1 Roadmap to Neurosurgery Residency

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1.1 Introduction

Neurological surgery is the field of medicine dedicated to the surgical treatment of nervous system pathology within the brain, spine, and periphery. The American Board of Neurological Surgery is responsible for selecting the training requirements for neurosurgery residents. Neurosurgery residency is 7 years (84 months) in duration, which consists of 54 months of core clinical neurosurgery and 30 months of electives. This chapter aims to lay down a framework for preparing for the neurosurgery residency application.

1.2 Applications

1.2.1 Match Data

Between 2013 and 2024, the number of neurosurgery residency programs accredited by the Accreditation Council for Graduate Medical Education increased from 99 to 166 (17.2% increase), and the number of residency positions increased from 204 to 241 (18.1% increase).[1,2] Generally, neurosurgery programs accept one to three incoming residents every year, with the larger programs accepting four residents per year. Neurological surgery was among the most competitive specialties in the 2024 match. According to the National Resident Matching Program (NRMP), there were a total of 423 applicants who preferred the specialty for 241 positions (1.76 applicants/positions).[3] The total match rate for neurosurgery was 57%. Over the past 10 years, the percentage of international medical graduates (IMGs) who matched into neurosurgery increased from 3.5% to 7%.[2]

The NRMP conducts surveys of residency program directors (PDs) every 2 years to determine criteria for selecting and ranking residency candidates. In a survey of 20 out of 115 residency directors (17.4% response rate) for neurological surgery conducted in March 2020, responders were asked to cite factors in interviewing and ranking applicants. Of all factors, most PDs cited the following as important factors for selecting applicants to interview[4]:

- Letters of recommendation (92%).
- United States Medical Licensing Examination (USMLE) Step 1 scores (92%).
- Demonstrated involvement and interest in research (69%).
- Performing a neurosurgery rotation in that department (69%).
- Personal statement (62%).

When asked about important factors in ranking applicants, residency directors most frequently cited[4]:

- Interpersonal skills (92%).
- Letters of recommendation (92%).
- Feedback from residents (85%).
- Interactions with faculty (85%).
- Interactions with house staff (85%).

Results from the NRMP suggest that academic achievements are most important in selecting applicants to interview, but personality and interactions with others are most influential in ranking applicants. It is important to note that the relative importance of each of these factors varies between programs.

It is worth noting that in 2024, the first wave of applicants with a pass/fail (P/F)

grading system for Step 1 will be entering the application process for neurosurgery residency. With Step 1 moving to pass/fail reporting, Step 2 clinical knowledge (CK) is expected to become the main standardized measure of academic performance for neurosurgery residency applications. However, it is important to note that students who have invested extra years in research or pursued MD/PhD programs likely took the Step 1 before the P/F era and will still have their scored Step 1 results reported. For those individuals with lower Step 1 scores, it may still have a negative impact on their overall candidacy.

1.2.2 Qualifications

Historically, USMLE Step 1 scores carried substantial weight in applicant selection due to their universal nature. However, the recent shift to P/F scoring has prompted PDs to reconsider. The survey of PDs attitude toward USMLE Step 1 P/F is summarized in ▶ Table 1.1. A survey of PDs found most had reservations.[5] Many PDs now emphasize USMLE Step 2 CK scores. Presently, 46% of neurosurgery programs do not use Step 2 CK scores. Among the rest, 29% require a passing score, while 25% set specific target scores. This highlights the rising importance

Table 1.1 Neurosurgery program director perspectives of binary Step 1 scoring

Statement	Disagree	Neutral	Agree
Changing USMLE Step 1 to P/F			
Is a good idea	78.7 (67.0–90.4)*	10.6 (1.8–19.5)	10.6 (1.8–19.5)
Will make it more difficult to objectively compare applicants	6.4 (0.0–13.4)	8.5 (0.5–16.5)	85.1 (74.9–95.3)*
Will increase emphasis on Step 2 CK scores in selecting applicants for my program	4.2 (0.0–9.8)	8.3 (0.5–16.2)	87.5 (78.1–96.9)*
Will put IMGs at a disadvantage	6.5 (0.0–13.7)	30.4 (17.1–43.7)	63.0 (49.1–77.0)*
Will decrease socioeconomic disparities in the application process	62.5 (48.8–76.2)*	27.1 (14.5–39.7)	10.4 (1.8–19.1)
Will decrease medical student knowledge of the basic sciences	4.2 (0.0–9.8)	43.8 (29.7–57.8)	52.1 (38.0–66.2)
Will improve medical student well-being	50.0 (35.9–64.1)	35.4 (21.9–48.9)	14.6 (4.6–24.6)
Will make the applicant screening more arduous	2.2 (0.0–6.5)	17.8 (6.6–28.9)	80.0 (68.3–91.7)*
As a result of changing USMLE Step 1 to P/F			
It will now require applicants to submit Step 2 CK scores with ERAS	8.5 (0.0–16.5)	6.4 (0.0–13.4)	85.1 (74.9–95.3)*

