Asia      | South Asia              | 0               | 0         | 0           |
| Albania                  | Europe    | Balkan Peninsula        | 4               | 0         | 3           |
| Algeria                  | Africa    | North Africa            | 3               | 0         | 1           |
| Angola                   | Africa    | South-Central Africa    | 1               | 0         | 0           |
| Antigua & Barbuda        | North America | Caribbean             | 0               | 0         | 0           |
| Argentina                | South America | Southern South America | 37              | 19        | 21          |
| Armenia                  | Eurasia   | Caucasia                | 1               | 0         | 0           |
| Australia                | Oceania   |                         | 140             | 140       | 117         |
| Austria                  | Europe    | Central Europe          | 75              | 65        | 81          |
| Azerbaijan               | Eurasia   | Caucasia                | 1               | 0         | 0           |
| Bahamas                  | North America | Caribbean             | 0               | 0         | 0           |
| Bahrain                  | Asia      | Gulf                    | 0               | 0         | 0           |
| Bangladesh               | Asia      | South Asia              | 5               | 0         | 1           |
| Barbados                 | North America | Caribbean             | 0               | 0         | 0           |
| Belarus                  | Europe    | Eastern Europe          | 0               | 0         | 1           |
| Belgium                  | Europe    | Western Europe          | 65              | 100       | 75          |
| Belize                   | North America | Central America         | 0               | 0         | 0           |
| Benin                    | Africa    | West Africa             | 2               | 0         | 0           |
| Bhutan                   | Asia      | South Asia              | 0               | 0         | 0           |
| Bosnia & Herzegovina     | Europe    | Balkan Peninsula        | 5               | 0         | 0           |
| Botswana                 | Africa    | South Africa            | 0               | 0         | 0           |
| Brazil                   | South America |                   | 234             | 110       | 103         |
| Brunei Darussalam        | Asia      | Maritime Southeast Asia | 0               | 0         | 0           |
| Bulgaria                 | Europe    | Southeast Europe        | 4               | 4         | 0           |
| Burkina Faso             | Africa    | West Africa             | 1               | 0         | 0           |
| Burundi                  | Africa    | East Africa             | 0               | 0         | 0           |
| Cabo Verde               | Africa    | West Africa             | 0               | 0         | 0           |
| Cambodia                 | Asia      | Southeast Asia          | 10              | 0         | 0           |
| Cameroon                 | Africa    | Central Africa          | 0               | 0         | 0           |
| Canada                   | North America |                   | 342             | 570       | 682         |
| Cayman Islands           | North America | Caribbean             | 0               | 0         | 0           |
| Central African Republic | Africa    | Central (Middle) Africa | 0               | 0         | 0           |
| Chad                     | Africa    | North-Central Africa    | 0               | 0         | 0           |
| Chile                    | South America | Western South America | 35              | 8         | 0           |
| China                    | Asia      | East Asia               | 1946            | 235       | 336         |
| Colombia                 | South America | Northern South America | 35              | 14        | 8           |
| Comoros                  | Africa    | East Africa             | 0               | 0         | 0           |
| Costa Rica               | North America | Central America         | 0               | 1         | 0           |
| Côte d’Ivoire            | Africa    | West Africa             | 0               | 0         | 1           |
| Croatia                  | Europe    | Balkan Peninsula        | 12              | 3         | 8           |
| Cuba                     | North America | Caribbean             | 2               | 1         | 0           |
| Cyprus                   | Europe    | Mediterranean Basin     | 4               | 0         | 0           |
| Czech Republic           | Europe    | Central Europe          | 20              | 16        | 33          |
| Democratic People's Republic of Korea | Asia | Korean Peninsula | 1               | 0         | 0           |
| Democratic Republic of the Congo | Africa | Central Africa | 0               | 0         | 0           |
| Denmark                  | Europe    | Scandinavia             | 25              | 31        | 36          |
| Dominica                 | North America | Caribbean             | 1               | 0         | 0           |

