Although females currently comprise approximately 50% of matriculating medical students, there remain multiple medical specialties with disproportionately low female representation. As of 2017, neurosurgery ranks as the third highest male-dominated surgical field, with females comprising less than 10% of practicing neurosurgeons in the US. Efforts to combat the gender gap in neurosurgery were put forth by the American Association of Neurological Surgeons (AANS) and Women in Neurosurgery (WINS) in 2008, which recommended addressing this gap through increased recruitment, retention, and mentorship. Despite these efforts to increase the proportion of females entering the field of neurosurgery, the current trends fall shy of the purported 20% goal. For neurosurgery residencies, recent studies have reported an increase in the number of female residents from 12.7% to

**Objective** At present, females constitute less than 10% of neurosurgeons in the US, despite representing approximately half of all medical students. Multiple barriers have been described for females entering the neurosurgical field, particularly academic neurosurgery. Understanding the environment that female neurosurgeons face and any potential barriers preventing career advancement is needed to recruit, promote, and retain females in neurosurgery.

**Methods** The gender composition of editorial boards for 5 high-impact neurosurgery journals was analyzed from 2000 to 2020. The names of editorial board members were obtained directly from the journal administration, physical copies of the published journal, or publicly available data through each journal’s website. The gender, degrees, academic titles, H-index, and country were determined for each individual and statistical tests were performed to identify significant differences.

**Results** Of the 466 identified individuals that served on at least one editorial board between 2000 and 2020, there were 36 females (7.7%) and 430 males (92.3%). There were no significant differences between males and females serving on multiple editorial boards. Most females possessed an additional graduate degree (58.3%), while only one-third of males (33.5%) obtained such a degree (p = 0.002). In addition, males had significantly higher average H-indices than females (p = 0.002). These trends were also observed when analyzing only US-based editorial board members. Although females were more likely overall to be identified as associate professors, males were more likely to be appointed as full professors (p = 0.001); this trend did not remain true in the US-based cohort. When analyzing the editorial boards for individual journals, all 5 journals experienced an increase of female representation since 2000 or since their inception after 2000. The highest proportion of females for a single journal was 27.3% in 2020. All other journals ranged from 11.0% to 13.5% in 2020.

**Conclusions** When entering the field of neurosurgery, females continue to face significant social and academic barriers. While the proportion of females on editorial boards for neurosurgery journals in 2020 is consistent with the proportion of practicing female neurosurgeons, there is a statistically significantly higher likelihood that females possess additional graduate degrees and lower H-indices compared to their male counterparts. The authors encourage neurosurgical journals to continue expanding female representation on editorial boards.

**Keywords** neurosurgical journals; editorial board; females; gender composition
Yet, neurosurgery remains the second most male-dominated residency, and approximately 11% of neurosurgery residencies do not have any female residents.6

The lack of female representation in neurosurgery and the inequalities experienced by females have been linked to gender gaps on multiple levels of career development. Although the attrition rate for neurosurgery as a whole is higher than that of all residencies accredited by the Accreditation Council for Graduate Medical Education, there was a significantly higher attrition rate for female neurosurgery residents (18.50%) compared to male neurosurgery residents (10.35%) between 2005 and 2010.5,7,8 This higher rate of attrition for females in neurosurgery was associated with a burnout prevalence of 33% and decreased support for pregnancy and motherhood.9,10

Following residency and fellowship training, females continue to face numerous obstacles in their professional careers. Compared to their male counterparts, female neurosurgeons feel significantly less equal in their treatment and believe that their gender serves as a disadvantage in the field.11,12 Within academia, there is a significant gender gap in female authorship, wherein females overall publish less than males in neurosurgery journals.13 Compared to males, there are significantly fewer females who are promoted to full professorship, and some institutions do not have any full-time female neurosurgery faculty members.14–16 Furthermore, of the females serving as faculty members, they are more likely to hold advanced degrees than their male counterparts.17