(Continued)

Table 1.1 (*Continued*) Neurosurgery program director perspectives of binary Step 1 scoring

Statement	Disagree	Neutral	Agree
Where an applicant goes to medical school will be more important in screening and selection	16.7 (6.1–27.2)	12.5 (3.1–21.9)	70.8 (58.0–83.7)*
Where an applicant goes to medical school will be more important in screening and selection for my program	16.7 (6.1–27.2)	12.5 (3.1–21.9)	70.8 (58.0–83.7)*
Step 2 CK should also be changed to P/F	78.3 (66.3–90.2)*	6.5 (0.0–13.7)	15.2 (4.8–25.6)

Abbreviations: CK, clinical knowledge; ERAS, electronic residency application service; IMGs, international medical graduates; P/F, pass/fail; USMLE, U.S. Medical Licensing Examination.
Note: Data presented as percentages (95% confidence intervals).
*Statistically significant plurality of responses shown by nonoverlapping 95% confidence intervals.

of Step 2 CK scores, potentially surpassing Step 1 as a screening criterion. Students may consider taking Step 2 CK earlier for comprehensive career planning.

The shift to P/F grading for Step 1 has reduced its significance. This change allows preclinical medical students more time to explore clinical and research experiences. Those interested in neurosurgery can allocate additional time to activities such as attending journal clubs, participating in conferences, and shadowing specialists, rather than focusing solely on Step 1 preparation. Early exposure to the field positively influences students' perceptions and may increase their interest in neurosurgery.

While alpha omega alpha (AOA) membership is not necessary for neurosurgery residency, top-tier programs may have a preference for selecting AOA members. Performance during clinical rotations is evaluated with grades, which are based on performance on shelf examinations, enthusiasm for the subject matter, and ability to assist other members of the health care team. Performance on clinical rotations is largely subjective, and if residents or preceptors detect arrogance or disinterest, it may be reflected in a low grade for the course. Given the competition for neurosurgery residency positions, applicants should strive for high grades in all of their rotations (high pass to honors).

The reputation of the medical school continues to play a significant role in neurosurgery match outcomes, expected to be even more critical post–Step 1 scoring changes. In addition, 63% of PDs believe that P/F scoring may disadvantage IMGs. IMGs can seek other ways to distinguish themselves, such as achieving higher h-indexes, publishing more research papers, and dedicating time to research activities.

1.2.3 Research

The NRMP publishes the charting outcomes in the match reports biennially. As of now, the 2024 reports have not been released. In the 2022 Match, the mean number of abstracts, presentations, and publications for

U.S. allopathic seniors who matched was 25.5, whereas that for unmatched applicants was 11.7.[6] The importance of research is especially true for candidates targeting highly ranked academic centers and for IMG applicants. One study suggested that student h-index was an independent predictor of matriculation into top-tier research institutions,[7] thus emphasizing the role of actively contributing impactful papers to the neurosurgical literature. Recognizing faculty that have a proven track record of working with students is a key aspect to identifying potential mentors in the field. Looking at past years' match lists may help to evaluate which prior students of the group were successful in matriculating into programs of interest. Other very important factors to consider in a faculty mentor are seniority, personality, projected timeline of the project, funding availability for conferences, impact of the research produced, and availability. Also remember, pairing up with residents who are active in research may open up connections with other more senior faculty members of the institution. In addition, getting involved with the institution's student interest group can open up networking opportunities and has also been shown to increase publication count and institutional match rate into neurosurgery.[8]

Given the short time frame for completing publications, prospective neurosurgery candidates should begin early, preferably in their first or second year of medical school. Early involvement in research is important because students are expected to attend to a higher load of clinical duties during rotations. Possible time for students to consider doing clinical research include the summer before matriculating to medical school (2–4 months), the summer break between first and second year of medical school (3 months), and the research electives during the third and fourth years of medical school (1–3 months). Opportunities to augment one's research portfolio also exist via dedicating a year to protected research time during medical school with graduation in 5 years, instead of 4 years. However, delaying graduation for dedicated research time is not necessary. In addition, an individual must be highly productive and must strive to complete several publications to account for this extra time. Of note, there are many funding opportunities available for medical students during the summer after first year (see Section 22.5 Grants and Awards).[9,10,11] Additional funding opportunities for medical students include the Howard Hughes Medical Institute Medical Research Fellowship and the National Institutes of Health (NIH) Medical Research Scholars Program.[12,13]

1.2.4 Research for IMGs

In the Step 1 P/F era, research is carrying more weight in determining the applicant's candidacy in obtaining an interview or the acceptance into the program, and the importance of research for IMG applicants cannot be stressed enough. Yekula et al[2] reported that IMGs that matched had a higher mean number of abstracts, presentations, and publications (51.9 vs 18.5, $p = 0.03$) and a higher mean number of work experience (5.09 vs 3.22, $p = 0.01$).