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| Country                     | Continent         | Region                  | No. of Publications | World Neurosurg | Neurosurg | J Neurosurg |
|-----------------------------|-------------------|-------------------------|---------------------|-----------------|-----------|-------------|
| Dominican Republic          | North America     | Caribbean               | 2                   | 0               | 0         | 2           |
| Ecuador                     | South America     | Western South America   | 3                   | 0               | 0         | 0           |
| Egypt                       | Africa            | Northeast Africa        | 92                  | 19              | 34        |             |
| El Salvador                 | North America     | Central America         | 0                   | 0               | 0         |             |
| Equatorial Guinea           | Africa            | Central (Middle) Africa | 0                   | 0               | 0         |             |
| Estonia                     | Africa            | East Africa             | 0                   | 0               | 0         |             |
| Ecuador                     | South America     | Western South America   | 3                   | 0               | 0         |             |
| Egypt                       | Africa            | East Africa             | 13                  | 0               | 0         |             |
| Federated States of Micronesia | Oceania       | Micronesia              | 0                   | 0               | 0         |             |
| Fiji                        | Oceania           | Melanesia               | 0                   | 0               | 0         |             |
| France                      | Europe            | Western Europe          | 4                   | 0               | 0         |             |
| Gabon                       | Africa            | West-Central Africa     | 0                   | 0               | 0         |             |
| Georgia                     | Eurasia           | Caucasia                | 0                   | 0               | 0         |             |
| Germany                     | Europe            | Western Europe          | 586                 | 754             | 644       |             |
| Ghana                       | Africa            | West Africa             | 4                   | 0               | 0         |             |
| Greece                      | Europe            | Balkan Peninsula        | 58                  | 7               | 5         |             |
| Grenada                     | North America     | Caribbean               | 58                  | 7               | 5         |             |
| Guatemala                   | North America     | Central America         | 58                  | 7               | 5         |             |
| Guinea                      | Africa            | West Africa             | 0                   | 0               | 0         |             |
| Guinea-Bissau               | Africa            | West Africa             | 0                   | 0               | 0         |             |
| Guyana                      | South America     | Northern South America  | 0                   | 0               | 0         |             |
| Haiti                       | North America     | Caribbean               | 5                   | 0               | 1         |             |
| Honduras                    | North America     | Central America         | 58                  | 7               | 5         |             |
| Hungary                     | Europe            | Central Europe          | 58                  | 7               | 5         |             |
| Iceland                     | Europe            | North Atlantic          | 5                   | 0               | 0         |             |
| India                       | Asia              | South Asia              | 56                  | 7               | 5         |             |
| Indonesia                   | Asia              | Maritime Southeast Asia | 56                  | 7               | 5         |             |
| Iran                        | Asia              | West Asia               | 12                  | 2               | 2         |             |
| Iraq                        | Asia              | West Asia               | 12                  | 2               | 2         |             |
| Ireland                     | Europe            | British Isles           | 12                  | 2               | 2         |             |
| Israel                      | Asia              | West Asia               | 12                  | 2               | 2         |             |
| Italy                       | Europe            | Southern Europe         | 12                  | 2               | 2         |             |
| Jamaica                     | North America     | Caribbean               | 12                  | 2               | 2         |             |
| Japan                       | Asia              | Eastern Asia            | 12                  | 2               | 2         |             |
| Jordan                      | Asia              | Western Asia            | 12                  | 2               | 2         |             |
| Kazakhstan                  | Asia              | Central Asia            | 12                  | 2               | 2         |             |
| Kenya                       | Africa            | East Africa             | 12                  | 2               | 2         |             |
| Kiribati                    | Oceania           | Micronesia              | 12                  | 2               | 2         |             |
| Kosovo                      | Europe            | Balkan Peninsula        | 12                  | 2               | 2         |             |
| Kuwait                      | Asia              | Arabian Peninsula       | 12                  | 2               | 2         |             |
| Kyrgyzstan                  | Asia              | Central Asia            | 12                  | 2               | 2         |             |
| Lao People's Democratic Republic | Asia         | Mainland Southeast Asia | 12                  | 2               | 2         |             |
| Latvia                      | Europe            | Northern Europe         | 12                  | 2               | 2         |             |
| Lebanon                     | Asia              | Western Asia            | 12                  | 2               | 2         |             |

