MAYO CLINIC

Innovations in Neurology & Neurosurgery

The departments of neurology and neurologic surgery at Mayo Clinic are a highly integrated, collaborative team of adult and pediatric neurologists and neurosurgeons who specialize in the research, diagnosis, and treatment of more than 500 conditions and diseases affecting the nervous system.

As a former Chair of the Department of Neurology at Mayo Clinic in Rochester, Minnesota, I was honored to serve with colleagues who exemplify the highest standards of collaborative, evidence-based patient care. This publication offers a window into what distinguishes the practice of neurology and neurosurgery at Mayo. It highlights the commitment of its members to interdisciplinary teamwork and thorough, individualized evaluation, state-of-the-art interventions, and to ground-breaking research and its efficient integration into clinical practice. Unnamed on its pages are dedicated clinicians, clinical researchers, and basic scientists whose work continues a 100-year legacy of advances in patient care and the field of neuroscience.

I'm often asked what sets Mayo Clinic apart. The answer is complex, involving a culture in which the patient always comes first and clinical practice, research, and education are tightly linked and focused on improving patients' lives. When asked why she came to Mayo, a recently hired, distinguished neurosurgeon answered, "because Mayo allows me to focus on practicing medicine. My patients come first, and I am supported in every way to make that possible."

For myself, one experience told me all I needed to know about Mayo's mission and its staff. As a young physician, before I came to Mayo, I was asked to host a dinner for an internationally recognized Mayo neurologist coming to my university to accept a prestigious award. He missed the dinner and later apologized, saying he'd missed his flight because he was "with a patient." I knew then and there that I wanted to devote myself and my life's work to such an institution.

I am not alone. What you will find in these pages are examples of Mayo's pioneering advances in the field of neuroscience and the practice of neurology and neurosurgery—innovations born out of a commitment held by each of its 160 neurologists and 32 neurosurgeons to provide patients with the best possible care.

John H. Noseworthy, MD
President and CEO, Mayo Clinic

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Autonomic Neurology

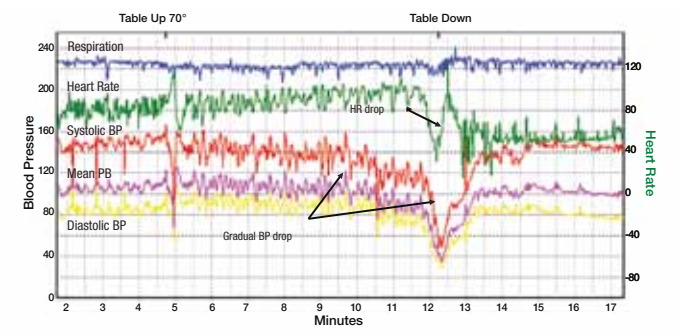
Syncope, flushing, bladder and bowel dysfunction, dizziness, endocrine dysfunction, Parkinson's disease–like symptoms, gastrointestinal tract distress, painful feet, orthostatic intolerance, extreme fatigue, tachycardia, cognitive dysfunction, anhidrosis, and hyperhidrosis. These are just some of the conditions for which patients are seen at Mayo Clinic for autonomic testing and management. As the symptoms suggest, referrals come from a wide range of disciplines—neurology, cardiology, endocrinology, dermatology, gastroenterology, internal medicine, and urology.

Mayo Clinic developed the norms and national standards for quantifying autonomic function and helped define the *Current Procedural Terminology* (CPT) codes for reimbursement. The tests used around the world to diagnose autonomic dysfunction and monitor response to treatment were also developed at Mayo—among them, the *Autonomic Reflex Screen*, the nation's standard for evaluating sudomotor, cardiovagal, and adrenergic functions; the *Autonomic Symptom Profile*, which evaluates 10 symptom domains to create an autonomic symptom score; the *Quantitative Sudomotor Axon Reflex Test*; and the *Thermoregulatory Sweat Test*.

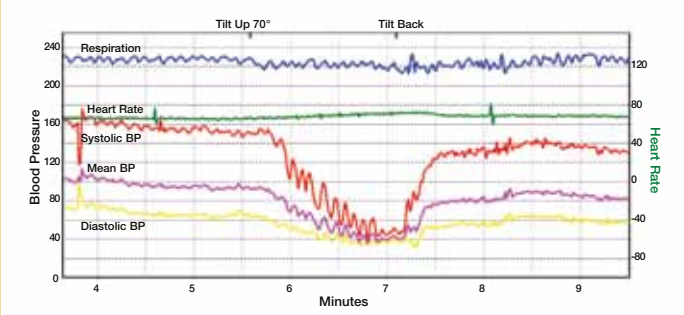
Conducting more than 3,000 autonomic tests per year, the autonomic testing laboratory at Mayo Clinic in Rochester, Minnesota, the first of its kind, was established 30 years ago. Across Mayo's three campuses, neurologists with specialized expertise in the autonomic nervous system routinely determine the presence, severity, distribution, and localization of autonomic dysfunction and differentiate the following:

- Primary from secondary autonomic disorders
- Autonomic neuropathy from conditions that mimic it
- Psychogenic from organic conditions
- Progressive neurologic diseases from one another
- Preganglionic from postganglionic lesions

Neurocardiogenic syncope in 7th minute of head-up tilt (HUT) in 17-year-old female with history of frequent syncopal spells



HUT in 55-year-old male with diabetic neuropathy showing profound orthostatic hypertension with systolic BP drop from 170 to 50 mm Hg in 1.25 minutes



Conducting more than 3,000 autonomic tests per year, the autonomic laboratory...was established 30 years ago.

The laboratory is equipped to use such noninvasive measures as:

- Beat-to-beat blood pressure, to evaluate both vagal and adrenergic baroreflex sensitivity
- Sudorometric and laser Doppler methods of measuring sudomotor and vasomotor activity
- Direct measures of muscle sympathetic activity using microneurography of peripheral nerves

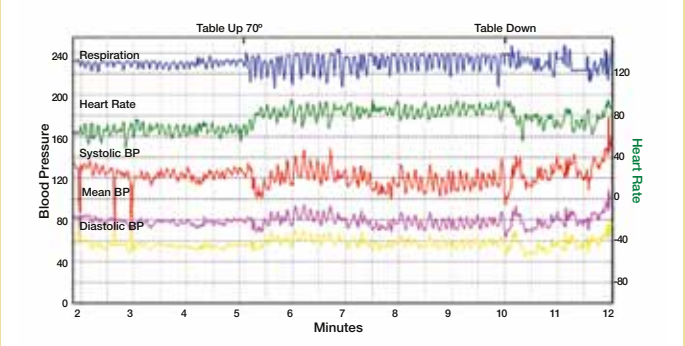
No other institution can match Mayo's autonomic clinical and research patient volumes. Its world-renowned research in this area has contributed to the understanding of the molecular and neurochemical mechanisms of a wide variety of autonomic disorders. For example, Mayo investigators have shown that multiple system atrophy (MSA) can be reliably differentiated from Parkinson's disease with sensitivity and specificity, and Mayo is now leading a multicenter therapeutic drug trial for MSA.

Mayo Clinic's Autonomic Research Programs Are Focused on Uncovering and Identifying the Following:

- The underlying mechanisms of peripheral nerve pathogenesis in diabetic and ischemic neuropathies and mechanisms of neuroprotection
- The neurochemical and structural brainstem lesions that underlie major dysautonomic syndromes, such as multiple system atrophy, Parkinson's disease, and Lewy body dementia
- The interactions between adrenergic dysfunction and pain
- The natural history and clinical outcome predictors of pure autonomic failure, autoimmune autonomic neuropathies, postural tachycardia syndrome, and multiple system atrophy

Led by practicing neurologists and driven by clinical experience and patient needs, Mayo Clinic's autonomic research, like its clinical practice, continues to improve the care of patients with autonomic dysfunction throughout the world.

Example of normal 10-minute HUT study



Innovation in Hyperhidrosis: Evaluation and Management

Clinically significant palmar-plantar hyperhidrosis (HH) affects approximately 1% of the US population and accounts for 25% of patients with HH. The HH practice at Mayo Clinic in Rochester, Minnesota, is unlike the practice at most academic medical centers, where thoracic and vascular surgeons are primarily involved in the management of surgical HH candidates. At Mayo Clinic, the vast majority of surgical HH candidates are seen collaboratively by neurology and neurosurgery. The clinical evaluation is led by neurologists with special expertise in HH and the surgery by neurosurgeons with decades of experience in HH.

The tests to measure the nature, distribution, and severity of HH, including the thermoregulatory sweat test and the ventilated capsule calibrated humidity sensor, were designed at Mayo Clinic. Administered by autonomic nervous system specialists, these objective measurements help stratify treatment options for patients, which may include topical agents, iontophoresis, or botulinum toxin. Patients with a diagnosis of axillary HH and HH that primarily affects the head and feet are typically referred to the Department of Dermatology.

Mayo's Successful HH Practice Can Be Attributed to:

- Detailed and objective diagnostic measurement of HH severity and distribution
- Expertise in differential diagnosis and patient stratification
- Integrated, collaborative medical and surgical management
- Objective criteria for and collaborative selection of surgical candidates
- An innovative, less invasive surgical procedure with low rates of postsurgical complication

For more than 75 years, surgery for severe palmar-plantar HH at Mayo Clinic has been conducted by neurosurgeons, who, along with their neurologic colleagues, add a unique "nervous system" approach to this disorder. The abnormally functioning sympathetic chain is located in the chest along the spine but is part of the nervous system.

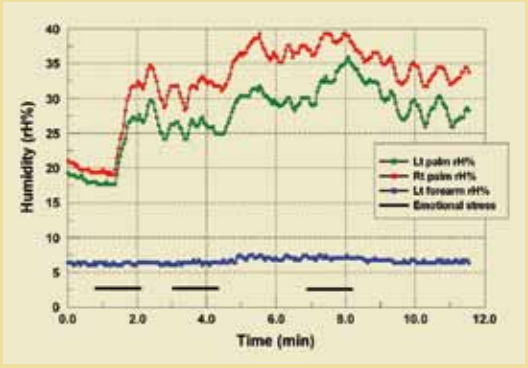
Surgery involves interrupting the sympathetic chain output. A common complication is severe compensatory sweating in other parts of the body. However, a neurosurgical technique pioneered at Mayo Clinic 10 years ago has significantly reduced this complication.