For IMGs, building a successful research portfolio is crucial for the success of their residency applications. Besides the quantity of publications, IMGs should also emphasize the impact factor of the journals in which their work is published. Moreover, IMGs should consider engaging in basic science research to gain valuable experience and include basic science publications on their CVs to enhance their application profiles. Given the significant weight PDs place on letters of recommendation, it is advisable for IMGs to undertake scientific research within the United States at a neurosurgical institution. This allows them to establish connections with research mentors and neurosurgery attending physicians from the outset.

For those who have already finished medical school and do not have research

experience, the best next step is to find a research position in a U.S. academic neurosurgery department. In this case, doximity.com is a very useful website for assessing the research output of different programs. Institutional websites can be utilized to assess research options within the department and contact information for lab directors. Students should contact various labs and not feel frustrated if emails go unanswered. Faculty members are extremely busy and often involuntarily forget to reply to emails. Persistence is key. Applying to several laboratories, as well as making an effort (if feasible) to meet in person, will increase the chances of success. IMGs must take into consideration the diverse types of research positions offered by the lab. For instance, some laboratories are very open to receive people for volunteer or unpaid research, which could dramatically impact entry into the United States. Students who are not U.S. citizens or Green Card holders will need to apply for a visa to start the research job.

Most labs will offer a J1 visa, which in most cases has a 2-year rule and a limit of 7 years. Visit the Department of State website for details regarding 2-year home-country physical presence requirements and eligibility for a waiver.[14] In order to apply for a J1 visa for a volunteer research position, the student will need to prove to the U.S. Government that the student or a sponsor (most likely your family) has the equivalent of $30,000 or more. Another factor to consider is that volunteer positions will not come with health insurance. The bottom line is that IMG students will need a significant amount of funds to apply for volunteering positions, which unfortunately are the most common.

The second option, which would be the best-case scenario, is to get a postdoctoral research fellow position. This case offers employment at the university, which comes with a salary, health insurance, and, in some cases, different benefits offered by the university. Again, a visa is required, which in this case could be a J1 or an H-1B. Please refer to the Department of State for detailed explanations regarding visa issues.[15] Given the complexities involved in acquiring J1/H-1B visas or a green card, it is highly advisable for IMGs to seek guidance from seasoned immigration attorneys. They should collaborate with immigration experts to define achievable goals, including securing a green card, and explore the most effective strategies for maintaining legal status while upholding academic productivity during research in the United States.

1.2.5 Away Rotations

As a candidate chooses where to do away rotations, it is important to define what the student's priorities are. It is critical to evaluate the culture and training available at each program. According to the Society of Neurological Surgeons (SNS), it is recommended that the fourth year medical students perform one 3-to 4-week home program subinternship with an addition of one or two 3- to 4- week away rotations. From a clinical standpoint, it is important to evaluate the case volume of each program the student is doing the away rotations. A useful metric is to compare the ratio of total case volume divided by the number of residents in the program. Low volume translates into lower operative exposure throughout residency. On the research side, perform a literature search on the entire faculty to understand the true academic commitment and faculty accomplishments. If the applicant is interested in research, search to determine the number of clinical neurosurgeons who are principal investigators of projects funded by NIH or Department of Defense. This will provide a measure of the role models available at the specific program.

Performance on the subinternship and away rotations is perhaps the most important aspect of a candidate's profile at that particular institution. During this time, students will spend a month with the

neurosurgery service and develop the basic foundations of neurosurgical knowledge and techniques. Here, both the faculty and house staff will have the opportunity to evaluate if a student has the caliber for the field of neurosurgery. By the end of the rotation, candidates should be in a position to request a letter of recommendation from the residency director or chairperson of the department. To stand out as a valuable member of the team during the neurosurgery clerkship, students will need to build on and utilize many of the skills learned in their prior rotations.

The 3 A's (affability, availability, and accountability) have been frequently cited as guidelines for medical students.

Many others cite *A Message to Garcia* as guiding principles to exceptional performance on the neurosurgery subinternship:

"The world bestows its big prizes, both in money and in honors, for but one thing. And that is Initiative. What is Initiative? I'll tell you: it is doing the right thing without being told. But next to doing the thing without being told is to do it when you are told once. That is to say, carry the Message to Garcia: those who can carry a message get high honors, but their pay is not always in proportion. Next, there are those who never do a thing until they are told twice; such get no honors and small pay. Next, there are those who do the right thing only when necessity kicks them from behind, and these get indifference instead of honors, and a pittance for pay. This kind spends most of its time polishing a bench with a hard-luck story. Then, still lower down in the scale than this, we have fellow who will not do the right thing even when someone goes along to show him how and stays to see that he does it; he is always out of job, and receives the contempt he deserves, unless he happens to have a rich Pa, in which case Destiny patiently awaits around a corner with a stuffed club. To which class do you belong?" [16]

For IMGs, although they may not have access to structured subinternships or away rotations like U.S. medical students, they are encouraged to engage in observerships at their desired institutions. Observerships usually involve shadowing experiences that offer a firsthand look into the daily workings of a medical practice. This opportunity not only provides valuable insights into the U.S. health care system but also serves as a platform for networking and building relationships with potential mentors.

