OBJECTIVE: Neurological surgery is historically among one of the most competitive residency matches, but data suggest a downward trend in neurosurgical residency applicants in the United States. In 2002, our department, in conjunction with our institution, began an initiative to increase exposure to and interest in neurological surgery, targeting both undergraduate and medical students. This study outlines and assesses the factors used by our institution to successfully prepare and recruit medical students for residency in the field of neurological surgery.

METHODS: This initiative has been divided into four phases to date. In phase one, a 2-week neurosurgical experience was incorporated into the existing Neurology/Psychiatry third-year clerkship, and a chapter to the Student Interest Group in Neurology was created. In phase two, the neurological surgery department increased efforts recruiting undergraduate students and preclinical medical students for research projects through a summer research program. During phase three, new neurosurgical course electives were added for third- and fourth-year medical students, as well as allowing earlier completion of a fourth-year acting internship. In phase four, a neurosurgical interest group was created.

RESULTS: Since the implementation of all four phases, the number of medical students matching successfully to neurological surgery at our institution has increased drastically.

CONCLUSIONS: An earlier, organized involvement of the neurosurgical department in medical student education can result in an improved understanding of the role of neurosurgeons among other practitioners as well as a greater number of well-qualified residency applicants into neurological surgery.

INTRODUCTION

In the United States, becoming a neurosurgeon is a lengthy process. Medical school in the United States is typically 4 years, with 3 or 4 years of premedical education at an undergraduate institution. The medical school curriculum is divided almost equally between preclinical (didactic courses in the basic sciences) and clinical (clerkships during which students rotate through different wards of a training hospital) training. After medical school, graduates must gain acceptance into a neurological surgery residency training program, where the average length of training is 7 years. Some programs are 6 years in duration, and others require 8. Neurological surgery is historically among one of the most competitive residency matches, but the data suggest a downward trend in neurological surgery residency applicants in the United States (7).

Herein, we discuss our institution’s successful initiative to address the shortage of neurosurgical residents compared with other specialties. It is difficult to ascertain the exact reasons for a downward trend in applicants in recent years, for there may be many factors, but there are a likely few key reasons that can likely explain the general shortage of neurosurgical residents. Some possible explanations for this trend include concerns with work-life balance, duration of residency, likelihood of litigation, or late exposure to neurological surgery (7). Often, students are not exposed to neurosurgery until their clinical rotations, and neurosurgery is only occasionally included with the core clinical curriculum, further impacting students’ exposure to the field.

In 2000, only one institution in North America reported that their program required a neurosurgical rotation for all medical students.
Before 2002, at our institution students had minimal interaction with the department of neurological surgery during both preclinical and clinical years. There were a limited number of preclinical lectures given by neurosurgical faculty and no dedicated neurosurgical rotation in clinical years. Medical students interested in neurosurgery had to actively seek out neurosurgical mentors. There was no organized system of research involvement or dedicated neurosurgical interest group, and students generally perceived the department of neurological surgery as isolated. There were, however, very enthusiastic residents and faculty with limited means to reaching out to the medical students. In 2002, our department began an initiative to increase exposure to and interest in neurological surgery, targeting both undergraduate and medical school students. This study specifically outlines and assesses the factors used at our institution to successfully prepare and recruit medical students for residency in neurological surgery.

Initiatives to increase the number of neurosurgical providers also have been used outside of the United States. Many African countries suffer from a severe lack of neurosurgeons. The examination of the successes of different initiatives is integral to the improvement of neurological medical student education and examination of the successes of different initiatives is integral to countries that only 33% (21 of 64) of neurosurgical medical student rotations or clerkships offer neurological surgery rotations to third-year students. The same questionnaire reported that 59% of the surveyed medical school deans believed that neurological surgery should not be a required rotation (8). Even if efforts are made to increase exposure to neurosurgery during the clinical years, this single-pronged approach may not be sufficient. Studies that have looked at students’ career choice suggest the majority of students have already decided on their specialties before the conclusion of their second year (5, 8).

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Initiatives to increase the number of neurosurgical providers also have been used outside of the United States. Many African countries suffer from a severe lack of neurosurgeons. The examination of the successes of different initiatives is integral to the improvement of neurological medical student education and the recruitment of more neurological surgeons on an international scale.