Called *endoscopic transthoracic limited sympathotomy*, the procedure is less invasive and less disruptive than a traditional sympathectomy. Rather than removing most or all of the upper sympathetic chain leading to the brachial plexus, it disconnects and divides all branches only at the superior end of the chain, at a level between the T1 and T2 ganglia. With use of a small-diameter uniportal approach, the procedure neither removes nor injures the ganglia of the chain or the axons from spinal cord neurons that innervate the ganglia. Thus, synaptic reorganization is minimized in the sympathetic chain or spinal cord—the probable main source of compensatory sweating.

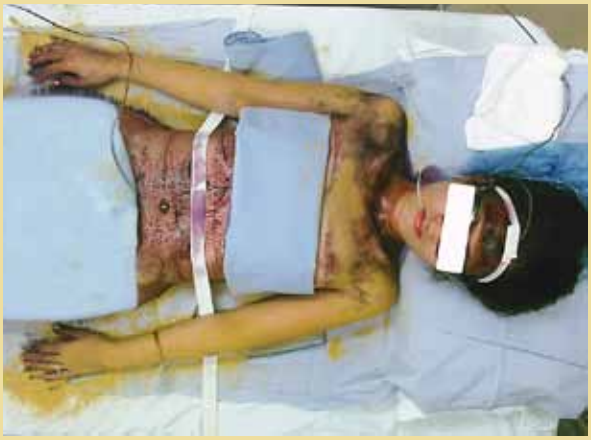
At Mayo Clinic, selected surgical patients are sent to the smooth muscle laboratory for measurement of parasympathetic and sympathetic cardiac function before and after surgery. The studies have produced extremely useful information, reassuring young athletes, for example, that sympathotomy does not alter their performance experience. Lasting approximately 40 minutes, sympathotomy is considerably shorter than sympathectomy and carries a high rate of success with minimal complications, as demonstrated in a 2011 ten-year retrospective study of 155 patients who underwent sympathotomy at Mayo Clinic.

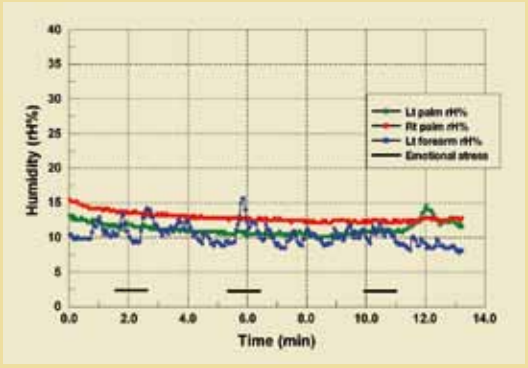
The tests to measure the nature, distribution, and severity of HH...were designed at Mayo Clinic.

Presurgery



Postsurgery





Sweat test and quantitative sweat measurements on a patient before and after surgery.

Behavioral Neurology

The majority of patients with cognitive impairment and behavioral changes seen in the Division of Behavioral Neurology at Mayo Clinic have symptoms of an evolving neurodegenerative disorder, the most common of which are Alzheimer's disease (AD), Lewy body disease (LBD), and the frontotemporal lobar degeneration (FTLD) syndromes. The practice also includes patients with treatable, nondegenerative conditions. Patients are monitored by neurologists with experience and expertise in the early detection of memory- and nonmemory-based dementias and their differential diagnosis, longitudinal characterization, and long-term management.

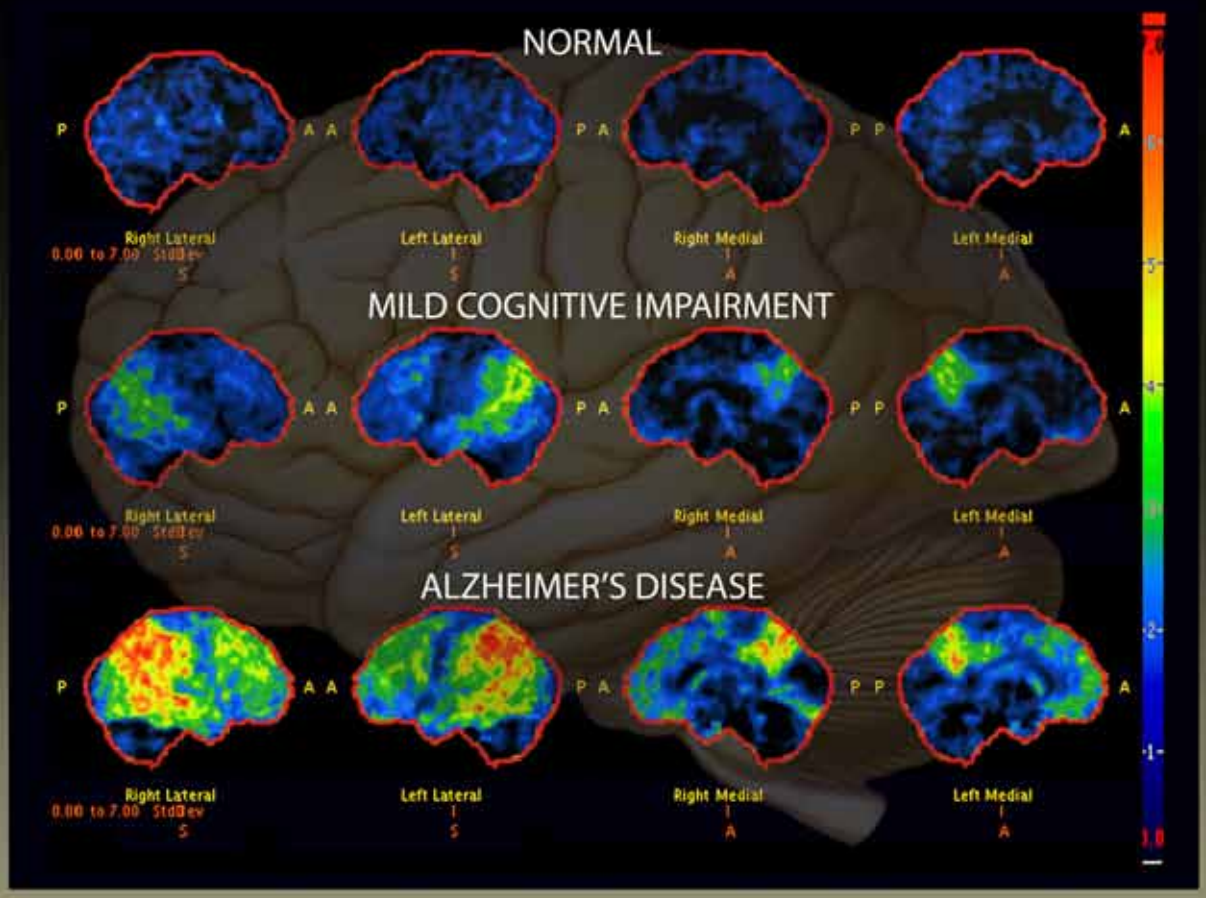
Identification of the biomarkers predicting the earliest stages of disease is critical to the development of innovative diagnostic, prognostic, and therapeutic strategies. Mayo's research in this area is distinguished by the depth and breadth of in-house resources that the institution has committed to the effort—from population studies to innovations in imaging and from genetics and molecular science to the uncovering of the behavioral, biologic, and environmental predictors of dementia. With tight links between clinical practice and research, its effort involves collaboration between behavioral neurology, neuropsychology, psychiatry, speech pathology, sleep medicine, neuroradiology, nuclear medicine, genetics, molecular biology, laboratory medicine, and neuropathology across Mayo's three campuses in Arizona, Florida, and Minnesota.

The Mayo Clinic Imaging Research Center leads the field in identifying and refining imaging biomarkers, including the following:

- MR volumetry to characterize patterns and degrees of atrophy across dementias and to measure longitudinal change over time, including the recently developed STructural Abnormality iNDex (STAND) scores based on the individual patient's MRI scans
- MR spectroscopy to characterize neuronal and glial changes that appear to differentiate key proteinopathies
- Dopamine transporter imaging (DaTscan) to identify early LBD

- Fluorodeoxyglucose PET (FDG-PET) scans and arterial spin labeling to reveal patterns of metabolic change in presymptomatic AD and FTLD and to differentiate AD from LBD and FTLD
- Resting-state functional connectivity to measure functional connections among brain regions, revealing differing patterns of functional loss relative to severity and type of dementia
- Amyloid PET imaging for early detection of AD and assessment of the efficacy of antiamyloid therapies

Mayo Clinic molecular scientists have been instrumental in identifying the proteomic and genetic underpinnings of AD and FTLD spectrum disorders. They refined the characterization of the amyloid proteins that signal risk for AD and discovered the genes, tau *(MAPT)* and progranulin *(PGRN)*, the mutations of which underlie



The top four images show metabolic levels in the brain in a person with no memory loss in normal ranges (z scores in the blue range). The middle four images in a person with mild cognitive impairment show that areas in the back of the brain (parietal, temporal, and posterior cingulate regions) have abnormally low levels of metabolism (green and yellow z scores). The bottom 4 images of an Alzheimer's disease patient show greater amounts of abnormal brain metabolism (z scores moving into the red ranges), still prominently in the back of the brain but also spreading to many areas of the brain.

genetically mediated FTLD spectrum disorders. Very recently, Mayo also discovered the most common genetic alteration that causes familial FTLD or amyotrophic lateral sclerosis, or both: a hexanucleotide repeat expansion in an intron on chromosome 9 *(C9ORF72).*

Non-AD Dementias

Work at Mayo Clinic has helped to characterize nonmemory-based dementias and to distinguish them from one another and from AD, thereby improving management and enhancing understanding of underlying mechanisms across the dementias. Mayo researchers are generating correlations among clinical signs, imaging patterns, and molecular biomarkers of protein-based categories of FTLD spectrum disorders. Mayo is one of the few institutions to study sleep disorders in LBD, identifying rapid eye movement sleep behavior disorder and hypersomnolence as early features of the disease.