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| Country                | Continent | Region                   | World Neurosurg | Neurosurg | J Neurosurg |
|------------------------|-----------|--------------------------|-----------------|-----------|-------------|
| Lesotho                | Africa    | South Africa             | 0               | 0         | 0           |
| Liberia                | Africa    | West Africa              | 0               | 0         | 0           |
| Libya                  | Africa    | North Africa             | 0               | 1         | 0           |
| Lithuania              | Europe    | Northern Europe          | 4               | 2         | 1           |
| Luxembourg             | Europe    | Western Europe           | 2               | 0         | 0           |
| Madagascar             | Africa    | East Africa              | 0               | 0         | 0           |
| Malawi                 | Africa    | Southeast Africa         | 2               | 0         | 0           |
| Malaysia               | Asia      | Maritime Southeast Asia  | 10              | 4         | 4           |
| Maldives               | Asia      | South Asia               | 0               | 0         | 0           |
| Mali                   | Africa    | West Africa              | 0               | 0         | 0           |
| Malta                  | Europe    | Mediterranean Basin      | 0               | 0         | 0           |
| Marshall Islands       | Oceania   | Micronesia               | 0               | 0         | 0           |
| Martinique             | North America | Caribbean       | 0               | 0         | 0           |
| Mauritania             | Africa    | Northwest Africa         | 0               | 0         | 0           |
| Mauritius              | Africa    | East Africa              | 0               | 0         | 0           |
| Mexico                 | North America | Asia                  | 104             | 61        | 58          |
| Mongolia               | Asia      | East Asia                | 3               | 0         | 1           |
| Montenegro             | Europe    | Southeast Europe         | 0               | 2         | 1           |
| Morocco                | Africa    | North Africa             | 22              | 6         | 3           |
| Mozambique             | Africa    | Southeast Africa         | 2               | 0         | 0           |
| Myanmar                | Asia      | Mainland Southeast Asia  | 3               | 0         | 0           |
| Namibia                | Africa    | South Africa             | 0               | 0         | 0           |
| Nauru                  | Oceania   | Micronesia               | 0               | 0         | 0           |
| Nepal                  | Asia      | South Asia               | 20              | 0         | 1           |
| New Zealand            | Oceania   | Polynesia                | 18              | 14        | 9           |
| Nicaragua              | North America | Central America | 4               | 0         | 0           |
| Niger                  | Africa    | West Africa              | 0               | 0         | 0           |
| Nigeria                | Africa    | West Africa              | 24              | 2         | 5           |
| North Macedonia        | Europe    | Balkan Peninsula         | 0               | 4         | 0           |
| Norway                 | Europe    | Scandinavian Peninsula   | 55              | 84        | 61          |
| Oman                   | Asia      | Arabian Peninsula        | 2               | 0         | 1           |
| Pakistan               | Asia      | South Asia               | 35              | 3         | 2           |
| Palau                  | Oceania   | Micronesia               | 0               | 0         | 0           |
| Panama                 | North America | Central America | 2               | 0         | 0           |
| Papua New Guinea       | Oceania   | Melanesia                | 1               | 0         | 0           |
| Paraguay               | South America | Central South America | 0               | 0         | 0           |
| Peru                   | South America | Western South America | 5               | 0         | 1           |
| Philippines            | Asia      | Maritime Southeast Asia  | 9               | 0         | 7           |
| Plurinational State of Bolivia | South America | Western South America | 4               | 0         | 1           |
| Poland                 | Europe    | Central Europe           | 36              | 9         | 16          |
| Portugal               | Europe    | Iberian Peninsula        | 17              | 15        | 7           |
| Puerto Rico            | North America | Caribbean       | 10              | 7         | 15          |
| Qatar                  | Asia      | Arabian Peninsula        | 5               | 0         | 2           |
| Republic of Korea      | Asia      | Korean Peninsula         | 252             | 75        | 100         |
| Republic of Moldova    | Europe    | Eastern Europe           | 0               | 0         | 0           |
| Republic of the Congo  | Africa    | Central Africa           | 0               | 0         | 0           |

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| Country                  | Continent     | Region                      | World Neurosurg | Neurosurg | J Neurosurg |
|-------------------------|---------------|-----------------------------|-----------------|-----------|-------------|
| Romania                 | Europe        | Balkan Peninsula            | 18              | 2         | 5           |
| Russian Federation      | Europe        | Eastern Europe              | 61              | 5         | 14          |
| Rwanda                  | Africa        | Central Africa              | 6               | 0         | 0           |
| Saint Kitts & Nevis     | North America | Caribbean                   | 0               | 0         | 0           |
| Saint Lucia             | North America | Caribbean                   | 0               | 0         | 0           |
| Samoa                   | Oceania       | Polynesia                   | 0               | 0         | 0           |
| São Tomé and Principe   | Africa        | West Africa                 | 0               | 0         | 0           |
| Saudi Arabia            | Asia          | Arabian Peninsula           | 71              | 15        | 22          |
| Senegal                 | Africa        | West Africa                 | 1               | 0         | 0           |
| Serbia                  | Europe        | Balkan Peninsula            | 15              | 8         | 3           |
| Seychelles              | Africa        | East Africa                 | 0               | 0         | 0           |
| Sierra Leone            | Africa        | West Africa                 | 0               | 0         | 0           |
| Singapore               | Asia          | Maritime Southeast Asia     | 32              | 26        | 22          |
| Slovakia                | Europe        | Central Europe              | 4               | 0         | 3           |
| Slovenia                | Europe        | Southern Central Europe     | 0               | 7         | 7           |
| Solomon Islands         | Oceania       | Melanesia                   | 0               | 0         | 0           |
| Somalia                 | Africa        | East Africa                 | 0               | 0         | 0           |
| South Africa            | Africa        | South Africa                | 27              | 30        | 21          |
| South Sudan             | Africa        | East-Central Africa         | 0               | 0         | 0           |
| Spain                   | Europe        | Southwestern Europe         | 169             | 110       | 144         |
| Sri Lanka               | Asia          | South Asia                  | 0               | 0         | 0           |
| State of Palestine      | Asia          | Western Asia                | 13              | 0         | 0           |
| Sudan                   | Africa        | Northeast Africa            | 3               | 0         | 0           |
| Suriname                | South America | Northeastern South America  | 0               | 0         | 0           |
| Sweden                  | Europe        | Scandinavian Peninsula      | 53              | 135       | 149         |
| Switzerland             | Europe        | Central Europe              | 190             | 134       | 140         |
| Syrian Arab Republic    | Asia          | West Asia                   | 1               | 0         | 0           |
| Tajikistan              | Asia          | Central Asia                | 0               | 0         | 0           |
| Tanzania                | Africa        | East Africa                 | 13              | 1         | 1           |
| Thailand                | Asia          | Mainland Southeast Asia     | 28              | 8         | 6           |
| The Gambia              | Africa        | West Africa                 | 0               | 0         | 0           |
| The Netherlands         | Europe        | Northwest Europe            | 123             | 197       | 192         |
| Timor-Leste             | Asia          | Maritime Southeast Asia     | 0               | 0         | 0           |
| Togo                    | Africa        | West Africa                 | 0               | 0         | 0           |
| Tonga                   | Oceania       | Polynesia                   | 0               | 0         | 0           |
| Trinidad & Tobago       | South America | Caribbean                   | 0               | 0         | 0           |
| Tunisia                 | Africa        | North Africa                | 15              | 1         | 2           |
| Turkey                  | Europe        | Eastern Europe              | 281             | 169       | 158         |
| Turkmenistan            | Asia          | Central Asia                | 0               | 0         | 0           |
| Tuvalu                  | Oceania       | Polynesia                   | 0               | 0         | 0           |
| Uganda                  | Africa        | East Africa                 | 12              | 3         | 6           |
| Ukraine                 | Europe        | Eastern Europe              | 0               | 0         | 1           |
| United Arab Emirates    | Asia          | Arabian Peninsula           | 8               | 0         | 3           |
| United Kingdom          | Europe        | British Isles               | 237             | 127       | 273         |
| United States           | North America |                             | 4375            | 4200      | 3724        |
| Uruguay                 | South America | Southeastern South America  | 3               | 0         | 3           |