**METHODS**

This initiative occurred in a step-wise fashion, with each phase addressing a recognized deficit in medical student exposure to neurological surgery. As each additional effort built upon both the success of the previous changes and expressed interests of the students, it remained a dynamic process in evolution. For the purpose of describing our efforts, we have retrospectively divided our initiative into four phases (Table 1). Each step was implemented to further increase exposure, education, and ultimately recruitment of students into neurosurgical residency.

**Phase One**

Phase one (2002) of our institution’s initiative incorporated an option for a 2-week neurological surgery experience into the existing Neurology/Psychiatry third-year clerkship. This allowed for eight students per rotation for six rotations, totaling 48 students to rotate through neurosurgery. The class size at our institution is approximately 200 students; subsequently, almost one-quarter of each class is now exposed to neurosurgery during their third year. Concurrent with phase one, the Student Interest Group in Neurology (SIGN), a national clinical neuroscience focus group, became increasingly active at our institution. Their activities included occasional guest lectures from neurosurgical faculty. For the first time, the neurosurgical faculty became more visible to and more involved with preclinical students.

**Phase Two**

During phase two (2007), our department more actively focused on recruiting undergraduate students (especially in 7-year accelerated BS/MD programs) and preclinical medical students for summer and yearlong research. By creating a formalized research program, the department defined time commitment and generated expectations for publications and abstracts. In addition, a web-based system for students describing ongoing research projects was implemented by the medical school, improving publicity of this program. The formal research program stipulated that there is to be a member of the faculty, a fellow/resident, a medical student, and/or undergraduate student on every project. This experience created clear expectations for students and their mentors. Crucial to the success of this program were: an open-door policy by the faculty; weekly research meetings with interchangeable faculty; and the ability for students (undergraduate and preclinical) to have access to neurosurgical procedures during their research experience. The addition of access to observing neurosurgical procedures was especially popular to participants.

**Phase Three**

Before phase three (2010) of our institution’s initiative, clinical year rotations were inflexible. Third-year students who did not get assigned to a 2-week neurological experience did not have an alternative means of experiencing neurosurgery that year, and our fourth-year students had limited openings for early acting internships at their home institution. During phase three, new
neurosurgical courses were added: third-year students were given the option to take a 2-week elective, and fourth-year students a 2- or 4-week elective in neurosurgery as well as an endovascular neurosurgical elective. Students also were permitted to complete their acting internship during the transition month between third and fourth year. The ability to do their acting internship at their home institution as early as June allowed the students to be better prepared for rotations at other institutions.

Phase Four
Despite continued participation in SIGN, students felt a more focused exposure to neurosurgery would be beneficial. Subsequently, phase four occurred in January of 2012, when our institution’s neurosurgery interest group was approved by the Student Council. This neurosurgery interest group was founded with the mission of improving undergraduate medical education in neurosurgery through a didactic curriculum, research opportunities, mentorship programs, and community outreach. The neurosurgery interest group was envisioned as a student-run, resident- and faculty-mentored organization whose focus is to disseminate neurosurgical-specific education to students as early as in their first few years of medical school.

RESULTS
Since the implementation of all four phases, the number of medical students matching into neurological surgery at our institution has increased drastically. From 1995 to 2007, this number has staggered between zero and three students matching into neurological surgery each year, without a new student in six of those years. From 2008 until 2012, the number of successful matches per year has been consistently greater (Figure 1).

In addition, in 2007, the neurosurgical department at our institution produced six abstracts and only four publications involving undergraduate or medical students. After the establishment of phase two, the number of publications and abstracts with student involvement increased. Already in the year 2012, the number of publications and abstracts drastically increased, with 12 abstracts and 28 publications produced by the time of this study in August of 2012 (Figure 2).

The summer program was initiated in 2008 with four students. In 2009 there were six students, and in 2010, there were eight. Ten students were recruited in 2011, and 12 students participated in the program during the summer of 2012. With the completion of phases one through four, the students at our institution have increased exposure to the field of neurosurgery through the addition of new neurosurgical electives, lectures, and sessions; the creation of the neurosurgery interest group; and increased interaction with neurological faculty. It is important to note that it is possible that there are other variables that have shaped the recruitment of residents that have not heretofore been identified or discussed.