Alzheimer's Disease

Mayo's landmark prospective population-based studies through the National Institutes of Health (NIH)–funded Mayo Clinic Alzheimer's Disease Research Center and the Mayo Clinic Study of Aging recently reported the prevalence of mild cognitive impairment (MCI) at 15%, a critical finding for early detection. With a study cohort maintained at over 2,000 patients, the behavioral and biologic aspects of MCI, including environmental risk factors, are being defined. The NIH-funded Arizona Alzheimer's Disease Center, of which Mayo Clinic leads the clinical core, is conducting an ongoing longitudinal study of cognitive decline beginning early in the life span of *APOE* gene carriers. Four Mayo Clinic researchers have been involved in the National Institute on Aging–Alzheimer's Association work groups in developing the newly published research criteria for MCI and AD and the current model of how biomarkers inform the identification of AD pathogenesis. Based on a dynamic model developed at Mayo Clinic and involving five distinct biomarkers, the notion has emerged of AD as a fluid and biologically evolving disease for which different biomarkers are prominent at different stages.

Cerebrovascular Disease

Across its three sites, Mayo Clinic's cerebrovascular neurologists, neurosurgeons, endovascular surgeons, physiatrists, neuroradiologists, interventional neuroradiologists, and other specialists offer comprehensive, interdisciplinary team care to patients with cerebrovascular disease. Patients have access to state-of-the-art facilities and management strategies in the inpatient, outpatient, and intensive care neurology and rehabilitation practices. For many cerebrovascular conditions, such as carotid occlusive disease, arteriovenous malformations, or intracranial aneurysms, there are several treatment options across subspecialites. Mayo's team approach ensures that the procedure selected is driven only by what would provide the best outcome for each individual patient.

Mayo's research and clinical expertise in cerebrovascular disease covers the evaluation and management of virtually all cerebrovascular entities, including the following:

- Cerebral infarction of common and uncommon cause
- Intracerebral hemorrhage
- Subarachnoid hemorrhage
- Transient ischemic attack
- Intracranial aneurysm
- Arteriovenous malformation
- Cavernous malformation
- Central nervous system vasculitis

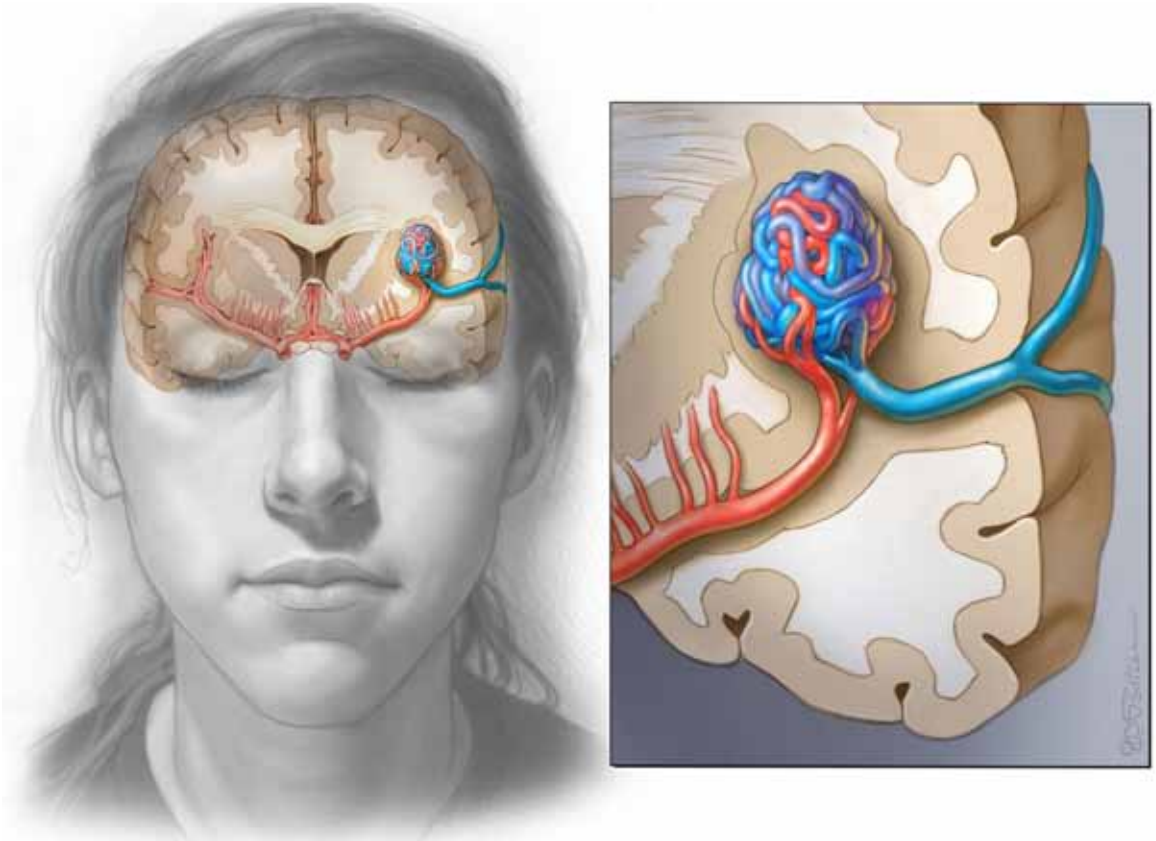
The practice is distinguished by the depth and breadth of research in cerebral infarction and other cerebrovascular disorders. The types of studies conducted range from population-based epidemiologic research to internationally recognized programs in genetics and from novel arterial, venous, and central nervous system imaging strategies to basic science research. The entire spectrum of care is addressed in Mayo Clinic's programs, including innovative primary prevention and secondary prevention treatment models and prehospital stroke management, as well as intensive care unit (ICU) and non-ICU inpatient neurologic care and rehabilitation services and widely recognized telestroke initiatives.

Mayo's extensive cerebrovascular research programs are making a difference in patient care and contributing to optimal outcomes. Examples include:

- **The International Study of Unruptured Intracranial Aneurysms** (ISUIA), a Mayo-led, 20-year, National Institutes of Health (NIH)–funded study to assess outcomes of surgical clipping, endovascular coiling, or observation in 5,500 patients. Data from this study continue to guide practice through the natural history of untreated, unruptured aneurysms, predictors of rupture, comparative effectiveness of interventional therapies, and new data regarding complex morphologic analysis of intracranial aneurysms.

- **The Carotid Revascularization Endarterectomy vs Stenting Trial** (CREST), another NIH-funded, Mayo-led study, was the largest revascularization trial of its kind, comparing outcomes of 2,502 patients. It found that both stenting and endarterectomy were associated with similar rates of the primary outcome, but it also identified some surprising age-related findings. For example, patients older than 70 years had somewhat better outcomes with endarterectomy.

- **The Stroke Genetics Network** is an NIH-funded, consortium-driven international initiative to identify inherited risk factors for ischemic stroke. Mayo physicians are taking a leadership role in the phenotyping activities of the study, which are uncovering distinctive genetic risk factors according to stroke type (eg, cardioembolic, atherosclerotic/large artery disease, lacunar).



An intracranial arteriovenous malformation (AVM) is an abnormal tangle of blood vessels within the brain. Common symptoms include headaches and seizures. Other symptoms may include vision changes, the sensation of a pulsing sound in the head, and progressive weakness and numbness. Patients with an intracranial AVM are seen in the multidisciplinary Cerebrovascular Clinic by vascular neurologists, neurosurgeons, and other specialists.

Mayo's advances in patient care include innovative diagnostic and treatment techniques, such as MR angiography, with sequences and algorithms developed at Mayo to provide clinical imaging solutions. The recently developed flow diversion Pipeline Embolization Device is available for appropriately selected cases of complex intracranial aneurysm.

Five years ago, Mayo Clinic in Arizona began one of the first telestroke programs in the country. Telemedicine is now provided by all three Mayo campuses to an extensive network of remote health care facilities. Recently, the governments of Bhutan and India invited Mayo's team to explore telemedicine in those countries—an international initiative in line with Mayo's goal for the 21st century of providing medical expertise wherever there is a need.

The rapid transition of telemedicine from inception to robotic realization is one example of Mayo's strength...

Child and Adolescent Neurology and Neurosurgery

The Mayo Clinic Children's Center in Rochester, Minnesota, encompasses pediatric care across medical subspecialities in the outpatient, acute hospital, and rehabilitation settings. Pediatric neurology and neurosurgery is a large and growing practice within the Center. As in comparable medical centers, the division has specialized clinics for children with brain tumor, cerebral palsy, craniofacial, epilepsy, neuro-oncology, spina bifida, and other conditions in which pediatric patients receive a multidisciplinary team evaluation, concentrated over a few days.

What sets Mayo's practice apart is that every child receives an interdisciplinary evaluation, regardless of whether or not the symptoms warrant specialized clinic designation. Every surgical candidate is seen by both neurology and neurosurgery. Most pediatric cases referred to Mayo are complex, and the institution has the capacity to quickly marshal the specialists needed to create a highly individualized, collaborative evaluation—for common and uncommon conditions.

Mayo's outpatient pediatric practice in the **T. Denny Sanford Pediatric Center** serves more than 45,000 children a year. Every aspect of its design, from the nature-themed environment to the furniture and three-level drinking fountains is intended for children of all ages. Most important, it is staffed by experts from every pediatric subspecialty who, working together in a central location, can efficiently coordinate full-service care.

Mayo Eugenio Litta Children's Hospital is staffed by more than 150 pediatric physicians who see patients in the general pediatric unit and the pediatric and neonatal intensive care units. The hospital has a dedicated 24-hour pediatric inpatient video-EEG monitoring and behavioral observation units. Other specialized neurologic tests for children include child-friendly EMG studies using "awake" anesthesia conducted by pediatric anesthesiologists and neurologists who ensure that the tests are completed in the shortest time possible with minimal discomfort.