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it was not required as a component of training. The average number of publications in World Neurosurgery, Journal of Neurosurgery, and Neurosurgery for each category of requirements is summarized in Fig. 1. Surprisingly, we observed a trend of increased average research productivity with the absence of designated research requirements. Similar results have been observed in a previous bibliometric analysis of research productivity among specific neurosurgical residency programs within the United States and will be discussed later. The heterogeneity of our results, especially the variance in research productivity among nations, unfortunately prevented statistical analysis of the relationship between research requirements and national research productivity. In addition, when we averaged publications in each journal among all countries, we found that World Neurosurgery had the highest number of publications (69.3, range 0–4375 vs 52.7, range 0–4200 and 53.4, range 0–3724 for Neurosurgery and Journal of Neurosurgery, respectively). This finding is consistent with the mission of World Neurosurgery to provide an “international forum” and “two-way dialogue” for neurosurgeons and those caring for neurosurgical patients. Once again, statistical analysis was not possible because of the high heterogeneity of the data. The breakdown of research productivity in these journals across continents is summarized in Fig. 2. Publication in these journals appears biased toward developed countries in North America, Europe, and Asia. Overall, we have been able to obtain and report interesting descriptive data regarding the types of research mandates imposed during training and/or prior to board certification via a global review of training curricula and requirements.

### Discussion

The goal of our study was to identify and describe research requirements during neurosurgical training and/or prior to board certification across the globe. In addition, we sought to quantify research output across various nations via publication in 3 of the most prominent journals in the field: World Neurosurgery, Neurosurgery, and Journal of Neurosurgery. Notably, specific research requirements were identified in countries in Africa, Asia, Europe, and Oceania. Countries for which requirement information was available in North America and South America identified no mandatory research requirements. We did not find a positive correlation between the presence of a research requirement and research output, as may have been intuited. In fact, our rudimentary analysis suggested that countries lacking research requirements had higher rates of research productivity, although this analysis did not account for other factors such as density of neurosurgeons, size, etc. A similar result was shown in a recent analysis of American residency program research output, in which mandated research did not correlate with improved productivity. Authors of that study postulated that this finding may be attributable to a culture in which research is informally established in many of the high-output institutions, thereby making a requirement unnecessary. However, for programs seeking to establish the culture, such a requirement may be useful.

While some countries detail explicit requirements for research experience during neurosurgical training, such as a minimum number of publications or presentations, others make broad recommendations or requirements, with individual programs then determining their own explicit guidelines. This is characteristic of the United States, in which the American Board of Neurological Surgery encourages resident involvement in research, and individual programs make subsequent decisions about the requirement for, and the timing of, research within the training program. We discuss below the research requirements of selected countries across the continents mentioned above, with a focus on the types of requirements and the timing of research involvement during training, as available.

