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Review Article

Assessment of the Interventional Neuroradiology Workforce in the United States: A Review of the Existing Data

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Endovascular surgical neuroradiology, also known as interventional neuroradiology, is a relatively new medical subspecialty. Endovascular surgical neuroradiology is now recognized as a specialty by the American College of Graduate Medical Education (ACGME), and training standards have been defined (1). The field has grown rapidly in the past decade and will likely continue to grow. Much of the growth in endovascular surgical neuroradiology has been driven by the success of the treatment of cerebral aneurysms with the Guglielmi detachable coil (GDC). Carotid stent placement, intracranial angioplasty and stent placement, and acute ischemic stroke therapy are being intensively investigated and might add to the demand for endovascular surgical neuroradiologists (ESNRs).

Endovascular surgical neuroradiology is a field that is procedure-based, and the complication rate in procedure-based fields of medicine is related to the individual operator's procedure volume (2, 3). A shortage of ESNRs could result in performance of procedures by individuals with inadequate training. A surplus of ESNRs could result in performance of procedures by practitioners who perform too few procedures to remain optimally skilled. Thus, either a shortage or surplus of ESNRs could have a negative impact on patient care. An analysis of factors affecting workforce demand may help in preventing excessive shortages or surpluses.

As ACGME-accredited training programs are being established, knowledge of the number of individuals who should be trained to meet the demands of the population of the United States is important. The supply of and demand for ESNRs cannot be precisely defined, but existing information exists allows for a reasonable estimation. By analyzing this information, we can also learn what important information is lacking so that we might be able to then gather additional information necessary for future workforce assessments.

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A History of Physician Workforce Assessments

Predictions of the physician workforce are notoriously inaccurate. Physician workforce predictions depend on predictions of economic conditions, epidemiologic and demographic trends, and scientific advances, all of which are unpredictable in their own right. Also, political agendas often affect the outcome of a workforce assessment more than the scientific evaluation of the facts. Therefore, physician workforce predictions should be viewed as crude estimates at best.

The Graduate Medical Education National Advisory Committee (4) evaluated the overall physician workforce in the United States in 1981. In 1992, the Council on Graduate Medical Education (5) reported ann updated assessment of the overall physician workforce. These studies examined the physician workforce as a whole, as well as the relative abundance of generalists and specialists. However, their reports are not useful for evaluating the ESNR workforce, because they were conducted before endovascular surgical neuroradiology was a recognized specialty.

Workforce assessments for the specialty fields of cardiology (6–10), diagnostic radiology (11), and interventional radiology (12) must be conducted and the results published. These studies provide a historical precedent for the assessment of manpower within a specialty. Perhaps most importantly, they demonstrate that workforce assessment is a rather inexact science.

The Current Supply of Interventional Neuroradiologists

Knowledge of the number of practicing ESNRs is important in assessing the adequacy of the workforce in the United States. Currently, we have no strict definition for an ESNR. Although ACGME training standards and program accreditation have been established, no one has yet completed an accredited training program. Active membership in American Society of Interventional and Therapeutic Neuroradiology (ASITN) could be used as a defining characteristic of an interventional neuroradiologist, as the ASITN requires documented experience in 80 interventional neuroradiology cases and the devotion of 50% of one's practice to interventional neuroradiology. As of September 2001, 208 active members of the ASITN met these stringent criteria. The 208 individuals practice in 170 hospitals or medical centers. The number of active members in ASITN is rapidly expanding, with a 10–15% increase in active membership each year since 1998.

Another indicator of the number of practicing ESNRs is the number of centers in which cerebral aneurysms are treated with GDCs. As of July 2002, the number was 282 in the United States (Lucie Thibault, Boston Scientific; personal communication). Each of these centers might be expected have at least one qualified ESNR who can perform the GDC embolization procedure, and some have as many as three qualified interventionists. However, at least some of these centers are staffed with minimally experienced, marginally qualified individuals.

An additional number of minimally qualified interventionists may not be trained in the treatment of aneurysms with GDCs, but they may be sufficiently trained in microcatheter techniques applicable to non-superselective thrombolytic acute ischemic therapy, intracranial vasospasm treatment with papaverine, and/or intracranial tumor embolization.

The Current Demand for Interventional Neuroradiologists

Multiple approaches have previously been used to assess manpower needs; however, none of these can be considered to be rigorous or exact. Methods of workforce assessment include the following: 1) comparing endovascular surgical neuroradiology with similar specialties such as diagnostic neuroradiology and neurosurgery; 2) estimating the number of comprehensive stroke centers that may exist in the future; 3) estimating the numbers of common types of cases that may be treated in the future and then using these numbers to predict manpower demands; and 4) comparing postings of ESNR positions with the number of individuals finishing training each year.