Mayo's pediatric hospital is distinct from, but located within Mayo's Saint Marys Hospital, allowing patients access to all the technological advances Mayo has to offer. Unlike free-standing children's hospitals in which pediatric physicians are physically separated from their colleagues in adult practice, Mayo's pediatric neurologists have access to the entire range of specialized expertise among Mayo's staff, including its 90 neurologists and 15 neurosurgeons.

That access translates into acute care and outpatient collaboration. For example, referrals for children with immune-mediated encephalopathy have been rising. Mayo is a world leader in adult autoimmune neurology with a reputation for uncovering novel syndromes and developing new biomarkers. Mayo's Neuroimmunology Laboratory has a track record of turning molecular discoveries into clinically relevant laboratory tests and therapies. Pediatric neurologists can call on this expertise to generate tailored, highly individualized laboratory tests and therapies for children with uncommon immune-mediated syndromes.

Neurologists and neurosurgeons in the adult and pediatric practice benefit from shared patient conferences, collaborative research, and educational opportunities that impact patient care—be it in deep brain stimulation, seizure management, novel subtypes of myofibrillar myopathy, inborn errors of metabolism, concussion, neuro-oncology, genetic, imaging and biomarker research, new surgical techniques, new diagnostic technologies, lab tests, and medical therapies. This level of cross-fertilization enriches the practice and improves patient outcomes across the age spectrum.

Mayo's pediatric neurologists and neurosurgeons work closely with patients and families, taking the time to learn from them, to educate and answer questions, and, with other members of the team, to provide comprehensive management strategies encompassing the latest behavioral, medical, and surgical interventions.

Critical Care Neurology

Fifty-four years ago, Mayo Clinic built one of the nation's first dedicated, combined neurosurgical/neurologic intensive care units (NICUs). In 1995, Mayo opened a modern, sophisticated neurosurgical/neurologic unit with a 20-bed capacity on its Rochester, Minnesota, campus. Neurologists who specialize in neurocritical care have a full-time presence in the NICU and provide its patients with 24-hour continuous coverage. Mayo's neurointensivists also provide consultative services in all of the medical, surgical, and transplant intensive care units (ICUs).

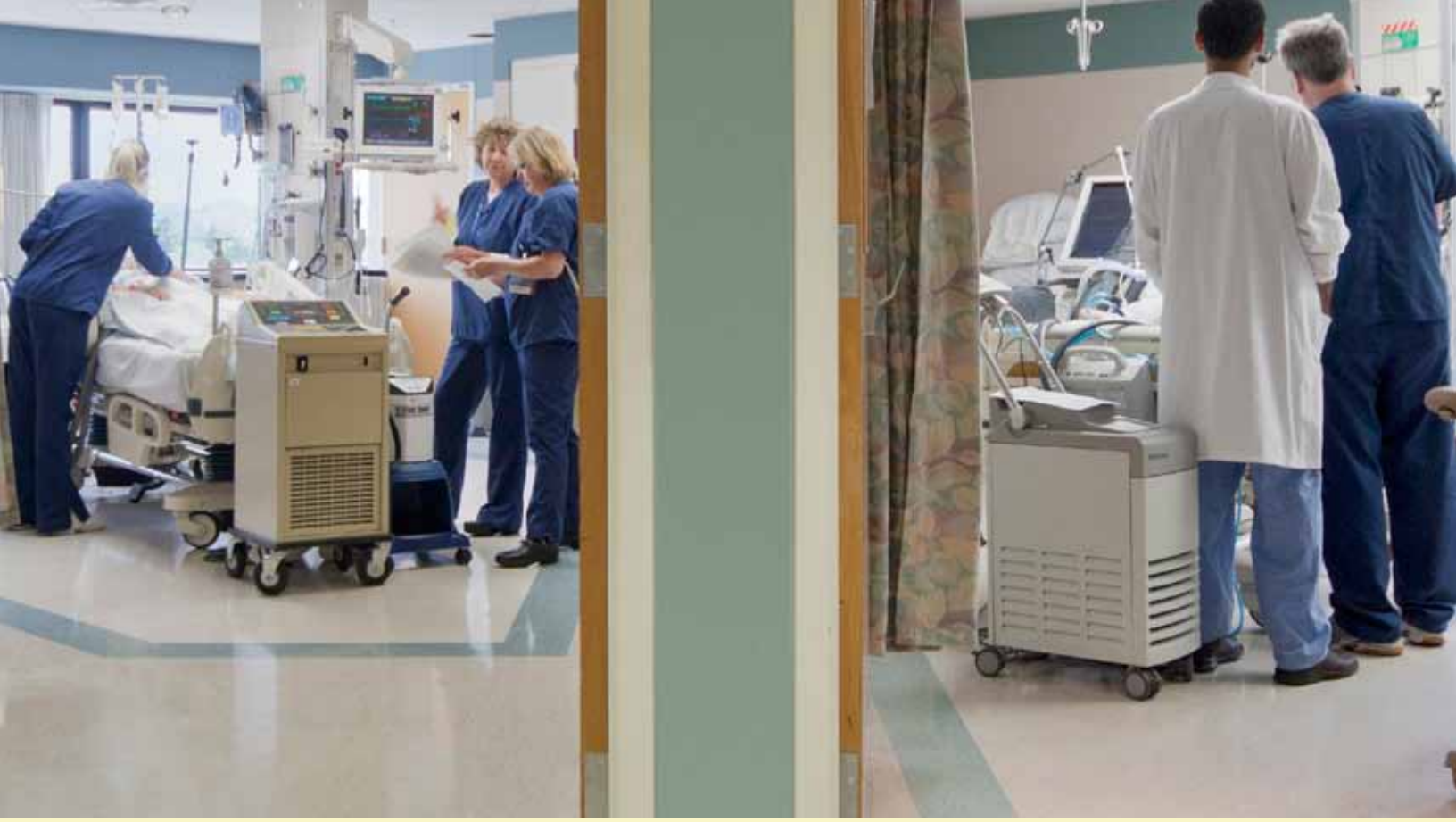
Mayo's critical care neurology research is stimulated by vital issues arising from the clinical practice...research findings are readily implemented...

Modeled on the practice in Rochester, the neurointensive care unit at Mayo Clinic in Florida opened in 2007 and is incorporated in the surgical ICU of the new hospital. At Mayo Clinic in Arizona, hospital neurologists and neurosurgeons provide comprehensive management for all life-threatening nervous system conditions. Across its three sites, Mayo's neurologists, neurosurgeons, endovascular surgeons, and anesthesiologists work in close collaboration.

The Division of Critical Care Neurology at Mayo Clinic operates in an evidence-based, teaching environment. The division offers a certified fellowship, and members of the division have published more than 750 peer-reviewed articles on essentially every topic pertinent to the specialty. Several leading textbooks have been authored by Mayo neurointensivists.

Mayo's critical care neurology research is stimulated by vital issues arising from clinical practice, and as a result, research findings are readily implemented into patient care. In the past 10 years, the Division of Critical Care Neurology has:

- Developed the national criteria for defining brain death
- Developed predictors of acute neuromuscular respiratory failure in Guillain-Barré syndrome
- Developed extubation criteria for acutely ill neurologic patients
- Characterized natriuretic factors in aneurysmal subarachnoid hemorrhage
- Characterized neurologic complications after organ transplant
- Characterized CT scan abnormalities predictive of ischemia-related cerebral swelling



The Mayo Clinic neurosurgical/neurologic ICU provides multidisciplinary care for patients with ruptured intracranial aneurysms and all other neurological and neurosurgical conditions that require ICU care.

- Developed noninvasive ventilation for myasthenic crisis, replacing invasive treatment as the preferred ventilation method for these patients
- Developed a standardized protocol for interpreting CT angiogram and CT perfusion scans to optimize patient selection for endovascular therapy in acute ischemic stroke

In 2005, critical care neurologists at Mayo Clinic developed a new clinical tool that allows improved precision in the initial evaluation and follow-up of comatose patients. Called the *FOUR* score, it has been extensively validated and is being adopted as the preferred coma evaluation instrument by major medical centers across the world.

Current Areas of Investigation Include:

- Assessment, through a randomized trial, of the impact of aggressive cerebrospinal fluid diversion via ventriculostomy or lumbar drain on the incidence of delayed cerebral ischemia
- Evaluation of outcomes from therapeutic hypothermia after cardiac arrest. Using a Mayo-developed standardized protocol for this therapy, ongoing studies are assessing both cognitive outcomes after the therapy and the value of continuous EEG monitoring during and after it
- Determination of the best practices for managing spontaneous intracerebral hemorrhage. Mayo Clinic is the only US medical center participating in the international, multicenter Second Intensive Blood Pressure Reduction in Acute Cerebral Haemorrhage Trial (INTERACT2) to evaluate the safety and effectiveness of aggressive early blood pressure reduction on functional outcomes of patients with intracerebral hemorrhage
- Evaluation of the safety and efficacy of hemostatic agents for rapid reversal of the effects of oral anticoagulants in patients who experience intracerebral hemorrhage while taking warfarin. Additional research is aimed at defining the protocols for bleeding related to use of novel anticoagulants, such as dabigatran
- Evaluation of outcomes of therapy for prolonged refractory status epilepticus, including the risks and benefits of hypothermia, drug therapies, and inhalation anesthetics