DISCUSSION
It is difficult to know the reasons for the downward trend in neurological residency applications with certainty because the reasons are likely multifactorial. One potential cause is the increasing cost of health care over the last few years, demanding a greater degree of scrutiny of medical practice by insurance companies. Neurological surgery being a high-risk specialty, and a likely target for malpractice claims, may be becoming a less-attractive specialty as many neurosurgeons have had to alter their practices as a defense mechanism. Studies show that approximately 60% of neurosurgeons consider medical malpractice premiums an extreme burden, resulting in almost half of this surveyed group to eliminate high-risk procedures from their practices (12).

It is also possible that lifestyle and work hours significantly affect medical students’ residency decisions. Neurological surgery is

![Figure 1. Number of students successfully matching into neurological surgery each year from 1995 to 2012.](image-url)
EDUCATION & TRAINING

As residency match, it was also advised that preclinical lectures by clinical surgeons, surgical clerkships, and neurological surgery exposure to medical students. The recent AANS pilot survey in 2010 of institutions with neurological surgery exposure to medical students aims to improve neurological surgery exposure. Our institution was included in this study and was encouraged to continue to recirculate on the internet. In fact, there was a letter to the editor written in response to this article, documenting studies revealing that almost 50% of surveyed physicians were in an advanced state of burnout. Given that neurological surgery is an especially demanding specialty, many more factors contribute to the declining number of neurological surgery residency applications. A number of studies address factors that improve medical student education and match rates among surgical residencies. These studies highlight the importance of resident involvement in medical student education, faculty-student interaction, the influence of mentors, didactic lectures by clinical surgeons, surgical clerkships, and early exposure. The majority of these studies are aimed towards surgery residencies other than neurosurgery.

The recent AANS pilot survey in 2010 of institutions with successful residency matches yielded strategies to improve neurological surgery exposure to medical students. The results only solidify the impact of these strategies previously suggested in other studies. Our institution was included in this AANS survey. On the basis of the responses from all participants, the creation of a mentorship program was advised, as was a neurosurgery interest group. To increase exposure and therefore residency match, it was also advised that preclinical lectures include topics relevant to neurological surgery and that medical students have access to neurosurgical research opportunities. Of these four suggestions, our institution was listed in this 2010 AANS pilot survey, to have three of the four elements, only excluding preclinical neurological lectures. Since 2010, our institution has incorporated neurological surgery into its preclinical lectures and has further expanded and strengthened its strategies to increase early exposure.

The United States is not the only nation that can benefit from an increased emphasis on the successful implementation of strategies to improve neurological surgery exposure. Many African countries also suffer from a severe lack of neurological surgeons. The major reasons for this deficiency in both quality and quantity are largely different from those in the United States. It is difficult for an African neurosurgeon trained in a developed country to return to his or her homeland, where he or she is likely to have experienced the lack of technology, limited resources, and will typically be busied with secretarial work because of a shortage of staff. Many cultural practices also make it difficult for neurosurgeons to practice totally effectively; the use of traditional folklore medicine is compromising.

It is thus integral that African nations strive to set up neurosurgical training programs. The article “African neurosurgery, the 21st-century challenge,” published in 2010, emphasizes the importance of the foundation of local neurological training programs supplemented with education in English or Francophone African nations so as to familiarize the physician with the language common in the scientific community. A study in 2012 reports the early successes of a specific initiative in Northwest Tanzania to train neurosurgeons at Bugando Medical Centre. The initiative focused on teaching local surgeons fundamental neurological surgery techniques and skills; by the end of the 15 week initiative, local surgeons were trained in 41 different neurological surgery techniques and skills; by the end of the 15 week initiative, local surgeons were trained in 41 different neurological surgical procedures and had discussed intraoperative decision making and clinical management.

The goal to increase the number of neurological surgeons through the creation of established initiatives is not solely American. We are hopeful that outlining the successful steps of our initiative will be of use not only to other American institutions but also to others across the globe.