1.2.6 Letters of Recommendation

Three letters of recommendation are required to apply for neurosurgery. One of these letters should be from the department chair and/or the PD at the home institution. While on away rotations, try to obtain a strong letter from the chairperson or PDs at those institutions. These letters will largely be based on input from residents and other faculty observing your performance. Letters from non-neurosurgeons are not encouraged as these may have a lower impact, given individuals outside of the field may have limited ability to comment on the qualities necessary for neurosurgery. The seniority of the letter writer may also affect the impact of the letter. Neurosurgery research mentors may have a unique ability to comment on candidate qualifications as they have likely overseen their work and long-term maturation. Students should also keep in mind that they can submit different letters to different programs. For instance, if a student knows that a certain letter writer has connections at a program of interest, that letter may be more strategic than others. In addition to letters, mentors may offer to call programs to advocate for the student.

1.2.7 Match without a Home Neurosurgery Program

Not having a home neurosurgery program poses unique challenges for medical students. These students should carefully plan to find mentors, build networks, gain productive research experience, and identify suitable away-rotation locations. One of the most daunting obstacles faced by applicants without a home program is securing research opportunities, especially given the increasing average number of publications required. To overcome this barrier, many students, including those from strong home departments, opt to take a research year. The timing of this research year varies, but choosing an institution with a home neurosurgery program can provide advantages such as building strong relationships with research mentors and attending weekly neurosurgery conferences to establish connections.

It is crucial to note that the recent change of Step 1 to P/F underscores the importance of research and could potentially further disadvantage students without a home program. For those who have developed substantial research experience, attending annual neurosurgery conferences is encouraged to enhance networking opportunities.

In addition, choosing appropriate away rotations is crucial for students without a home neurosurgery program. These rotations provide an excellent chance to showcase genuine interest in a specific neurosurgical program, acquire invaluable letters of recommendation, and set themselves apart through their dedication and strong work ethic.

1.2.8 Match into a Top Neurosurgery Program

Matching into a top neurosurgery program necessitates that candidates closely adhere to the provided guidelines. In addition to excelling academically, candidates are expected to demonstrate rich academic productivity, have strong letters of recommendation, and have stellar performance during their subinternship and away rotations. Each top-ranked neurosurgery program has its own unique departmental culture and specific characteristics they seek in candidates. It is advisable for candidates to begin exploring their desired programs early on and become familiar with each department's culture. A helpful starting point is for candidates to engage in candid self-reflection regarding whether they are seeking a surgery-heavy program, an academic research-intensive program, or a more balanced program. This self-assessment can guide candidates toward departments where they are more likely to find a good fit. Furthermore, each top neurosurgery program specializes in particular sub-fields, and candidates should align their program preferences with their research interests. Lastly, completing an away rotation at the institution where the candidate aims to match can provide valuable firsthand experience for both the candidate and the program, facilitating mutual understanding and informed decision-making.

1.2.9 Interviewing

Interview season is an expensive and stressful process. With the majority of institutions transitioning back to in-person interviews, applicants should plan their travel and accommodations strategically.

Despite these costs, in-person interviews are important for learning about the culture of each institution, touring the facilities, and meeting potential colleagues and mentors. Know that once an interview has been obtained, the applicant pool has become significantly narrowed down. Most successful applicants aim to attend 10 or more interviews to optimize their chances to match.[8] The interview day itself will be hectic. Most applicants will have an

introduction by the chairperson, interviews by program faculty, a walking tour of the hospital, and some time to spend with the residents. Arrive at the interview with a handful of prepared questions. Ask about key faculty projections and transitions, operating room experience, programs for team building and social activities, variety of experience from hospitals within the health care system, enfolded fellowships, research opportunities and support, resident matriculation into academic centers, and any other areas of interest. During interview sessions, candidates should strive for a bidirectional conversation. Be a good storyteller and emphasize key strengths of the application. Candidates will likely be asked about their specific interests and long-term goals in neurosurgery as well as their research. Conveying background knowledge, roles, and key findings of research projects will be expected of interviewees. After interviewing, make sure to send thank you notes to each program. Generic communications sound like generic communications. Write about something specific and meaningful about the program and visit. Email communication is an acceptable form of postinterview communication and follow-up inquiries. If an applicant is still undecided about where to rank programs, a second look is always an opportunity to reevaluate a program and demonstrate interest.