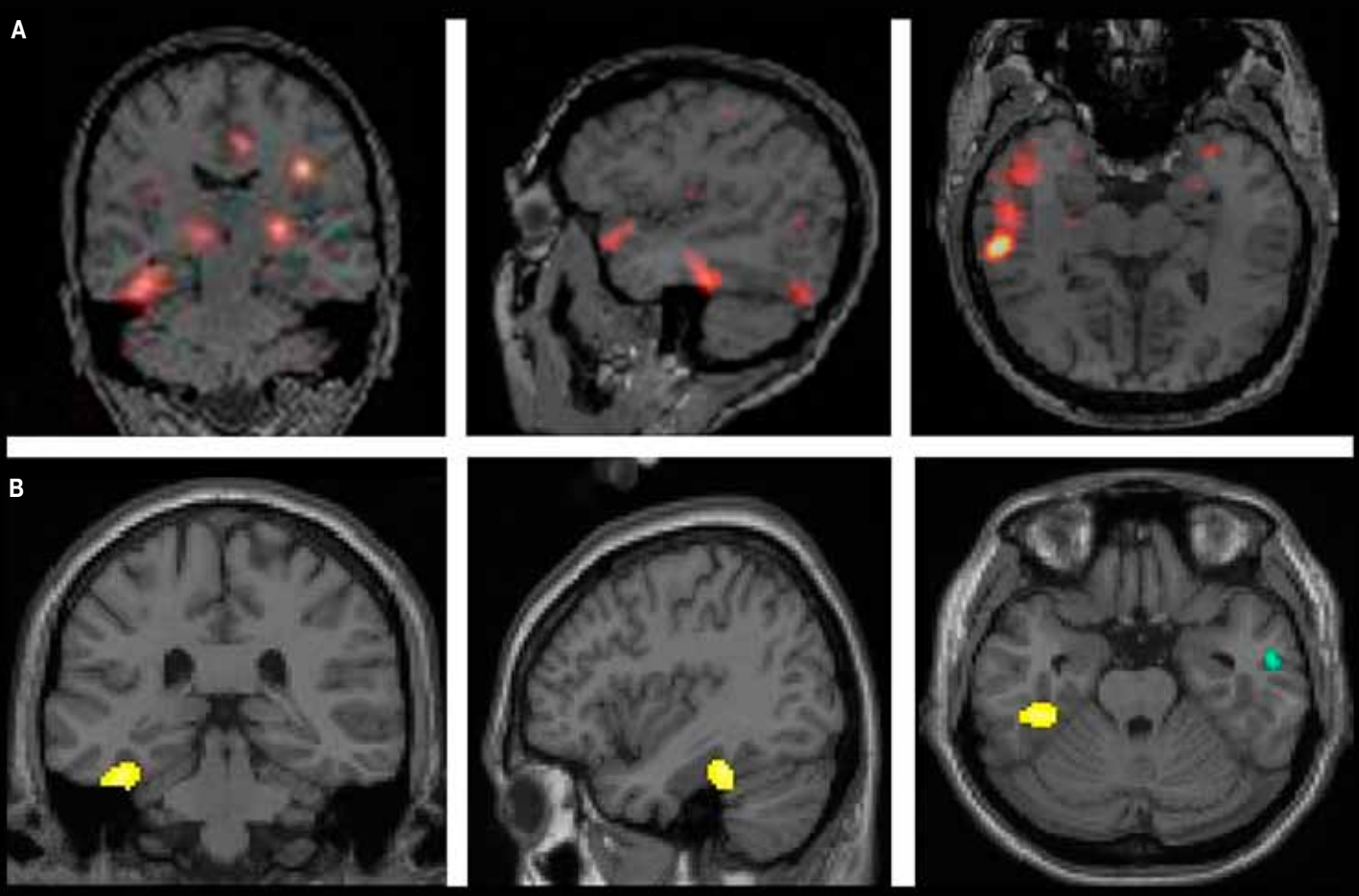
Epilepsy

Last year, more than 1,450 adult and pediatric patients were seen in the Epilepsy Monitoring Unit (EMU) at Mayo Clinic. For cases of unconfirmed seizure diagnosis or intractable recurrent seizures, inpatient video-EEG epilepsy monitoring is the best diagnostic tool available. Not only does the inpatient setting allow for safe monitoring in a controlled environment, continuous monitoring provides an opportunity for definitive diagnoses and treatment changes not available from routine, shorter-duration EEG studies.

Inpatient monitoring is only one of the resources Mayo brings to the diagnosis and treatment of epilepsy. For example, Mayo uses state-of-the art imaging protocols, such as subtraction ictal SPECT coregistered to MRI (SISCOM) and the even more advanced statistical ictal SPECT coregistered to MRI (STATISCOM). These two methods of coregistering SPECT with MRI were pioneered at Mayo Clinic for improved identification of seizure type and localization of seizure focus in patients with nonlesional MRI findings. Surgical options for intractable seizures include the latest techniques in resection and disconnection for tumors, vascular malformations, and areas of cortical dysplasia, with physiologic monitoring and image guidance for precise target location. Additional techniques include hemispherotomy (a less radical procedure than hemispherectomy) and radiosurgery or microsurgical resection of seizure-causing arteriovenous malformations, as well as neuromodulation (vagus nerve and deep brain stimulation) for generalized seizure control.

Perhaps Mayo's greatest resource in its epilepsy practice is the commitment and experience of its physicians and the institutionalized collaborative approach to the care of patients with seizures.

Technology continues to be only as good as the people using it. Perhaps Mayo's greatest resource in its epilepsy practice is the commitment and experience of its physicians and the institutionalized collaborative approach to the care of patients with seizures. Patients may be seen by an interdisciplinary team that includes members from neurology, neurosurgery, psychiatry, neuropsychology, and neuroradiology, as well as allied health professionals with expertise and years of experience in epilepsy monitoring, stimulator programming, and pre- and postsurgical care. Weekly case conferences include as many as 30 health care professionals. The pediatric teams include neurologists, neurosurgeons, and neuropsychologists who specialize in pediatric epilepsy. A dedicated pediatric EMU is located in Mayo Eugenio Litta Children's Hospital in Rochester, Minnesota.



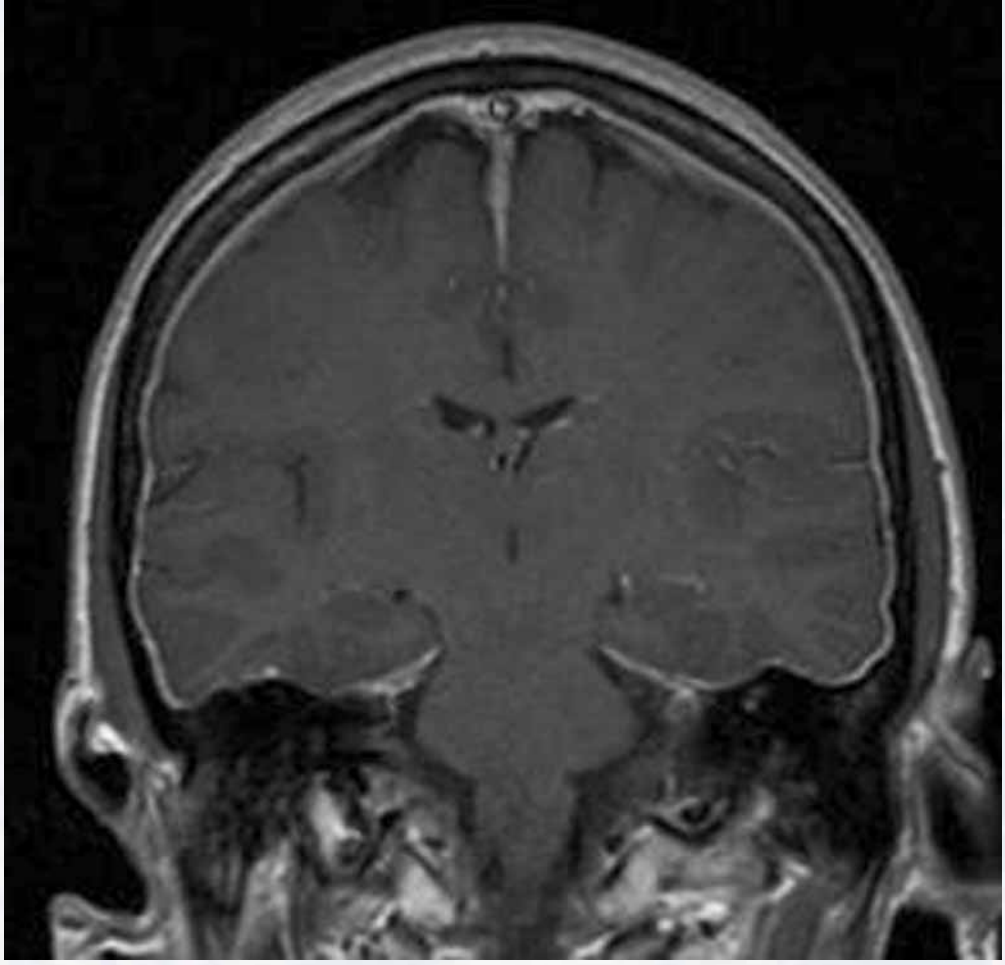
Imaging studies from a 35-year-old patient with medically intractable epilepsy. After intracranial electrode implantation, the patient underwent right temporal lobectomy and subsequently became seizure-free. Row A, Subtraction ictal SPECT coregistered to MRI shows multiple foci of increased perfusion in the coronal (left), sagittal (middle), and axial (right) planes. Row B, Statistical ictal SPECT coregistered to MRI shows a dominant hyperperfusion focus at the right posterior neocortical temporal region in all planes.

Image reproduced with permission from Wolters Kluwer Health in the Journal of Neurology.