In addition, most neurosurgery departments only have a small minority of females in leadership positions and even fewer females serving as department chairs.14,16 This trend in female leadership is also true in neurological societies as fewer than 30% of US state neurological society presidents were female.17

These studies have uncovered some of the barriers that females face in neurosurgery, academia, and leadership; however, much remains unknown regarding the difficulties encountered by females in this field. To further establish the climate and gender disparities experienced by female neurosurgeons, we investigated the presence of females on neurosurgery journal editorial boards, an additional proxy for leadership opportunities afforded to medical professionals.18 To the best of our knowledge, this is the first study to analyze the gender composition of the editorial boards for 5 high-impact neurosurgery journals. In addition, we explored the academic characteristics of the individuals who comprised the board membership to determine if any differences existed between males and females.

Methods

Data Compilation

Using the methods described in Harris et al. as a framework,19 the editorial boards of 5 major neurosurgical journals were analyzed: Journal of Neurosurgery (JNS), Journal of Neurosurgery: Spine (JNS Spine), Journal of Neurosurgery: Pediatrics (JNS Peds), Neurosurgery, and World Neurosurgery. Names of the editorial board members were obtained from 2000 to 2020 at 5-year intervals (i.e., 2000, 2005, 2010, 2015, and 2020). To ensure accurate comparisons, in instances in which the journals and their editorial boards were restructured, we attempted to maintain consistency by analyzing the position of the same name. For the current 2020 editorial board compositions, names were obtained through publicly available data on the websites of the respective journals. For the years 2000 to 2015, lists of board member names were received directly from the journals if available. In cases in which this information was not available, names were extracted from physical copies of the published journals for each of those missing years.

For each board member, gender, graduate degrees, academic titles, country, and H-indices were compiled. Additionally, individual graduate degrees, academic titles, and countries from institutional profiles, curricula vitae, or prior publications were obtained. In cases with multiple academic titles, the highest and most advanced title was selected. Individuals with “clinical” titles such as “clinical assistant professor” were categorized as the equivalent full professorship title (e.g., “assistant professor”). Other titles, including clinical lecturers, were grouped into an “other” category. Due to the variability of institutional structures, appointments such as heads/chiefs/chairs of departments were not considered. As described in the Methods section of Harris et al.,19 the gender of each individual was determined using gendered pronouns and photographs available through institutional profiles and biographies. H-indices were found using Scopus Author Index (https://www.scopus.com/free lookup/form/author.uri). Author identification was confirmed through matching institutional profiles and comparing listed publications if needed. In cases in which multiple H-index values were listed for a single author, we used the higher value.

For the characterization of the editorial board members (based on academic degree, position, H-index, and continental location), we pooled together all individuals identified for each of the journal editorial boards. Non-physicians (i.e., PhD only) and non-neurosurgeons were excluded. For our combined cohort, the finalized list of unique members was created by removing the duplicated names of individuals who served on multiple journals or for multiple years. However, we provided a separate analysis of members who served on multiple boards.

Statistical Analysis

All statistical analyses were performed using the R statistical program (version 4.0.1). Univariate analysis comparing the characteristics of male and female members of editorial boards was performed using the tableBy() function in the R package “arsenal.” T-tests were used to compare numerical variables, whereas chi-square tests were used for categorical variables. Plots were created using the ggplot() function in the R package “ggplot2.” Two separate analyses were completed: all identified board members (Table 1), and US editorial board members alone (Table 2).

Results

Editorial Board Member Characterization: All Members

As highlighted in Table 1, after excluding non-neurosurgeons, our study identified a total of 466 individuals
who served as an editorial board member on at least 1 of the 5 neurosurgery journals during the analyzed time frame (2000–2020). Of these individuals, 36 (7.7%) were females and 430 (92.3%) were males. Overall, 70 members (15.0%) served on multiple editorial boards at least once during the analyzed time interval. There were no significant differences in multiple editorial board memberships between males and females. The vast majority of these individuals were based in North America (73.8%), with small representation from Europe (12.0%), Asia (8.4%), Africa (0.9%), South America (2.6%), the Middle East (1.7%), and Oceania (0.6%).