The format of residency interviews has undergone significant changes since the onset of the COVID-19 pandemic. Specifically, the field of neurosurgery transitioned to an entirely virtual format for the 2020–2021 application cycle due to the public health crisis. While many programs have since returned to in-person interviews, several continue to utilize virtual formats. Virtual interviews offer notable advantages in terms of both time and cost efficiency. They enable students to take less time off from their medical school rotations, and importantly, they eliminate a substantial barrier for students from lower socioeconomic backgrounds.

However, it is important to acknowledge that the field of neurosurgery also has some special characteristics and needs, as compared with other specialties. Given its extensive training duration, in-person interviews offer candidates a firsthand understanding of how well they align with the department's culture and the geographic location of the institution. While both virtual and in-person interviews have their merits, there is not a one-size-fits-all approach that suits every applicant and program. Applicants should carefully weigh the advantages of each method alongside their individual circumstances to make an informed decision.

1.2.10 Ranking

Much of ranking is based on the applicant's feeling for the program on interview day. There are many aspects of a program that an applicant should consider when ranking, and these vary based on personal preference. If an applicant genuinely disliked a program and would not be happy working there for 7 years, then it might be best not to rank it highly, regardless of perceived prestige. It is vital that applicants build an intimate understanding of the matching algorithm. In brief, the Match algorithm is "applicant proposing," which means that preference is given to the applicant's ranking of a program, over the program's ranking of an applicant.[17] The algorithm thus encourages students to rank programs in order of preference rather than in order of candidacy at each program. In essence, the order of the rank list does not influence the chance of matching into neurosurgery. Applicants should not rank lower-tier programs higher because they believe it will increase their chances of matching. On the contrary, it only increases the chances of matching at a less preferable institution.

1.2.11 Preference Signaling

In the period 2022–2023, neurosurgery actively participated in the Supplemental Application Pilot, as outlined by the SNS. Most applicants and programs took part in this pilot, where preference signaling became a key element. According to data from the Association of American Medical Colleges (AAMC) and responses from the SNS Post-Match survey, preference signaling was advantageous for the majority of neurosurgery applicants and programs. For the 2023–2024 Match, neurosurgery will allow applicants to use up to 25 signals. As per AAMC guidelines, applicants should signal programs where they completed rotations (either at their home programs or during away acting internship (AI) rotations) if they still have a strong interest in those programs after their rotations.

The use of preference signaling remains optional for both applicants and programs. Applicants should carefully consider which programs to signal, aiming to do so for a variety of programs with different levels of competitiveness. Mentors play a crucial role in providing honest guidance to applicants, assisting them in evaluating the strength of their application and selecting the appropriate group of programs to signal.

1.3 Profiles

Robert M Friedlander, MD, MA
Chair, Department of Neurological Surgery
Walter E. Dandy Distinguished Professor of Neurosurgery, Neurology, and Neurobiology
Co-Director, UPMC Neurological Institute

"On my surgery rotation, I really liked taking care of an acute patient and fixing things. Sometimes, we were breaking things, but hopefully not too many times. The problems with surgery, however, were several in my mind. I did not think it was a field that was conducive to laboratory research. Residents were on-call every other night for 5 years, which to me at that point felt like too much. I then remember talking to the Surgery clerkship director about the dilemma that I was in.
I liked surgery but it seemed really hard and a lot of work. He said 'Robert, you can be a dermatologist or a surgeon. If you like dermatology, then God bless you. In dermatology, residency is going to be much shorter, there will be fewer hours, your career will be more or less 9 to 5, and you will not have weekend emergencies. But if you dislike what you do, you are going to wake up miserable, go to work miserable, go home miserable, and not be happy. Surgery, sure, you wake up early, you work hard, you may have to take call every other night, but its 5 years. It's a long time, but it's a limited amount of time, and you have the next 30 years to practice something that you love. You are going to love waking up, you are going to be excited to go to work, you are going to love doing surgery, you are going to go home and be happy with your family. But it really depends if you like it or not.' So that conversation at least opened my eyes to a surgical career and was a very transitional conversation for me. It was my good friend in medical school who put the neurosurgical bug in my head. He was doing research and always so excited about neurosurgery that I decided to do a rotation in neurosurgery. And I loved it. I remember the first time that I saw a neurosurgical operation. It was a cerebellar met. I remember just seeing the cerebellum pulsate and to me it was really cool and exciting, just seeing the brain, opening the fissure, and seeing the blood vessels. To me, it was just phenomenal. So, at that point, I decided to do neurosurgery, about midway through third year of medical school. To me, having the privilege of opening someone's head and fixing it, being able to use my hands, and being able to teach residents—to me, it is too fulfilling. To have the ability to do research, which I love; surgery, which I love; and teaching, which I love; and now, to be able to administer and have a vision, to not only impact what I do but to mentor a large number of faculty and

residents, and to establish a neurosurgical legacy in a leading neurosurgical department, to me is a privilege, an honor, and a great responsibility."