Early Faculty-Student Relationship

Mentorship is of great importance to the success of this initiative. Much of the success of our initiative can be attributed to the involvement of the neurological residents and faculty. Unless there is an initiative emphasizing the importance of mentorship, there are many challenges that inhibit the initiation of these successful relationships. The early access to faculty and residents by medical students is generally limited, and many students may be intimidated to approach their superiors. The summer internship program is a prime example of the dedication of the neurological faculty and staff at our institution. Students, both undergraduate and preclinical, interact constantly with each other and with members of the Department of Neurological Surgery: residents, fellows, faculty, staff, etc. Each student is assigned at least one research project on which he or she will usually collaborate with another member of the team. Undergraduate students also are provided with a very unique opportunity. During the summer internship program, students are
Increased Research Productivity
The department of neurological surgery has demonstrated a boon in productivity since the start of this initiative. The number of abstracts and publications has seen a dramatic increase due to the organization and formalized expectations of the department and the tiered relationships between students and mentors. The excitement and enthusiasm fostered by the participants as a result of these elements has created sustained productivity. The department of neurological surgery was the department with the most posters at the last symposium in the summer of 2011.

Neurological Surgery Clinical Rotation Flexibility
Increased flexibility of neurosurgery clinical rotations for third and fourth students has resulted not only in increased exposure, but also heightened interest. With a structure clinical rotation in neurosurgery, students have access to a better teaching and learning environment. Students are encouraged by the faculty and residents to take an active role in patient care. Although the aforementioned experience does lead to increased interest, early exposure also allows our students to be more competitive for the neurosurgical match. Early acting internships enable our students to be more prepared and competitive when rotating at outside institutions.

Neurosurgery Interest Group
The future of the neurosurgery interest group is especially promising, and we strongly feel it has the potential to create an impact not only at our institution but also on a national scale. The group has already been successful in their mission to increase exposure to the field of neurological surgery via a variety of lecture topics and seminars (Table 2).

Furthermore, the neurosurgery interest group has been successful in reaching out to women. Women now compose approximately 60% of graduating medical school class years, but the number of female neurosurgeons has not increased proportionately (1). In 2008, Benzil et al. (1) recommended that to address issues such as gender inequity or lack of female role models in neurological surgery, the field needs to encourage female medical students to become neurosurgeons. Our residency program currently has three female residents, comprising 21% of our residency. The neurosurgery interest group at our institution has encouraged and cultivated relationships between female members of the interest group and female resident mentors in neurological surgery.

The 3-year goal is to expand the neurosurgery interest group with the help of the department to other centers that may be interested. These institutions could unite their neurosurgery interest groups with web-based live seminars, annual conferences, and lecture.

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<th>Agenda</th>
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<td>Didactic Lecture</td>
<td>Healthcare Policy and Neurosurgery</td>
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<td>Seminars</td>
<td>Neuropathology</td>
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<td>Expansion plans</td>
<td>For the 2012—2013 academic year, the interest group plans to host a lecture series in which medical students may formally register and receive a notation of their attendance on their academic transcript. The interest group also strives to spread its message on a larger scale with other medical schools. Ultimately, the group hopes to serve as a model and promote the creation of other focus groups nationwide.</td>
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Outcomes
Each step taken in our institution’s initiative has built upon the preceding. By the completion of phase four, our institution has seen a general increase in residency matches, abstracts and publications, and student involvement in the summer research program and neurosurgical interest group. The strategies used and progress that our institution has seen will not only increase exposure to neurological surgery and draw a larger number of well-suited and enthusiastic residents but will also help to establish a more educated group of non-neurosurgeons. A paper by Fox et al. in 2011 highlights physicians are commonly confronted with neurosurgical problems, underscoring the importance of exposing and educating medical students in the field of neurological surgery. The future non-neurosurgical colleagues of neurosurgical faculty will be better able to deduce which patients should be referred to the neurosurgical colleagues of neurosurgical faculty will be better able to deduce which patients should be referred to the department of neurological surgery, or know when to send a patient to the emergency room as opposed to the neurological surgery clinic.

CONCLUSION
An earlier, organized involvement in medical student education can result in an improved understanding of neurological surgery among other practitioners as well as a greater number of well-qualified residency applicants into neurosurgery. The model
should consider improved faculty-student interactions and access; the establishment of early mentoring relationships between students and faculty or residents; organized research opportunities with a tiered system for projects; greater flexibility in neurosurgical clinical rotations either as part of other clerkships or stand-alone electives; and a student run, faculty supported neurosurgery interest group with planned didactics and shadowing opportunities. With institution specific modifications, others institutions may also benefit from this neurosurgical education recruitment model.

REFERENCES