The H-indices were identified for all individuals except for 1 male. For the remaining members, the average H-index value was 35.013 with a range of 1.000–120.000. When analyzing the H-indices of each gender separately, there were significant differences (p = 0.002), as the average value for males was 35.895 with a range of 1.000–120.000, and the average for females was 24.500 with a range of 6.000–63.000.

Most of the individuals were designated as full professors (n = 336, 75.0%). This was true when analyzing both genders individually and combined. Associate professor was the second most common designation (n = 60, 13.4%), followed by assistant/adjunct professor (n = 37, 8.3%). Twelve males were identified as emeritus professors (2.7%) and 3 as having a nonstandard academic title, listed as “other” (0.7%). However, when analyzing each gender independently, females were more likely to be associate professors compared to males, who were more likely to be full professors (p = 0.001).

Two hundred eighty-five males obtained a medical degree without any additional graduate degrees (66.3%). The remaining males obtained either a PhD in addition to their medical degree (25.8%) or a master’s level degree (7.7%). These results contrast with the females who had a higher incidence of obtaining additional graduate training overall. Most females (58.3%) had a graduate degree in addition to their medical degree, with 12 females possessing a PhD (33.3%) and 9 obtaining a master’s degree (25.0%). Fifteen females (41.7%) acquired a medical degree without any additional graduate training. These differences in likeliness of having an advanced degree between males and females were statistically significant (p = 0.002), indi-
cating that females were more likely to have an advanced degree in addition to their medical degrees compared to their male counterparts.

**Editorial Board Member Characterization: US Only**

The results of the US-only analysis are highlighted in Table 2. Thirty female neurosurgeons were identified, thereby constituting 9.1% of all US-based neurosurgeons. Sixty-one individuals served on multiple editorial boards during the analyzed time period. Similar to the all-members analysis, there were no significant differences between the proportion of males and females serving on multiple boards (p = 0.836).

Trends between advanced degrees and H-index were similar to those found in the analysis of all members. Female neurosurgeons were more likely (p < 0.001) to possess advanced degrees compared to their male counterparts. The majority of females (60.0%) had advanced degrees, with 30.0% obtaining a master’s level degree and 30.0% having a PhD. Significant differences in H-indices were also present between the two genders (p = 0.002). The average H-index for males was 37.397 (range 1.000–120.000), while the average H-index for females was 24.967.

When examining academic titles, the majority of individuals were designated as full professor, regardless of gender. Although a higher percentage of females were associate professor (31.0%) than males (12.7%), these results were not statistically significant (p = 0.061). These results are in contrast to the analysis of all members, in which females were more likely to be designated as associate professors and males more likely to be full professors.

**Gendered Proportions of Members on Individual Boards**

The proportions of females comprising individual editorial boards are highlighted in Figs. 1 and 2. When examining membership worldwide (Fig. 1), there is a clear trend that female membership has increased in the 5 analyzed journals since 2000 or since their inception after 2000. In 2 of the journals (JNS and JNS Spine), 2020 was the first analyzed year that included female membership. A third journal (World Neurosurgery) also has a positive trajectory, with 2020 having the highest proportion of female representation. The remaining two journals (JNS Peds and Neurosurgery) had an overall increase in female representation; however, the proportion of females in 2020 is slightly decreased from 2015. JNS had the highest proportion of female representation in 2020, with the editorial board consisting of 27.3% female membership, corresponding to 6 females. All other journals have comparable female membership in 2020, ranging from 11.0% (World Neurosurgery) to 13.5% (Neurosurgery).