Demand Relative to Other Specialties

The number of ESNRs needed in the United States is unlikely to ever exceed the number of diagnostic neuroradiologists or peripheral interventional radiologists. As of December 2000, 2153 individuals had received a Certificate of Added Qualification in Neuroradiology Radiology from the American Board of Radiology, and 2155 individuals had received a Certificate of Added Qualification in Vascular and Interventional Radiology from the American Board of Radiology (*www.theabr.org*). These Certificates of Added Qualification have been offered only since 1994, and the number of qualified neuroradiologists and peripheral interventional radiologists who were practicing for years before these examinations were offered is unknown, as is the number who may never take the examination before retiring. Nonetheless, most practicing neuroradiologists and peripheral interventional radiologists have probably passed these examinations, and that 2000 ESNRs will ever be needed in the United States is highly unlikely. On the basis of the current practice patterns, one might estimate that the number of interventional neuroradiologists is likely to be 10–20% the number of diagnostic neuroradiologists (ie, 200–400 ESNRs in the United States).

The number of neurosurgeons is likely to always be higher than the number of ESNRs, because ESNRs primarily serve a subset of neurosurgical patients. In 2001, members in the active category totaled 2536 for the American Association of Neurologic Surgeons (AANS) and 2429 for the Congress of Neurological Surgeons (CNS). As of September 2001, the Joint Section in Cerebrovascular Surgery of the CNS and the AANS had 528 active members, including neurosurgeons who specialize in cerebrovascular disease. ESNRs treat patients with essentially the same diseases as those treated by members of the Joint Section in Cerebrovascular Surgery. Therefore, expecting that a similar number of ESNRs are needed in the United States seems reasonable.

Physician manpower is often measured in terms of covered lives, or the number of physicians per 100,000 patient lives. As of 1996, the workforce of neurosurgeons and neurologists in the United States consisted of 1.6 and 3.4 physicians, respectively, per 100,000 patient lives (13). In the future, endovascular surgical neuroradiology workforce may be measured in this way, but the benefit of using this type of statistic to estimate workforce requirements is not clear at present.

Demand Estimate Based on Acute Stroke Center Concept

The concept of the acute stroke center is rapidly developing (14). The practice of acute stroke care is dependent on access to technology and to skilled physicians and on a commitment to treat acute stroke as an emergency (15). Acute stroke centers should be able to care for patients with all subtypes of stroke, including hemorrhagic strokes that require treatment by a neurosurgeon. Acute stroke centers need to have emergency medicine physicians, neurologists, neurosurgeons, intensive care specialists, and ESNRs available 24 hours a day (14). Basic laboratory tests, CT, and angiography must also be available around the clock (14). Clinical trials of thrombolytic agents in the treatment of stroke have relied on CT for evaluations of the status of the brain, but MR imaging may ultimately prove to be more useful than CT (16–19). If so, emergency MR imaging will be another requirement for an acute stroke center. Currently, the number of hospitals have all of the requisites of an acute stroke centers is unknown.

Level I and level II trauma centers are similar to acute stroke centers in that they must have basic laboratory, CT, and angiography facilities; an emergency room; an intensive care unit; and access to a variety of specialists who are available around the clock (20). According to the American Hospital Association, 174 level I trauma centers exist. The number of acute stroke centers in the United States might be expected to someday be similar to the number of such regional trauma centers. Centers with endovascular surgical neuroradiology services would probably be the highest-level stroke centers. These might be called level I stroke centers, and, like level I trauma centers, approximately 200 regional centers might eventually exist. We do not mean to imply that hospitals other than these 200 centers would never treat patients with acute ischemic stroke, but cases requiring advanced stroke therapy might primarily be treated at the acute stroke centers.

Estimating Demand Relative to the Potential Number of Procedures

GDC embolization of aneurysms, carotid angioplasty and stent placement, and intra-arterial thrombolysis are the three neurovascular procedures that are frequently discussed as having potential for growth. Therefore, these procedures may have the largest potential impact on the demand for ESNRs.