### Africa

African countries specifying research requirements spanned the continent in terms of regional representation; however, the majority fell within Eastern, Central, and Southern Africa in territories under the purview of the COSECSA, which has been instrumental in the development and standardization of surgical training curricula in a variety of surgical subspecialties, including neurosurgery, throughout Sub-Saharan Africa. COSECSA currently represents 14 countries, although according to the most re-
TABLE 2. Summary of research requirements and output for countries

| Country        | Continent | Region                | Requirement Type | Requirement(s) or Comment(s)                                                                 | Requiring or Reporting Agency                              | No. of Publications |
|----------------|-----------|-----------------------|------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------|---------------------|
| Botswana       | Africa    | South Africa          | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 0                   |
| Burundi        | Africa    | East Africa           | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 0                   |
| Egypt          | Africa    | Northeast Africa      | Specific         | Multiple degrees available to neurosurgeons, 1 pathway requires thesis defense              | Egyptian Society of Neurological Surgeons                 | 92                  |
| Ethiopia       | Africa    | East Africa           | Specific         | Complete thesis                                                                             | COSECSA                                                    | 13                  |
| Ghana          | Africa    | West Africa           | Specific         | Complete dissertation                                                                       | Ghana College of Physicians & Surgeons                    | 4                   |
| Kenya          | Africa    | East Africa           | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 15                  |
| Malawi         | Africa    | Southeast Africa      | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 2                   |
| Morocco        | Africa    | North Africa          | Specific         | Unspecified no. publications & presentations                                               | WFNS Rabat Reference Center                               | 22                  |
| Mozambique     | Africa    | Southeast Africa      | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 2                   |
| Namibia        | Africa    | South Africa          | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 0                   |
| Nigeria        | Africa    | West Africa           | Specific         | Complete dissertation                                                                       | West African College of Surgeons                          | 24                  |
| Rwanda         | Africa    | Central Africa        | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 6                   |
| South Sudan    | Africa    | East-Central Africa   | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 0                   |
| Sudan          | Africa    | Northeast Africa      | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 3                   |
| Tanzania       | Africa    | East Africa           | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 13                  |
| Uganda         | Africa    | East Africa           | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 12                  |
| Zambia         | Africa    | South-Central Africa  | Specific         | Complete thesis & 1 publication                                                             | School of Medicine, University of Zambia; COSECSA          | 0                   |
| Zimbabwe       | Africa    | South Africa          | Specific         | Complete dissertation                                                                       | COSECSA                                                    | 2                   |
| Bahrain        | Asia      | Persian Gulf          | Specific         | Publish 1 article                                                                           | ABNPE                                                      | 0                   |
| China          | Asia      | East Asia             | None             | Neurosurgical training standardized nationwide in 2015; will not be fully implemented till 2020; new program does not appear to have specific research requirements or provide dedicated research time | Chinese Congress of Neurological Surgeons                 | 1946                |
| India          | Asia      | South Asia            | Specific         | Complete dissertation                                                                       | Medical Council of India                                   | 448                 |
| Iraq           | Asia      | West Asia             | Specific         | Publish 1 article                                                                           | ABNPE                                                      | 6                   |
| Japan          | Asia      | Eastern Asia          | Specific         | >1 presentation & 1 publication                                                            | Japan Neurosurgical Society                                | 1108                |
| Jordan         | Asia      | Western Asia          | Specific         | Publish 1 article                                                                           | ABNPE                                                      | 7                   |
| Kuwait         | Asia      | Arabian Peninsula     | Specific         | Required to take 3 mos dedicated research time                                             | Ministry of Health, Kuwait                                 | 8                   |
| Lebanon        | Asia      | Western Asia          | Specific         | Publish 1 peer-reviewed article & 1 presentation                                            | ABNPE                                                      | 48                  |
| Malaysia       | Asia      | Maritime Southeast Asia| Specific         | Complete thesis                                                                             | Neurosurgical Association of Malaysia                       | 10                  |

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### TABLE 2. Summary of research requirements and output for countries

| Country | Continent | Region | Requirement Type | Requirement(s) or Comment(s) | Requiring or Reporting Agency | No. of Publications |
|---------|-----------|--------|-----------------|------------------------------|-------------------------------|---------------------|
| Myanmar | Asia      | Mainland Southeast Asia | None | New surgical program in conjunction w/ Switzerland, but no mention of research in curriculum | Swiss Neurosurgeons International | 3 0 0 |
| Pakistan | Asia      | South Asia | Specific | Complete independent research project | College of Physicians & Surgeons of Pakistan | 35 3 2 |
| Qatar   | Asia      | Arabian Peninsula | Specific | Publish 1 article | ABNPE | 5 0 2 |
| Saudi Arabia | Asia | Arabian Peninsula | Specific | Publish 1 article | ABNPE | 71 15 22 |
| Singapore | Asia      | Maritime Southeast Asia | Partial | Research principles must be taught, but no specific requirements on research projects | Specialists Accreditation Board | 32 26 22 |
| Sri Lanka | Asia      | South Asia | Specific | Complete dissertation | Postgraduate Institute of Medicine | 0 0 0 |
| Syrian Arab Republic | Asia | West Asia | Specific | Publish 1 article | ABNPE | 1 0 0 |
| Albania | Europe    | Balkan Peninsula | Specific | Present research thesis | School of Neurosurgery | 4 0 3 |
| Croatia | Europe    | Balkan Peninsula | Partial | NDA on national requirements, but JRAAC accredited 2 neurosurgical programs in Croatia, & per JRAAC, residents must be trained on research methodology, but no specific requirements | JRAAC | 12 3 8 |
| Czech Republic | Europe | Central Europe | Partial | NDA on national requirements, but JRAAC accredited 2 neurosurgical programs in Czech Republic, & per JRAAC, residents must be trained on research methodology, but no specific requirements | JRAAC | 20 16 33 |
| Denmark | Europe    | Scandinavia | Partial | NDA on national requirements, but JRAAC accredited 1 neurosurgical program in Denmark, & per JRAAC, residents must be trained on research methodology, but no specific requirements | JRAAC | 25 31 36 |
| Germany | Europe    | Western Europe | Partial | NDA on national requirements, but JRAAC accredited 4 major neurosurgical programs in Germany, & per JRAAC, residents must be trained on research methodology, but no specific requirements | JRAAC | 586 754 644 |
| Ireland | Europe | British Isles | Specific | Publish 1 peer-reviewed article & 1 presentation | Joint Committee on Surgical Training | 22 19 14 |