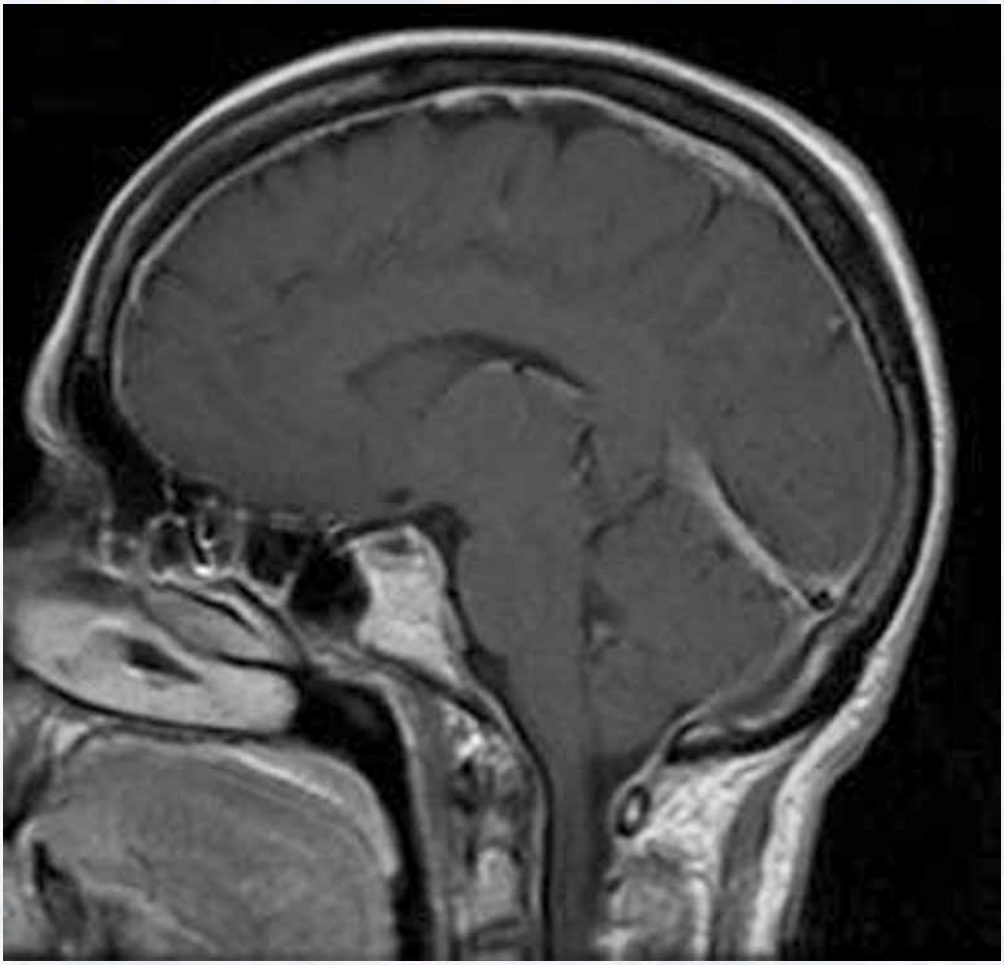
The collaborative approach translates what could be a fragmented diagnostic process into one of shared competencies and collective wisdom brought to bear on complex cases. Comprehensive evaluations that at many institutions take months to complete are conducted at Mayo in one to three weeks for the great majority of patients.

Mayo Clinic's practice is enhanced by its research in imaging, the molecular mechanisms of seizures, the epidemiology of epilepsy, prospective and retrospective studies of seizure management through drug therapies, surgery and neurostimulation, and the microdomains of seizure origin. Mayo is a national leader in a multicenter, National Institutes of Health–funded study on the genetics of epilepsy. It is participating in multicenter trials on implantable devices that use electrical stimulation to treat medically refractory epilepsy.

Seizure prevention rests on understanding seizure initiation. Mayo Clinic has made significant contributions in identifying the smallest anatomical unit that gives rise to seizures—the cortical column. Findings suggest that both high- and low-frequency oscillation are clinically relevant signatures or biomarkers of the epileptogenic zone. Mayo is now developing a prototype of a next generation of EEG machines that will improve recording sensitivity through increased spatial sampling and wide-frequency bandwidth recording. The ultimate goal of this research is an implantable device that can detect subclinical microseizure activity and use continuous feedback to prevent clinical seizures.



Low cerebrospinal fluid (CSF) pressure in a 52-year-old woman with postural headache following epidural injection for cervical disk disease.



Diagnosis: MRI head scan with T1-weighted coronal and sagittal views demonstrates typical findings of low CSF pressure, including flattening of the pons against the clivus with diffuse dural thickening and enhancement.

Headache

Mayo Clinic has one of the largest group practices for headache in the country, delivering care across its three campuses to patients with all types of headache, including migraine, cluster headache, and headache secondary to trauma or medication. Mayo's headache neurologists serve leadership roles in the American Headache Society and major headache journals. Mayo has a robust program of clinical and basic science research, collaborating with the departments of anesthesiology, neurosurgery, and neuroradiology and with external institutions. Mayo's Arizona and Minnesota headache practices are two of only 13 academic headache centers in the country with accredited fellowship programs.

Mayo Clinic's funded research feeds the practice and patient care. Clinical investigations include testing novel compounds for the acute treatment and prevention of migraine and cluster headache and clinical trials to evaluate the safety and efficacy of peripheral neurostimulation devices for chronic head pain or chronic migraine, and management of less common syndromes such as low pressure headache. Basic science research in headache at Mayo is addressing central nervous system abnormalities involved in chronic daily headache and the molecular mechanisms of migraine.

Mayo's investigation into the genetic basis of migraine has established an electronic database that stores a computerized questionnaire and standardized assessment tools from patients before each visit. Physicians can review the previsit assessment protocol ahead of time, allowing more time for patient-physician interaction and education. Clinicians and researchers can readily access subgroups of patients on the basis of headache type, medication type, or symptoms. Mayo has collected almost 4,000 samples in a migraine DNA repository, the largest such repository in the United States. The goal is to identify various molecular categories of migraine through exome sequencing, moving care toward individualized, targeted molecular therapies.

Mayo Clinic in Arizona has also established a Comprehensive Concussion Center focused on patient care, education, and research. Patients treated at the center are treated by a collaborative team that includes 13 disciplines. The focus is on accurate assessment; vestibular, cognitive, and pain rehabilitation; and safe return-to-activity recommendations using objective measures of brain recovery. Collaborative concussion research across Mayo's three campuses is aimed at establishing protocols to:

Mayo has collected almost 4,000 samples in a migraine DNA repository, the largest such repository in the United States.

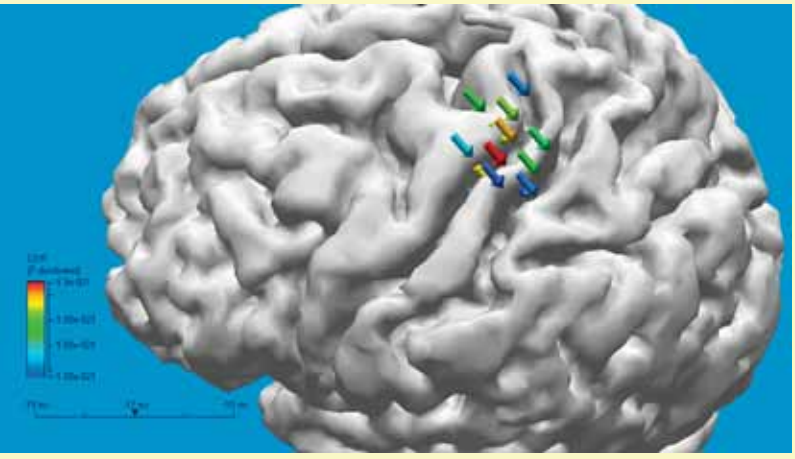
- Evaluate the cellular pathophysiology of concussion
- Identify clinical, imaging, or neurophysiological diagnostic biomarkers
- Identify risk factors and prediction models for patients at risk for long-term neurologic sequelae (eg, dementia, stroke, psychiatric disease)

Like all other headache research efforts at Mayo Clinic, this initiative is focused on improved patient care and reflects the highest standards of practice-research integration.

Movement Disorders

Mayo Clinic has a legacy of excellence in treating the full spectrum of movement disorders, including tremor, dystonia, myoclonus, chorea, ataxia, and dyskinesias of both common and uncommon origin and presentation. Across its three sites, neurologists and neurosurgeons with movement disorders subspecialty expertise work in close collaboration with one another and other specialists to provide patients with the highest standard of care. This standard is met not only in technological advances, but also in the depth of experience brought to bear on interpreting test results and clinical findings. Symptom management includes state-of-the-art tests, therapies, and neurosurgical techniques. Mayo's innovative deep brain stimulation (DBS) practice is one of the largest in the world (see pages 22-23 on DBS).

Mayo Clinic is one of very few institutions in the United States to use a wide spectrum of movement neurophysiology methods, a core assessment tool comprised of simultaneous polygraphic recording of EEG electrode, EMG electrode, and video recordings taken while the patient exhibits abnormal movements. Diagnostic utility is gained from EMG pattern recognition, source classification, and EEG and video correlates of abnormal movement. The data are recorded digitally, and analyses are conducted offline. Once the type of movement disorder is known, appropriate in-depth analysis can be conducted.



Localization of the electrical activity at the motor cortex during myoclonus in a patient with Parkinson's disease.

Mayo Clinic is an internationally recognized leader in addressing the mechanisms of movement disorders associated with neurodegenerative disease. A collaborative effort across Mayo's three campuses, this research includes neurologists, neurosurgeons, pathologists, geneticists, molecular biologists, and imaging scientists. It integrates new clinical discoveries with newly identified radiographic and biologic biomarkers of disease, proceeding with an organizational efficiency that few institutions can match.