The trends as described above for the worldwide editorial board membership remain true when examining US-only members (Fig. 2). All journals experienced an increase in female representation from 2000 or date of inception after 2000 until 2020. The highest proportion of females occurs in 2020 for three journals: JNS, JNS Spine, and World Neurosurgery. While 2020 does not represent the highest proportion of females in the history of JNS Peds and Neurosurgery, these journals still experienced a positive trajectory overall. The range of female membership in 2020 ranged from 12.5% (JNS Spine) to 28.6% (JNS). This represents a slight increase in proportions when compared to the female representation of worldwide membership.
Current Environment for Females in Neurosurgery

Of the 5 high-impact neurosurgery journals analyzed, we found that females constituted 11.3%–27.3% of the editorial board members as of 2020. When examining US-based neurosurgeons, we found the proportion of females to be 12.5%–28.6%. Given that less than 10% of active neurosurgeons in the US identified as female in 2017, the percentage of female representation on each of the neurosurgery editorial boards is proportional. Furthermore, the proportion of female neurosurgeons on individual edito-
ial boards is similar to that described by Harris et al., who found that editorial boards for high-impact surgery journals had 19% female membership on average in 2019. 19

When examining the combined data of all editorial board members from these 5 journals across all years, we found that females constituted only 7.8% of editorial board members worldwide and 9.1% in the US. This may indicate that female representation overall is lacking and is in stark contrast to the approximately 25% of females identified in the journals analyzed in Harris et al. 19 However, these data are representative of an average over the past 20 years and include time periods in which there were no female editorial board members. While one may suspect oversampling of female neurosurgeons given this percentage, our results showed that there were no significant differences in multiple editorial board memberships between males and females. Therefore, we suspect that our results from the all-members analysis is likely a consequence of the lack of female representation in the past, and we anticipate that these results will improve as female membership on editorial boards continues to improve in the future.

Similar to the study of Harris et al., in this study females on editorial boards were more likely to possess additional graduate degrees than their male counterparts, both in the US cohort and in the all-members cohort. 19 This may suggest that females are held to a different educational standard than their male counterparts, or may reflect an intrinsic selection bias for females to have additional graduate degrees when entering neurosurgery training. Another potential implication is that females may feel pressure to pursue graduate education to be successful in such a male-dominated field. This finding is not isolated to editorial boards; previous studies have also documented significantly higher rates of female faculty neurosurgeons possessing additional graduate degrees. 17 However, it is difficult to determine if this trend remains true of female neurosurgical applicants and neurosurgery residents, as no studies have been performed as of yet.

In addition, the analysis of the US and all-members cohorts revealed statistically significant differences in H-indices, showing males having higher average H-indices than females overall. This trend may not be surprising as recent studies have found that significant barriers exist for females, especially in research productivity and academia. 13–15 Even though there was a significant increase in female first authorship for neurosurgery journals between 2013 and 2018, there was no increase in senior authorship, and there were significantly fewer publications by females than males overall. 13 This decreased productivity also manifests in neurological research conferences, where females constituted a minority of speakers from 2014 to 2018 and were generally underrepresented. 20 In addition, researchers found that females had an overall lower H-index in every neurosurgical subspecialty, despite having higher rates of fellowship completion. 15 However, in reporting these differences in H-indices and additional graduate degrees, we cannot make a truly objective statement about these trends given that we were not able to control for length of practice or age of the individuals.

Professorship ranking is an additional factor influencing neurosurgeons’ academic productivity as it was found that higher H-indices corresponded to higher academic rankings in neurosurgery. 23 Unfortunately, there are significantly fewer females promoted to full professors in academia, and females are more likely to serve as assistant/associate professors. 14,15,22,23 While we found that trend to be true in our analysis of the large cohort, we were encouraged that there were no significant differences in academic rank between males and females in the US cohort. Overall, this information, combined with the representative proportions of female editorial board members, may be reassuring and suggests that there is progress toward equal standards among the board members when analyzing individual academic accomplishments.