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### TABLE 2. Summary of research requirements and output for countries

| Country                  | Continent   | Region          | Requirement Type | Requirement(s) or Comment(s)                                                                 | Requiring or Reporting Agency                                      | No. of Publications |
|--------------------------|-------------|-----------------|------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------|
| Lithuania                | Europe      | Northern Europe | Partial          | NDA on national requirements, but JRAAC accredited 1 neurosurgical program in Lithuania, & per JRAAC, residents must be trained on research methodology, but no specific requirements | JRAAC                                                              | 4 2 1               |
| Malta                    | Europe      | Mediterranean   | Specific         | Publish 2 articles & conduct 2 clinical audits                                                                 | Specialist Accreditation Committee                                   | 0 0 0               |
| Poland                   | Europe      | Central Europe  | Partial          | NDA on national requirements, but JRAAC accredited 1 neurosurgical program in Poland, & per JRAAC, residents must be trained on research methodology, but no specific requirements | JRAAC                                                              | 36 9 16            |
| Portugal                 | Europe      | Iberian Peninsula | Partial       | NDA on national requirements, but JRAAC accredited 1 neurosurgical program in Portugal, & per JRAAC, residents must be trained on research methodology, but no specific requirements | JRAAC                                                              | 17 15 7            |
| Russian Federation       | Europe      | Eastern Europe  | None             | NA                                                                                                                                             | NA                                                                 | 61 5 14            |
| Spain                    | Europe      | Southwestern Europe | Specific    | Training on research methodology & involvement in research project resulting in presentation/publication | Comisión Nacional de Neurocirugía                                    | 169 110 144        |
| Turkey                   | Europe      | Eastern Europe  | Specific         | Complete thesis                                                                                                                                | Turkish Neurosurgical Society                                      | 281 169 158        |
| United Kingdom           | Europe      | British Isles   | Specific         | Research encouraged but no specific requirements                                                                                             | Joint Committee on Surgical Training                                 | 237 127 273        |
| Canada                   | North America |              | None             | NA                                                                                                                                             | Royal College of Physicians & Surgeons of Canada                   | 342 570 682        |
| Haiti                    | North America | Caribbean      | None             | NA                                                                                                                                             | Haitian Ministry of Health, Hospital Bernard-Mevs/Project Medishare | 5 0 1              |
| United States            | North America |              | None             | NA                                                                                                                                             | American Board of Neurological Surgeons                           | 4375 4200 3724     |
| Australia                | Oceania     |                | Specific         | 1 presentation & 1 publication                                                                                                               | Neurosurgical Society of Australasia                               | 140 140 117        |
| New Zealand              | Oceania     | Polynesia       | Specific         | Publish 1 article & 1 presentation                                                                                                           | Neurosurgical Society of Australasia                               | 18 14 9            |
| Colombia                 | South America | Northern South America | None  | NA                                                                                                                                             | No centralized certification system                               | 35 14 8            |