L. Dade Lunsford, MD, FACS
Lars Leksell & Distinguished Professor
Director Emeritus, Center for Image Guided Neurosurgery
Associate Director, Neurological Surgery Residency

On my path to neurosurgery

"My interests in neuroscience probably began in college. At the University of Virginia, I got to participate in a master's level undergraduate program, where I spent 2 years working on neuroscience research. At that time, we were working on the transfer of learning information in a rat model and doing things like corpus callosum resections and using a technique called 'spreading depression' to functionally inactivate brain function and study memory function in one hemisphere of the rat. That stimulated my interests in neuroscience. I already knew that I wanted to go to medical school, so during that same time, I completed my pre-med requirements. I had lived in the state of Virginia for 21 years and made the decision that it was probably a good idea to go somewhere else for a period of time for medical school. So I ended up going to Columbia University and started working for a neurologist who was focused on epilepsy, before my first year of medical school. Over the course of time, my clinical interests in neuroscience centered on neurosurgery. I spent time on the neurosurgical service at Columbia Presbyterian Hospital and did rotations at a couple other places during my third and fourth years. I decided to go back to University of Virginia to do my internship for a year, but after a year, I decided I wanted to go to Pittsburgh to do my neurosurgical training. I came here in 1975. At the time that I came, the first major breakthrough in brain imaging came with the development of the computed tomography (CT) scan, which showed up on the same day I started my residency. It became clear to me immediately that the world was going to change in a big way. So I worked on combining imaging with guiding technology. At the time, that was not actually done in brain surgery since movement disorder surgery had died during that era after the development of L-dopa. To precisely reach areas in the brain, I developed, as a resident here, a stereotactic guiding device that was CT-compatible. I became further interested in deep brain types of surgery. I had an opportunity to spend a few months in Europe in 1979, trying to decide where I wanted to do a fellowship after I finished training in neurosurgery here. I applied for an American Association of Neurological Surgeons (AANS) supported William P Van Wagenen fellowship, which is given once a year. This allowed me to spend a year in Sweden doing training in stereotactic surgery and functional neurosurgery. I came back to Pittsburgh in 1981, and joined the faculty and, in essence, I have been here ever since. My interests have still remained in minimally invasive surgical techniques to be able to avoid the risks and complications of more aggressive brain surgery, while finding ways to minimize collateral damage in brain surgery. One of the techniques that we developed was the first dedicated stereotactic operating room with a CT scanner, which was put in 1981 here at UPMC. In 1987, we brought in the first 201 source Gamma Knife (fifth unit ever built) for brain surgery. Over the last 30 years, we have updated the various Gamma Knife devices five times and now radiosurgery has become a major component of what is done in neurosurgery, both in the brain and spine. Currently in our program, which is probably one of the busiest in the United States, we do about 9,000 operations per year. Radiosurgery techniques, using things

like Gamma Knife and spine radiosurgery devices, account for somewhere around 12% of the total neurosurgery practice. It has become a major component of what the field is and it is a major component of what current residents in training need to learn while they are in training. My other interests have been related to proving that new technology has value. One of the crazy things about U.S. health care is that sometimes industry develops tools that are expensive but are not always shown to have sustained value over the course of time. What we have done in working with tools like Gamma Knife is to maintain comprehensive patient databases that allow us to do long-term outcomes research. We have published somewhere around 650 peer-reviewed articles in the scientific literature plus 12 books related to technology, a large number of them related to Gamma Knife. Patient care, teaching, and academic publishing in clinical research are what I have been doing for 40 years or so that I have been in practice."

On mentorship:

"When I was in childhood and through high school, I studied piano for many years, and I had a 90-year-old piano teacher who was a concert pianist. She had a significant impact on me in terms of the need to study and apply myself. I was a never a natural talent in piano, but I was someone who was able to work hard to meet her demanding nature. Similarly, I do not think that people who go into neurosurgery should be rocket scientists in the sense of being 200-level IQs. I think those people are brilliant theoreticians but they cannot deal with the reality of taking care of a patient sitting in the emergency room with a blood clot in their head. You have to be able to focus and apply yourself. Certainly, when I decided to come to Pittsburgh for training, Peter Jannetta, who was the first truly academic chair of this department, was a major influence on me because of his somewhat demanding nature, but also his requirement that you provide skillful surgical care of patients. After that, I had experience working with two Swedish neurosurgeons, Eric Olof Backlund at the Karolinska institute, and Lars Leksell, who was the originator of Gamma Knife. He was no longer clinically active, but was very much active in terms of his continued research interests and how to do this type of noninvasive surgery."