Mayo Clinic's work in Parkinson's disease (PD), for example, is identifying early predictive clinical signs and new molecular biomarkers. Mayo was instrumental in discovering the association between common variations in the *MAPT* gene and PD, identifying the effects of the *LRRK2* gene on familial PD, and solidifying the evidence that overproduction of the α-synuclein protein was a predisposing factor in PD. More recently, using exome sequencing, a Mayo-led international team discovered two new PD genes, *VPS35* and *EIF4G*, that

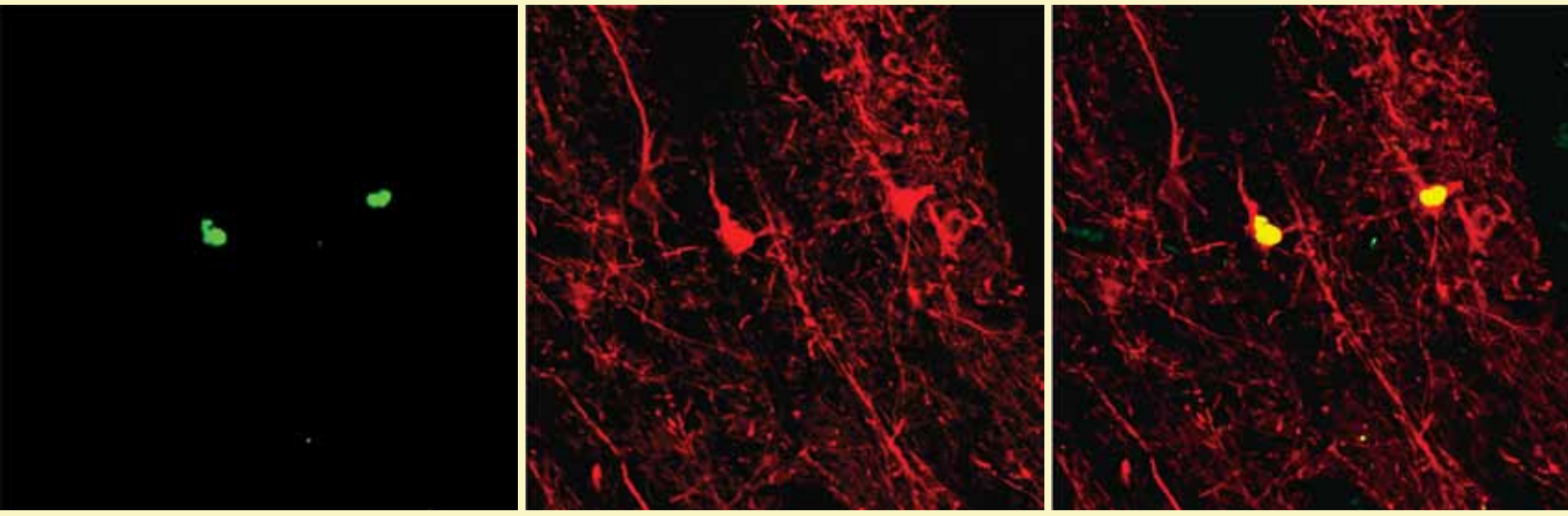
Mayo is one of very few institutions in the United States to use a wide spectrum of movement neurophysiology methods...

may explain the errant buildup of protein in some cases of PD and Alzheimer's disease. Another Mayo-led, North American investigation has identified mutations in the *C9ORF72* gene that may have a significant role in familial frontotemporal dementia and amyotrophic lateral sclerosis. The research team at Mayo Clinic in Florida is also investigating induced pluripotent cells, an emergent technology that may allow neuronal and cell repair from the development of stem-like cells taken from a skin biopsy.

Investigations such as these are focused on improving clinical outcomes. Mayo Clinic movement disorders specialists place the highest priority on providing patients with innovative, thorough, and individualized diagnostic evaluations and treatment strategies.

The Analysis Techniques Include the Following:

- Tremor spectrometry
- Tremor analysis
- Quantitative brain wave analysis
- Parkinson's disease brain wave analysis
- Myoclonus source analysis
- Dyskinesia analysis
- Muscle localization
- Movement pattern analysis



Staining of pyramidal neurons in the motor cortex with α-synuclein and neuronal marker in a patient with the small-amplitude myoclonus of Parkinson's disease.

Deep Brain Stimulation

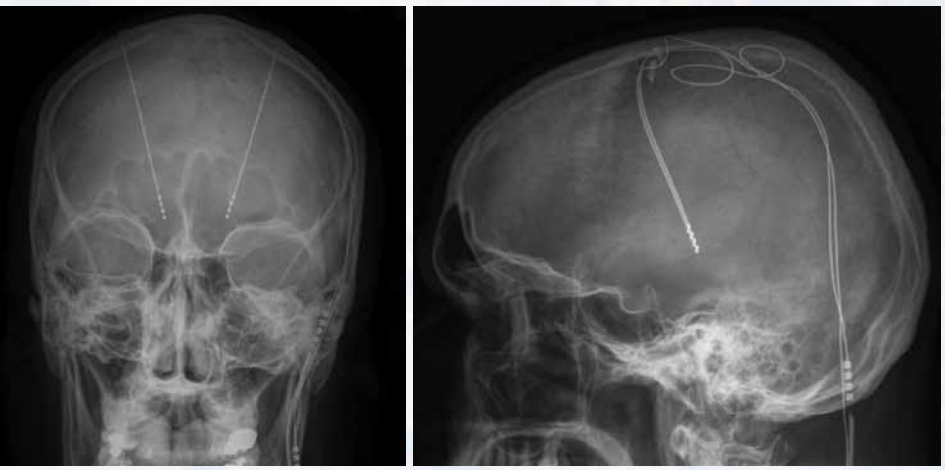
Mayo Clinic's deep brain stimulation (DBS) practice was pioneered at Mayo Clinic in Florida. It was refined in the late 1990s as part of the first US research studies on the applicability of DBS for essential tremor, which were the clinical trials that led to approval of DBS for essential tremor by the US Food and Drug Administration. Today, across its three campuses in Arizona, Florida, and Minnesota, Mayo's DBS practice is one of the largest neurostimulation practices in the world.

Interdisciplinary DBS teams carefully screen candidates, provide treatment for common and uncommon neurologic conditions, and follow up with expert stimulator programming. They collaborate on research and practice standards. Their success rests on experience, expertise, cutting-edge technology, and rigorous patient selection. Using brain mapping technology developed at Mayo Clinic, the DBS program has a history of exceptional targeting accuracy. Mayo treats patients across the age spectrum, including the youngest patient ever treated with DBS, a three-year-old child with Lennox-Gastaut syndrome, who had marked seizure reduction.

The Mayo DBS Profile

A distinguishing feature of Mayo's DBS practice is that every aspect of the patient's candidacy for surgery and postsurgical needs is carefully evaluated prior to intervention. A DBS profile is created for each patient and discussed at weekly interdisciplinary team conferences. The profile includes an evaluation of surgical candidacy from the perspective of the following specialties:

- Neurology, Neurosurgery, and Neuroradiology, for neurologic diagnosis and assessment of DBS candidacy
- Psychiatry, to assess mental health
- Neuropsychology, to assess cognitive status
- Speech Pathology, to assess speech, language, and swallowing competence
- Physical Medicine and Rehabilitation, to assess postoperative rehabilitation needs
- Anesthesiology, to assess tolerance for a lengthy surgical procedure
- Medical subspecialties, as needed, to assess general health and comorbidities



Skull radiograph (anterior/posterior [left] and lateral [right]) showing a DBS lead in the human thalamus.

The preoperative assessment often includes the patient's social, housing, and physical assistance needs and resources. Many of Mayo's patients come from a distance, and the surgery may be staged with a week between operations. For such patients, Mayo's social service professionals help find housing and in-home health care.

A recent retrospective study of 60 cases at Mayo Clinic, for example, found that the combination of levodopa and DBS was superior to either treatment alone.

Research

Mayo Clinic investigators are addressing clinical and basic science issues in neurostimulation. A recent retrospective study of 60 cases at Mayo Clinic, for example, found that the combination of levodopa and DBS was superior to either treatment alone. Other studies have examined DBS efficacy in various conditions, including benign tremulous parkinsonism, X-linked dystonia parkinsonism (Lubag), and Meige syndrome. Mayo also participates in clinical trials, including a current study of a new stimulator device.

Neurostimulation is widely used but little understood. Mayo Clinic is committed to identifying DBS-induced molecular and neurochemical changes in the brain. Using the Mayo-designed Wireless Instantaneous Neurotransmitter Concentration Sensing System (WINCS), biomedical engineers, neurosurgeons, neuroscientists, imaging scientists, and molecular biologists are conducting real-time tests of changes in neural and neurochemical activity during DBS surgery. This pioneering work is helping to elucidate the underlying mechanisms of DBS. The goals are to improve target identification and placement precision, generate technological advances in stimulation, and pave the way for novel DBS applications.

Mayo Offers Neurostimulation for the Following Conditions:

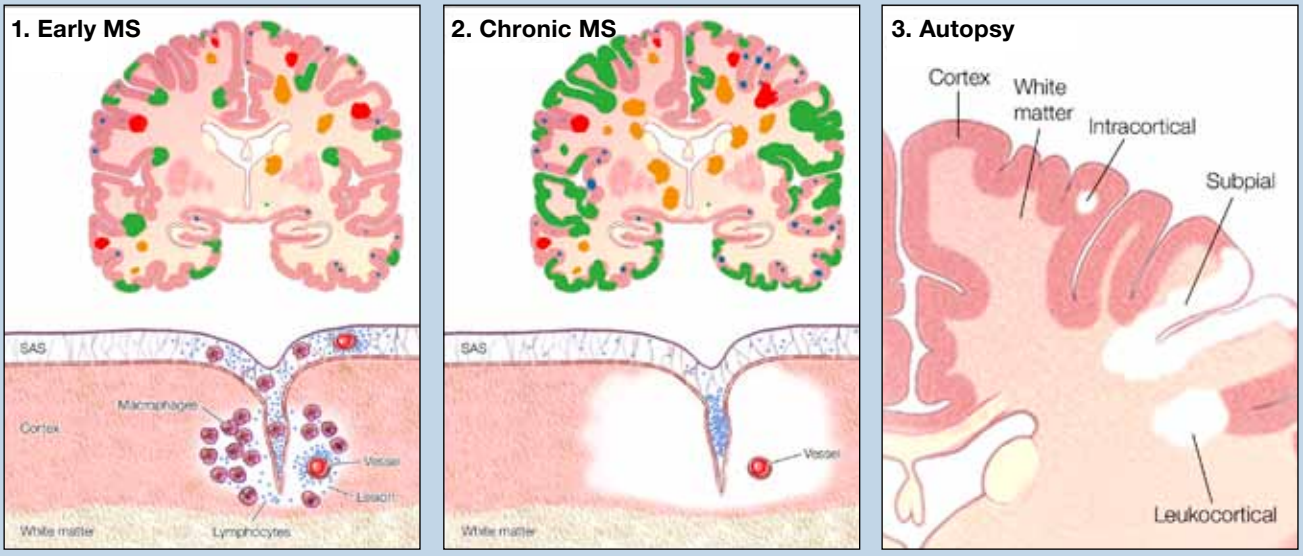
- Parkinson's disease
- Essential tremor
- Centrally mediated neuropathic pain
- Chorea
- Cluster headache
- Dystonia
- Poststroke pain
- Trigeminal neuralgia
- Pediatric epilepsy
- Tourette syndrome

Multiple Sclerosis and Autoimmune Neurology

Mayo Clinic is not alone in providing interdisciplinary care for patients with multiple sclerosis (MS) in an MS center or clinic. What sets Mayo's practice apart is the breadth of its coverage and the efficient integration of its state-of-the-art research into clinical practice. The practice addresses the full spectrum of inflammatory central nervous system (CNS) demyelinating diseases—not just MS, but also its known mimickers (of which there are more than 100), as well as acute demyelinating encephalomyelitis (ADEM), neuromyelitis optica (NMO), inherited leukodystrophies, and paraneoplastic syndromes.