ABNPE = Arab Board of Neurosurgical Programs and Examinations; COSECSA = College of Surgeons of East, Central and Southern Africa; JRAAC = Joint Residency Advisory and Accreditation Committee; NA = not applicable; NDA = no data available; WFNS Rabat Reference Center = WFNS Rabat Reference Center for Training Young African Neurosurgeons.
cently available data, accredited programs are only present in Kenya, Uganda, Tanzania, Ethiopia, Zambia, Rwanda, and Malawi. In the training guidelines established by COSECSA, trainees who have earned a doctorate in medicine are registered as members of the COS (MCS) after they complete 2 years of training and subsequently complete 4 years of training in neurosurgery, culminating in the Fellow of the COS (FCS) certification. Participation in research projects during this training period is expected, including completion of a dissertation and preparation of a presentation for an international surgical conference. Additionally, 1 non-thesis research paper must be submitted at least 3 months prior to sitting for the oral/clinical FCS examination. Individual programs within Africa have also implemented research requirements, including the newly developed University of Zambia School of Medicine Neurosurgery Training Program, developed in partnership with the University of Cambridge. This program, spanning 5 years and 3 stages (initial, intermediate, and final), requires registrars to complete a thesis for the
Master of Medicine degree, with research beginning in the first 2 years and completed in the 3rd or 4th years. Publication of at least 1 peer-reviewed article is required prior to progression to the chief registrar year. During this final year, registrars take on additional scholarly responsibility including delivering student lectures and running morbidity and mortality conferences.\textsuperscript{20}

Asia

Once again, the specification of research requirements traverses regional boundaries across the Asian continent. Within the Middle East and Gulf region, neurosurgical training and certification is overseen by the Arab Board of Neurosurgical Programs and Examinations and includes the countries of Iraq, Jordan, Bahrain, Saudi Arabia, Lebanon, Qatar, and Syria. In the 5th or 6th years of the training program, trainees take the final examination for certification including written, clinical, and oral portions. Prior to this examination, trainees must complete and publish 1 research project, as well as maintain a log of attendance at scientific sessions.\textsuperscript{4,14} Kuwait is one of the few countries whose Ministry of Health mandates the completion of a dedicated research period during neurosurgical training. This dedicated time occurs during the 3rd year of a 5-year program,\textsuperscript{20} resembling the timing of the research year that is typical of many programs within the United States. Japan is one of the most productive countries in neurosurgical research that utilizes a research requirement. The Japan Neurosurgical Society requires an individual to present at an academic conference more than once and write research papers, at least one of which must be accepted into a peer-reviewed journal to obtain eligibility for the board certification examination. Additionally, recertification is contingent upon continued scholarly work in the form of academic presentations and/or publications.\textsuperscript{16} According to our analysis, Japan ranks just second to the United States in research output in the American literature, suggesting that its requirements place an appropriate emphasis on lifelong scholarship, which translates into exceptional productivity. Notably, a similarly industrialized nation, China, bears no research requirement in its newly developed standardized training program, which is set for nationwide adoption by 2020. But a lack of flexibility in the training schedule, limiting the time for research and/or enfolded fellowships, is considered a limitation of this program.\textsuperscript{22} While China ranks highly at present in terms of research output, the impact of the program’s design may perturb this. Finally, in Singapore, while no specific requirements for research involvement exist, programs are required to teach principles of research within the training curriculum. Residents are encouraged to participate in scholarly activity, although this is undefined, and sponsoring institutions are encouraged to provide adequate resources for such involvement.\textsuperscript{25}

Europe

The JRAAC is the central monitoring body for the field of neurosurgery within Europe and is a joint committee between the European Association of Neurosurgical Societies (EANS) and the European Union of Medical Specialists (UEMS). There are currently 16 JRAAC-accredited programs in Turkey, Germany, Czech Republic, Denmark, Lithuania, Poland, Spain, Portugal, and Croatia.\textsuperscript{11} Guidelines released from the UEMS in 2015 recommend that neurosurgical training programs provide training in research methodology, as well as the opportunity for protected research time during the 6-year training program.\textsuperscript{12} However, these recommendations do not represent explicit requirements for compulsory participation in research as a trainee. Despite the lack of requirements by this multinational organization, individual nations within Europe do maintain prerequisites for research participation during training. For example, in the United Kingdom (UK) and Republic of Ireland, where neurosurgical training is overseen by the Joint Committee on Surgical Training, research requirements are quite extensive: trainees must publish 1 peer-reviewed paper covering a laboratory experiment and a case series or systematic audit, as well as deliver 2 verbal presentations at national or international conferences, with attendance at a minimum of 4 conferences in total during training.\textsuperscript{17} Furthermore, in Albania, presentation of one’s research thesis is, in fact, a component of the final board-certifying examination.\textsuperscript{27}

Oceania

Neurosurgical training in Australia and New Zealand is overseen by the Neurosurgical Society of Australasia, an organization founded in 2014, which currently boasts a membership of 95\% of neurosurgeons within the 2 countries.\textsuperscript{25} The neurosurgical training program guided by the society involves 3 phases: basic, constituting 1–2 years; intermediate, constituting 2–3 years; and advanced, constituting 1–3 years. Research requirements are primarily restricted to the intermediate years including participation in the Critical Literature Evaluation and Research course and completion, presentation, and publication of an approved research project. In fact, prior to 2012, all trainees in neurosurgical training programs were required to complete a compulsory research year during the 4th year of training.\textsuperscript{26}