Nathan Zwagerman, MD, FAANS
Director of Pituitary and Skull Base Surgery
Surgical Director of WINS
Associate Professor of Neurosurgery, Otolaryngology and Surgery
Program Director Neurosurgery Residency
Program Director Skull Base Fellowship
Medical College of Wisconsin

"I grew up on a small farm in Michigan. My parents are hog farmers and I am the oldest of four boys. In rural west Michigan, the plan was that I would continue the farming line. However, early on, I realized that I did not want to be on a farm. Farming just was not for me. I did not mind the work, but I just did not like it. So I was looking for every opportunity I could get to leave. It was clear from an early age that I enjoyed learning about the biology of the hogs, and when I was in high school, I took Advanced Placement biology.
During medical school, I enjoyed anatomy and doing dissections in the cadaver lab. I realized very quickly that I could not sit in class anymore. I was very tired of lectures and lecture halls and all the lectures were available online at twice the speed. To get me out of the house, I ended up going to different grand rounds, depending on what subject we were studying. During neuroanatomy, I interacted with a couple of neurologists in the beginning of my third year and they told me about neurosurgery grand rounds. I was leaning toward surgery

at that point. I went to neurosurgery grand rounds midway through my third year. They were presenting at morbidity and mortality (M&M); it was an aneurysm case, which was initially nonruptured. The video was up and as they were about to clip the aneurysm and the aneurysm ruptured. I remember the intensity of the room changed. The entire atmosphere was something that I had never experienced before. I thought this is something I must know more about. As a result, during my third year, I learned more about it, spent more time going to grand rounds, meeting the residents, picking their brains, just kind of hanging out around the department, while doing my rotations. I did a month of research with Dr Ding, who also helped guide me further toward neurosurgery. I did a couple of rotations at Wayne State, Northwestern, and the University of Vermont, and was totally secured that neurosurgery was where I wanted to be. That is how I got into neurosurgery, I was a late bloomer, so to speak. Ten years ago, I would have never pictured myself as a skull-based surgeon in Milwaukee, but it is funny how life takes you on a ride."

Shelly D. Timmons, MD, PhD, FACS, FAANS
Professor and Chair
Sanford J. Larson Chair in Neurosurgery
Department of Neurosurgery
Medical College of Wisconsin

"From the time I was a little girl, I had a keen interest in all things medical and anatomical, and I knew that I wanted to be a doctor at a very early age. When I was about 16, I read an article about brain surgery, and from that moment on, there was nothing else I ever wanted or planned to do. The brain as the arbiter of our interactions with others and the world had always fascinated me, and the opportunity to work with my hands (as is so prevalent among surgeons) was a driving factor, as well as the chance to study and understand the most complicated organ in existence! That interest also led me to pursue my PhD in neurophysiology when the opportunity arose at the end of my residency training."

Robert F. Heary, MD FAANS
Chief of Neurosurgery
Department of Neurosurgery
Mountainside Medical Center

"I began my career as a general surgery resident. Midway through my third year of residency, I rotated on the neurosurgery service and had a great time. It became apparent that neurosurgeons had the opportunity to use their minds to think through complex decisions and help many people in the process. The thrill of taking care of debilitated and injured patients was fabulous. After my rotation on neurosurgery was completed, the Chief of the Section of Neurological Surgery (part of the Department of Surgery in those days) asked me to leave General Surgery and become a neurosurgery resident. It took me less than an hour to realize that this was the chance of a lifetime. Between the various spine surgeries and brain operations that I had the good fortune of participating in, I was thoroughly convinced that the correct career path for me was being handed to me and I accepted the position. I then began 5 more years of residency in neurological surgery and I have never regretted this decision for an instant. Later in my neurosurgical training, I decided to specialize in spinal surgery and I took an offer at a prestigious orthopaedic spine program to become a spine fellow. Once again, I was very fortunate to make an excellent decision. Having spent the past 2 + decades performing complex surgery, and training a large number of superb neurosurgery residents during this time, has been the best decision I have ever made. I would not trade the career in neurosurgery for any other job in this world. I am also completely confident that our wonderful profession will continue to

attract the 'best and brightest' to enter into the rapidly expanding field of medicine that enables us to do more positive things for our patients than any other field in medicine."