While these factors may not directly impact a female’s opportunity to become an editorial board member, barriers in research, academia, and leadership certainly have the potential to limit further academic opportunities. Previous studies have suggested the use of editorial board membership as a proxy of leadership opportunities afforded to physicians, which can further guide career development. 18 Moreover, reduced female editorial board representation may have the potential to perpetuate the already present shortage of female first- and senior-author publications. For example, although Mahajan et al. found no significant difference in the academic productivity of females when using a single- versus double-blind review process in JNS and Neurosurgery, there was still a significant reduction in invitations to female authors. 24 Therefore, we believe that potential barriers toward editorial board membership for female neurosurgeons would represent another reduced opportunity, thereby limiting potential academic success and career advancement along with indirectly potentiating the gender pay gap. 25

Aside from academic barriers mentioned above, females in neurosurgery also face different social circumstances compared to their male colleagues, a factor that may also contribute to the lack of representation and inequality that is present in this field. Gadjradj et al. found that 83% of female neurosurgeons viewed their gender as a disadvantage. 12 There were also prominent differences between males and females in the workplace environment, with males feeling more acknowledged for ideas, being accepted by coworkers, and perceiving equal treatment. 12 In addition, females are less satisfied with work-life balance, less likely to have children, and less likely to be married. 12,26,27 Family planning is especially difficult as many institutions do not have a formal policy for family leave and responsibility of childcare often falls disproportionately onto females. 26,28,29 Overall, we believe the current lack of female representation is multifactorial, likely stemming from decreased support and combined with challenges in career development. In supporting and creating opportunities for females to develop successful careers, we hope to be able to attract more females to the field and continue to expand female representation.

Limitations

There are several limitations to our study. All included neurosurgery journals underwent restructuring at some point between 2000 and 2020. In many of these instances, it resulted in the addition of new positions and the restruc-
turing of roles. To account for this change, we attempted to keep the position title the same to ensure the most accurate comparisons between the different years. Our study is also limited by the heterogeneity of the editorial board positions themselves among the different journals. The contracted time that an individual serves on an editorial board likely varied between the journals and was not something that we were able to assess. In addition, we were not able to quantify each individual’s contribution to a particular editorial board or determine female reviewers who are invited reviewers and are not yet appointed to an editorial board. To minimize these factors, we analyzed the characteristics of all individuals in a single cohort, so as not to isolate a single journal. We believe that these differences are less likely to affect the proportions of genders that compose the editorial board for each individual journal.

We recognize that searching for genders, degrees, and academic titles may be biased if the information obtained as described in the Methods section was out of date. It is also worth noting that gendered pronouns were not available for all editorial board members, thereby limiting objective assessment for all individuals. However, in combining all years together into a single cohort for our analysis of editorial board member characteristics, we believe that any differences would be minimized, and this limitation would not significantly change our results. Due to the cross-sectional nature of our study and our decision to combine all data into a single cohort for analysis of individual characters, we are not able to provide discrete conclusions about the changes from year to year. Finally, when comparing H-indices and degrees between the genders, we were not able to standardize these results to age or years in practice, as the information was not available for all board members. However, we believe that our study provides a valuable glance at the climate of neurosurgery editorial boards for the past 20 years and can potentially inform decision-making in the future for these boards.

Conclusions

Females in neurosurgery continue to face academic and social barriers to enter the field. While there was a proportional representation of females on neurosurgery journal editorial boards in 2020 compared to the prevalence of females in the field, our study suggests that females on editorial boards possess additional graduate degrees and have lower average H-indices. These trends may be residual findings from the current state of neurosurgery. While differences between academic rank exist in our all-members cohort, we find it encouraging that this trend does not hold true for US-based neurosurgeons. Nevertheless, we commend the journals for increasing female representation over the past 20 years, and hope that this trend will continue, so as to recruit more females into the fields of neurosurgery and ensure an infrastructure for their success therein.

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Author Contributions
Conception and design: Bauman. Acquisition of data: Bauman, Wang. Analysis and interpretation of data: Bauman, Bhandarkar. Drafting the article: Bauman. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Clarke. Statistical analysis: Bhandarkar.

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