Perhaps the most important procedure to analyze with regard to volume growth and change in manpower is GDC embolization of aneurysms, because GDC embolization is an accepted treatment approved by the U.S. Food and Drug Administration that has demonstrated substantial volume growth since its introduction. With an incidence of 9.0 cerebral aneurysms per 100,000 patient-years (21) and with a population of 285,400,000 as of 2000, as many as 27,000 aneurysms that could be treated each year in the United States. Boston Scientific Corporation estimates that the fraction of cerebral aneurysms treated with GDC embolization was 20% in 2001 (Anthony Werner, Boston Scientific; personal communication). Treating 20% of 27,000 aneurysms at 282 GDC centers yields a rate of 19 GDC cases per center per year. The fraction of all cerebral aneurysms that will be eventually treated by endovascular means remains unclear. If *all* 27,000 cerebral aneurysms in the United States were treated by 300 ESNRs, each operator would perform an average of 90 procedures per year. This is an extreme scenario, and not all cerebral aneurysms will be treated with endovascular therapy in the foreseeable future. Some unruptured aneurysms will not be treated because of a favorable natural history, some patients with ruptured aneurysms will not be treated because the effects are neurologically devastating, and some aneurysms will not be amenable to endovascular techniques in the foreseeable future.

Another potential major growth area is carotid artery angioplasty and stent placement. This topic, however, is a quagmire of speculation. That outcomes with carotid angioplasty and stent placement will be better than or equivalent to surgery in the upcoming clinical trials is not yet certain. If carotid angioplasty with stent placement favorably competes with carotid endarterectomy (CEA), ESNRs may not perform most of these procedures. We can consider an extreme case scenario and assume that the 125,000 CEAs performed in the United States each year could become 125,000 cases involving stent placement. If we assume that ESNRs have one third of the market share, with cardiologists having one third and vascular surgeons and peripheral vascular interventionalists having one third, the result would be about 40,000 cases per year.

Like carotid stent placement, the issue of intraarterial ischemic stroke therapy is controversial. If a drug is eventually approved by the U.S. Food and Drug Administration for use in intra-arterial thrombolysis, the demand for ESNRs will almost certainly increase, but the extent of the change is unclear. Intra-arterial thrombolysis remains a procedure under investigation. Predicting the future demand for intraarterial thrombolysis is difficult because the management of stroke in the future will certainly continue to evolve, and we do not know the fraction of patients with acute ischemic stroke for whom intra-arterial thrombolysis is best. Many ischemic strokes are caused by small-vessel occlusions that are not likely to benefit form intraarterial therapy.

Developments in intravenous therapy, such as a combination of intravenous thrombolytic therapy and neuroprotective agents (22), will possibly and perhaps likely advance to the point that invasive intra-arterial thrombolysis will become obsolete or have a limited application. Intravenous therapy for acute stroke could also improve if the GIIB/IIIA inhibitors prove to be as useful in treating thromboembolic disease in the cerebral circulation as they are in treating such disease in the coronary circulation. A combination of abciximab and tissue plasminogen activator given intravenously is more effective than either drug alone in the treatment of coronary thrombolysis (23, 24). Such a synergistic intravenous drug therapy may also be effective in the treatment of acute ischemic stroke. Alternatively, new mechanical means of thrombectomy (25, 26) and angioplasty (27–29) may increase the demand for acute endovascular intervention in cases of acute stroke. Because ischemic stroke is a heterogeneous disease with regard to its etiology and presentation, the future treatments are likely to be heterogeneous, with no "magic bullet" for all ischemic strokes.

The number of intra-arterial thrombolysis procedures currently performed can be estimated from numbers in published experiences from medical centers (18, 30–32) (Table). Data from multicenter trials of thrombolysis are also useful in estimating the number of potential cases (33–35, Table). Although that these reports reflect trials with exclusion criteria that restricted patient selection, these criteria were largely based on patient-safety considerations that would also apply to patients treated outside of a research protocol. On the basis of findings in these reports, intra-arterial thrombolysis is currently performed at a rate of 0–15 cases per year per major medical center (18, 30–35).

A delay in a patient's presentation to a hospital that can providing intra-arterial thrombolysis certainly disqualifying may patients from treatment with this technique. Currently, 25–59% of patients with stroke arrive at an emergency room within 3 hours of onset of

Demand for thrombolysis for acute ischemic stroke in the United States based on the published literature

Report*	Cases per Year per Medical Center†
Intra-arterial treatment, multicenter trials	
PROACT (34)	1 (0–10)
PROACT II (33)	1 (0–17)
EMS (35)	5 (2–10)
Intra-arterial treatment, single-center experiences	
Suarez et al, 1999 (18)	15
Jahan et al, 1999 (31)	5
Barnwell et al, 1994 (30)	7
Hill et al, 2002 (32)	4
Intravenous treatment, multicenter trials	
ATLANTIS (40)	1
NINDS (41)	20
Intravenous treatment, single-center experience	
Chiu et al, 1998 (42)	30
Zweifler et al, 1998 (43)	9

* Data in parentheses are reference numbers.