Barriers to Trainee Research Involvement

Studies identifying barriers to resident/trainee research involvement have been conducted in several countries, identifying results similar to those within the United States: a lack of protected time for both trainees and faculty, a lack of mentorship, and unfamiliarity with research methodologies continue to be reported as the greatest obstacles.\textsuperscript{5,22} But research requirements that are instituted in environments conducive to research and offering the necessary training, resources, and protected time are likely to be more fruitful than similar requirements without the necessary support. International collaboration may provide an important avenue to enhance the research involvement of trainees from institutions without a strong research infrastructure, especially those within low- and middle-income countries. Various models for collaboration exist, often with the primary goal of enhancing clinical productivity within developing countries, although opportunities for involvement in research exist as well. One of the most common models involves integration of a visiting neurosurgeon within the department of a host institution for a short- or long-term fellowship, during which the
visiting fellow trains in clinical and operative care while also participating in clinical research projects. Trainees can also seek involvement in research collaboratives by partnering their home countries with large international institutions. For example, the UK-based Global Health Research Group on Neurotrauma is conducting a multinational research project to identify optimal strategies for the management of patients with traumatic brain injury via partnership with countries throughout South America, Asia, and Africa.

Study Limitations

This analysis represents a review of trainee research requirements across the globe via internet query of guidelines produced by certifying and/or accrediting bodies, as well as regional research productivity via advanced search of the PubMed database. We recognize that our study is limited in scope because of its third-person analysis of published requirements, rather than direct survey of individuals from the various nations. While we can comment on the presence or absence of documented guidelines or requirements, we cannot determine the way in which these requirements are enforced, nor how they are perceived by trainees and faculty. Additionally, our study is inherently biased toward English-language literature based on the restriction of our literature search to the PubMed database. Publication within the major peer-reviewed journals of the field is considered a gold standard for the dissemination of research. However, barriers to publication do exist, such as language differences and financial limitations. Various initiatives have been undertaken by neurosurgical publishers to promote access to neurosurgical literature by stakeholders across the world. As an example, the Neurosurgery Speaks program, undertaken by Neurosurgery, provides written and oral abstracts for dozens of publications translated into 10 different languages by native speakers. We also cannot fail to acknowledge the importance of international scholarly contributions outside of the peer-reviewed literature, including social media posts and digital teaching. The website Neurosurgical.TV (https://www.neurosurgical.tv/) provides a forum for hosting video conferences by neurosurgeons across the globe and is broadly shared across neurosurgery pages on social media platforms such as Facebook and Twitter. While these are not a substitute for the peer-review process, they are important modalities for improving international dissemination of neurosurgical research and knowledge. We anticipate that as social media continues to rise in prominence within neurosurgery and the field of medicine as a whole, tools for the assessment of scholarly productivity will adapt to account for such contributions.

Recommendations and Future Directions

Clinical experience must remain the focus of neurosurgical training to maintain the most appropriate care for patients. However, the importance of research and scholarship in establishing training programs and evolving care cannot be understated. Protected research time is common in training programs throughout developed countries, but is often reliant on an established research infrastructure. Thus, partnerships permitting integration of local trainees into the scholarly activities of an outside institution may circumvent a lack of resources in less-developed programs. Institutions in developed countries seeking to aid in global surgical efforts can effect some of the greatest changes by assisting in the development of local training programs, as has been accomplished via Duke University and Mulago Hospital in Uganda. Such efforts should include training in research methodologies and collaborative projects to characterize aspects of neurosurgical care in developing countries and assess the impact of any interventions that are instituted. Finally, we believe instituting a requirement can help establish research involvement in the culture of an institution and/or nation. Future prospective research in the form of surveys administered to trainees and faculty across the globe would provide a more direct assessment of the requirements and understanding of individuals’ personal experiences. We believe it is critical for such perspectives to be collected to inform efforts targeted at augmenting research productivity.

Conclusions

Overall, we found that research requirements during training or prior to board certification are common in neurosurgical programs across the globe as an incentive to contribute novel knowledge to the field while maintaining research productivity and academic standing. These requirements vary in intensity and timing during training, ranging from exposure to research methodology or critical literature evaluation to completion of a thesis and publication in a peer-reviewed journal. While our analysis is quite limited, we failed to demonstrate a correspondence between the presence of requirements and research output. We hope that this study will provide a set of novel preliminary data through which the global neurosurgery community can begin to systematically assess the importance of research participation throughout the spectrum of neurosurgical training.

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**Author Contributions**

Conception and design: Nanda, Rallo, Ashraf. Acquisition of data: Rallo, Ashraf, Jamah. Analysis and interpretation of data: Rallo, Ashraf, Gupta. Drafting the article: Rallo, Ashraf, Jamah, Gupta. Critically revising the article: Nanda, Rallo, Jamah, Gupta. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Nanda. Statistical analysis: Rallo. Administrative/technical/material support: Nanda. Study supervision: Nanda, Gupta.

**Correspondence**

Anil Nanda: Rutgers Robert Wood Johnson Medical School, New Brunswick, NJ, an651@rwjms.rutgers.edu.