M. Sean Grady, MD
Emeritus Professor of Neurosurgery
University of Pennsylvania

"Entering medical school at Georgetown, I was unsure of what specialty I might ultimately choose. I was fascinated by anatomy and challenged by neurosciences, so I felt, upon starting clinical rotations, that somewhere in the field of surgery would lie my future. A 2-week rotation on the neurosurgery service set my career for the next 35 years. Unlike other services, I would enthusiastically spend all day and night taking care of the patients, being in the operating room, and reading and learning nonstop. It was phenomenally exciting and I now realize that level of commitment is the hallmark for someone interested in a career in neurosurgery. It is an enormously rewarding and at the same time incredibly humbling career in which I thought then and know now that I would be an eternal student. In my training at the University of Virginia from 1981 to 1987, I never saw a magnetic resonance imaging (MRI); there was no endovascular neurosurgery, endoscopic neurosurgery, major spine instrumentation, or deep brain stimulation, to name just a few advances in the field. I am most certain that much of what our trainees learn today will be abandoned for new approaches or whole new areas will open for surgical intervention. So, if you like continuous learning and change, neurosurgery is the specialty for you. Finally, what we do as neurosurgeons has huge implications for our patients and their families, both positive and negative. There is no higher high nor lower low than the surgical results in neurosurgery—a neurosurgeon must possess equanimities. Always remember: do no harm."

Pearls

- It is important to prepare early during medical school to build a competitive neurosurgery residency application.
- IMG applicants should focus on expanding their research portfolio and developing relationships with senior neurosurgery faculty in order to enhance their chances for matching.
- Subinterns should always exhibit Affability, Availability, and Accountability towards patients and colleagues.
- Applicants should curate their signaling list to include programs with varying levels of competitiveness, guided by advice from a clinical mentor.
- USMLE step 2 scores, research accomplishments, and letters of recommendation will help to secure interviews.
- Letters of recommendation and interpersonal skills influence applicant rank order.

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References

[1] Main residency match. Results and data 2024. Web site. https://www.nrmp.org/wp-content/uploads/2024/06/2024-Main-Match-Results-and-Data-Final.pdf. Published March 2024. Accessed March 11, 2025.

[2] Yekula A, Sreeram S, Dhawan S, et al. Neurosurgery residency match for international medical graduates in the United States. J Neurosurg. 2023; 140(1):291–298

[3] National Resident Matching Program. Charting Outcomes in the Match for U.S. Allopathic Seniors. 2023

[4] National Resident Matching Program. Data Release and Research Committee: Results of the 2020 NRMP Program Director Survey. Washington, DC: National Resident Matching Program; 2020

[5] Ganesh Kumar N, Makhoul AT, Pontell ME, Drolet BC. Characterizing the effect of pass/fail U.S. Medical Licensing Examination Step 1 scoring in neurosurgery: program directors' perspectives. World Neurosurg. 2020; 142:e440–e444

[6] Charting Outcomes in the Match: Senior Students of U.S. MD Medical Schools. Web site. https://www.nrmp.org/wp-content/uploads/2022/07/Charting-Outcomes-MD-Seniors-2022_Final.pdf. Accessed December 09, 2024.

[7] Kashkoush A, Prabhu AV, Tonetti D, Agarwal N. The neurosurgery match: a bibliometric analysis of 206 first-year residents. World Neurosurg. 2017; 105: 341–347

[8] Agarwal N, Norrmén-Smith IO, Tomei KL, Prestigiacomo CJ, Gandhi CD. Improving medical student recruitment into neurological surgery: a single institution's experience. World Neurosurg. 2013; 80(6):745–750

[9] AANS. Grants and fellowships. 2017. Accessed March 2018. Web site. https://www.aans.org/residents-students/grants-and-fellowships/. Accessed December 09, 2024.

[10] Alpha Omega Alpha. Student research fellowships. 2017. Web site. https://www.alphaomegaalpha.org/programs/carolyn-l-kuckein-student-research-fellowship/. Accessed December 09, 2024.

[11] Council of State Neurosurgical Societies. Fellowships & awards. 2017. Web site. https://csnsonline.org/fellowships-and-awards/#:~:text=Fellowships%20%26%20Awards,-Awards&text=The%20fellowship%20consists%20of%20a,of%20the%20CSNS%20is%20required. Accessed December 09, 2024.

[12] NIH. Medical research scholars program. 2017. Web site. https://www.cc.nih.gov/training/mrsp. Accessed December 09, 2024.

[13] hhmi.org. Medical Research Fellows Program. 2017. Web site. https://www.hhmi.org/sites/default/files/2018%20Med%20Fellows%20Program%20Highlights.pdf. Accessed December 09, 2024.

[14] Agarwal N, Choi PA, Okonkwo DO, Barrow DL, Friedlander RM. Financial burden associated with the residency match in neurological surgery. J Neurosurg. 2017; 126(1):184–190

[15] Travel.State.gov. Visitor Visa. Web site. https://travel.state.gov/content/travel/en/us-visas/tourism-visit/visitor.html/visa. Accessed December 09, 2024.

[16] Hubbard E. A Message to Garcia. [pdf] 1913

[17] Williamson E, Soane C, Carmody JB. The US residency match at 70: what was, what is, and what could be. J Grad Med Educ. 2022; 14(5):519–521