† Data in parentheses are ranges.

symptoms, and 35–66% arrive within 6 hours (36). On the basis of these numbers, programs aimed at developing the general public's awareness of stroke symptoms and at minimizing the delay in transporting the patient to an appropriate medical center might be expected to increase the number of patients who might be treatable with intra-arterial thrombolysis by a factor of 2–4. Such an aggressive educational program in Texas increased the number of patients treated with intravenous thrombolysis by a factor of 4 (37). Improving the access of patients to acute stroke centers and educating physicians and patients to respond to stroke as an emergency can increase the demand for intra-arterial thrombolysis; however, this process will be gradual and must be dealt with primarily at the local level.

The Cincinnati metropolitan area has been a leader in the development of regional acute stroke care, and examining the experience in this region may give us some insight into the the national demand for intra-arterial thrombolysis. The Greater Cincinnati/Northern Kentucky Stroke Team consists of 13 hospitals that refer patients to three centers for intra-arterial therapy. Approximately 1 million people live in this region. With no competing clinical trials of stroke therapy, this team treated patients with intra-arterial thrombolysis at a rate of 23 cases per year from October 1998 to March 2001. An additional 54 patients per year were treated with intravenous thrombolysis during the same period (unpublished data).

Coordinated regional stroke care has also been developed is in Southeastern Ontario, Canada, in which a population of 500,000 is served by the Regional Acute Stroke Protocol (38). In this region, 403 acute ischemic strokes occurred during 1 year. Of these, 42 were treated by means of intravenous thrombolysis. The population of the United States is 281 million, based on data from the 2000 Census. If we extrapolate the numbers of strokes treated with intra-arterial and intravenous thrombolysis in the Cincinnati region to estimate the number of stokes that can be treated with thrombolytic therapy in the United States, the number is 21,600 per year. Using the population in Southeastern Ontario as the basis for the extrapolation, we estimate that 23,600 cases of ischemic stroke can be treated with thrombolytic therapy. The effect of advanced imaging techniques such as diffusion-perfusion MR imaging, perfusion CT, xenon CT, and cerebral blood flow single-photon emission CT (SPECT), on patient selection for acute stroke therapy is unclear. These technologies show promise in the selection of patients who might benefit from therapy.

In terms of intra-arterial thrombolysis in the treatment of acute ischemic stroke, regardless of how much the demand eventually increases, the number of centers providing this treatment is likely to be limited because of the expensive infrastructure and level of expertise required. A minimum of two ESNRs would be required at each center to provide around-the-clock coverage. As stated before, the number of such acute stroke centers might be 200. If each of the 200 acute stroke centers treated 100 patients per year with intra-arterial thrombolysis, 20,000 individuals would be treated annually in the United States. This level of service would suffice in treating nearly all cases of ischemic stroke in the United States with intra-arterial rather than intravenous therapy, if we use the estimated number of cases based on extrapolations from the Cincinnati and Southern Ontario regions. A rate of 100 patients per year per medical center is at least six times the rate in medical centers that aggressively use intra-arterial thrombolysis (Table). That is, 6% of the 353,000 patients hospitalized for acute ischemic stroke in the United States each year (39) could be treated with intra-arterial thrombolysis; this rate is four times the percentage of patients with acute stroke who qualified for intra-arterial thrombolysis in the PROACT II study (33).

The future demand for intra-arterial reperfusion techniques remains unclear, but the number of patients who require intra-arterial thrombolysis is currently low, and the number of qualified ESNRs is grossly adequate. The current data do not justify an increase in the number of ESNRs to treat acute ischemic stroke. Each evolving acute stroke center will need to determine its own demand for intra-arterial thrombolysis and to have an adequate number of qualified ESNRs to meet this demand. Local shortages in the supply of qualified acute stroke centers are likely, and these must be dealt with on a regional basis.

All of the other neurovascular interventions are performed in relatively low numbers and are not likely to support a large number of ESNRs. These interventions include tumor embolizations, arteriovenous malformation embolizations, arteriovenous fistulas embolizations, intracranial angioplasty, and intra-arterial chemotherapy, for example.

Another procedure important for its potential growth is percutaneous vertebroplasty. However, vertebroplasty is not endovascular surgical neuroradiology, and it is arguably the easiest procedure that ESNRs perform. Vertebroplasty can be performed with little additional training beyond radiology residency, and it is already becoming widespread in community hospitals staffed by general radiologists. Therefore, an increased demand for vertebroplasty does not translate into an increased demand for fully trained ESNRs.

If we add the numbers for cerebral aneurysms, carotid stent placement, and endovascular treatments for ischemic stroke, we have 90,000 cases per year for interventional neuroradiologists in the United States as a theoretical maximum. Thoracic surgeons can perform 300 open-heart operations per year. Many, perhaps nearly all, ESNRs perform fewer than 100 interventional cases per year, and they supplement their workload by reading diagnostic radiology studies. Many surgeons and interventional cardiologists perform 300 cases each year, but ESNRs in current practice may or may not want the lifestyle that results from this workload. If an ESNR performed procedures on only 2 days each week and if he or she performed three procedures on each of those 2 days, for a total of six procedures per week, the total would be 300 cases per year. Physician-extenders such as physician assistants, nurse practitioners, and fellows could be used to maximize efficiency to allow for such a large case volume. If ESNRs were to perform a number of cases similar to that of surgeons, 300 ESNRs would be required to perform the theoretical maximum of 95,000 cases per year. The number of cases will likely remain well below the theoretical maximum level of 90,000 cases per year for the foreseeable future, because the carotid stent and ischemic stroke cases are based on very speculative data.

Estimating Demand from Posted Positions

Another way to estimate manpower needs is to compare the number of positions posted with the number of physicians finishing training each year (11, 12). Such postings are difficult to quantify because they are conveyed in variety of ways, for example, in print journals, on the Internet, and by word of mouth. In the past, many if not most ESNR positions were never formally advertised other than by word of mouth. Another difficulty is that some institutions want to hire an ESNR to perform only a few cases each year between barium enema studies. Is that really an ESNR position?

Therefore, quantification of positions posted over time is not a useful method for measuring the demand for ESNRs. The fellows currently finishing training are in demand; therefore, the job market seems good at the moment, and manpower should increase over the short term. However, we cannot easily quantify this trend. Unfortunately, training programs are only now becoming accredited. Consequently, the number of people trained each year in formal fellowships is not known.

Education

The supply and demand for ESNRs has a direct impact on the educational process. Endovascular surgical neuroradiology is a specialty newly recognized by the ACGME, and the process of accrediting the training programs has begun. At present, we do not know how many training programs will eventually exist or how many trainees will graduate each year. Ideally, the number of graduating trainees each year should equal the number of practitioners leaving the profession. To illustrate, if we estimate that the length of the average career length is about 30 years, then about 1/30th, or 3%, of the total number of practitioners would need to be replaced each year. A 20-year average career length yields a need to replace 5% of the practitioners each year. If we were to assume a total of 300 practicing interventional neuroradiologists, the graduation of 10–15 newly trained interventional neuroradiologists from accredited programs each year would likely maintain a reasonable equilibrium. Note that the growth rate of ASITN membership since 1998 has been 10–15% per year. If the supply of ESNRs grows at that rate, a surplus of ESNRs could be generated within just a few years if the demand does not increase at a similar rate.

Conclusions

We have recently witnessed a rapid growth phase in endovascular surgical neuroradiology due to the rapid growth in the number of centers performing GDC procedures. Also, the demand for ESNRs has probably increased because of a perceived increasing demand for intra-arterial thrombolysis and carotid angioplasty with stent placement. Although these factors have recently created a demand for ESNRs that exceeds the supply, this situation could soon change. The growth in the number of centers performing GDC procedures has reached a plateau, and the theoretical boom in cases of thrombolysis cases and carotid stent placement may never occur. Thus, the demand for ESNRs in may be stabilized in the short term.

If we assume that endovascular aneurysm therapy, endovascular acute ischemic stroke therapy, and carotid stent placement reach the maximum potential for growth previously discussed, as many as 600 interventional neuroradiologists may be needed. If this growth does not occur, far fewer ESNRs will be needed. In such a situation, cerebral aneurysm therapy will likely remain the most common procedure, and 300 ESNRs could treat all 27,000 aneurysms in the United States each year if they each performed 90 procedures per year.

With 208 active members in the ASITN and with 282 centers performing GDC procedures, we may be nearing an adequate total supply of ESNRs. The number of available jobs each year recently has exceeded the number of available applicants, but with membership in the ASITN growing at a rate of 10–15% annually, the availability of open positions should soon rapidly decline. We can avoid doing a disservice to our patients and the field of endovascular surgical neuroradiology by carefully monitoring the supply of and demand for ESNRs and by trying to prevent either a surplus or a shortage.

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