Recognized as a world leader in the diagnosis and treatment of demyelinating disease and autoimmune neurologic disorders, Mayo Clinic mounts unmatched resources for uncovering novel syndromes, developing new diagnostic biomarkers and unique laboratory tests, and generating paradigm shifts in theories of disease pathogenesis. These discoveries inform the differential diagnosis and make Mayo's tailored, highly individualized treatment possible. Mayo's advances in the field are supported by a dynamic translational research program that defines the standard and includes the following resources:

- Mayo Clinic Center for Multiple Sclerosis and CNS Demyelinating Diseases, which brings together basic scientists and clinical researchers across Mayo's



MS can involve the white matter as focal plaques (yellow) or as cortical lesions, either subpial (green), intracortical (blue), or leukocortical (red). Microscopic comparison of early and chronic cortical MS lesions reveals that: 1) Early cortical lesions are inflammatory and can contain myelin-laden macrophages (red), as well as parenchymal and perivascular lymphocytic infiltrates (blue). In contrast, chronic cortical lesions are largely devoid of parenchymal inflammation; 2) Meningeal infiltrates (both diffuse and focal perivascular) are present in the subarachnoid space (SAS) of early MS and are topographically associated with cortical demyelinated plaques. Myelin-laden macrophages can be found in the SAS. With disease chronicity, meningeal inflammation becomes concentrated in deep cortical sulci and acquires features of organized meningeal lymphoid follicles; and 3) Cortical demyelination becomes more extensive with disease chronicity, particularly with respect to subpial plaques. (Lucchinetti et al. Inflammatory Cortical Demyelination in Early Multiple Sclerosis. N Engl J Med. *2011:365[23]:2188-97.)*

three sites and generates high-impact research with profound and often immediate clinical implications

- Mayo Clinic Neuroimmunology Laboratory, which has a track record of turning ground-breaking molecular discoveries into clinically relevant laboratory tests

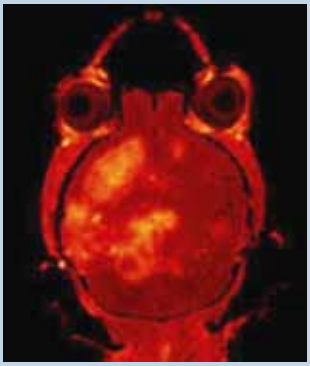
- Unmatched repositories of blood, spinal fluid, DNA, and MRI from one of the longest-followed MS populations in the world, as well as the largest well-characterized repository of MS and related disease brain pathology, the largest well-characterized database of progressive MS, and the largest database of NMO spectrum disorders in the world

It was Mayo Clinic research that 20 years ago uncovered evidence of limited, naturally occurring remyelination in response to MS inflammatory attacks, at a time when CNS repair was thought impossible. This discovery generated new lines of research and therapeutic approaches. It led to the discovery and manufacture of recombinant monoclonal antibodies, patented by Mayo and about to enter clinical trials, that show promise in promoting both remyelination and CNS axonal growth. This research is but one example of the kind of pioneering work that is altering disease concepts and impacting treatment. In addition, Mayo Clinic researchers:

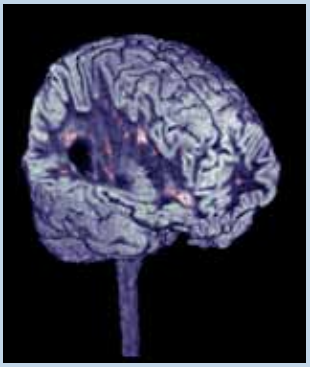
- Identified NMO as separate from MS. NMO was considered a variant of MS for over 100 years, an assumption that led to unsuccessful interventions. In the past decade, Mayo researchers successfully differentiated the two diseases, discovered and developed a blood test for an NMO diagnostic antibody, and identified the target antigen. These discoveries have implications for the molecular basis and treatment of NMO and other autoimmune CNS inflammatory conditions

- Identified four distinct tissue types of MS and reported their distinguishing features and implications for interventions tailored to each subtype

- Recognized that MS may be driven by cortical gray, rather than white matter demyelination, a discovery that represents a major shift in understanding the origin and mechanisms of CNS inflammatory demyelinating disease



Extensive gadolinium contrast–enhancing areas in a mouse model of fulminant demyelination. T1-weighted brain MRI scan with "hot-iron" pseudocolor encoding.



3-D rendering of a novel double inversion recovery (DIR) brain MRI dataset demonstrating numerous white matter (red) and gray matter (green) lesions in a patient with relapsing-remitting MS.

- Identified and characterized novel CNS inflammatory diseases, the most recent of which was CLIPPERS (chronic lymphocytic inflammation with pontine perivascular enhancement responsive to steroids)

- Introduced plasma exchange as an effective treatment for patients with acute inflammatory attacks and defined the clinical, serological, and radiographic predictors of successful outcomes

- Established the first comprehensive serological evaluations for the diagnosis of paraneoplastic neurologic autoimmune disorders, a group of disorders in which unusual neurologic signs and symptoms are the initial manifestations of cancer

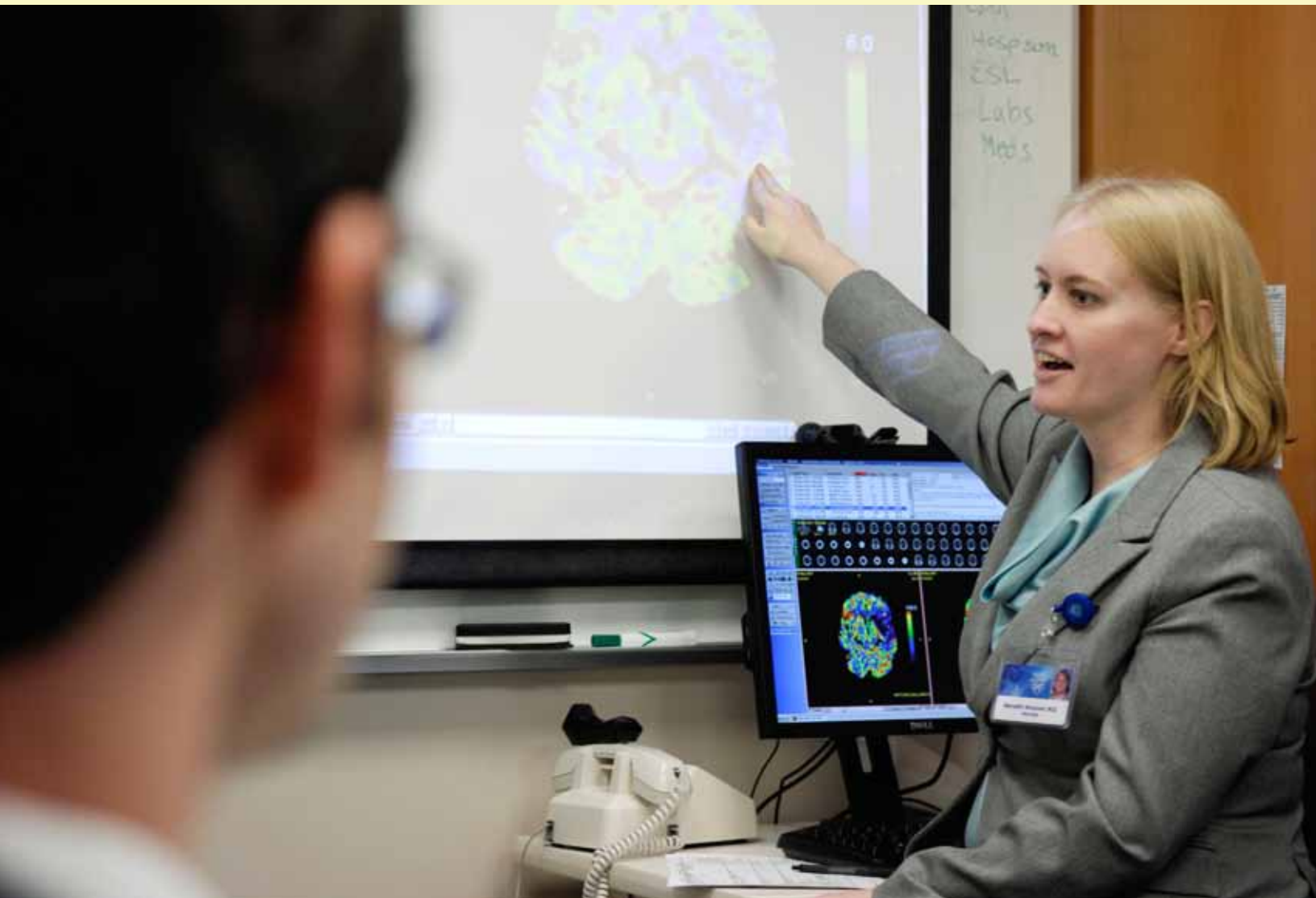
- Created the nation's first clinic specializing in the management of patients with non-MS autoimmune neurologic disorders, including immunotherapy-responsive epilepsy, dementia, psychoses, movement disorders, and disorders of the peripheral and autonomic nervous system (including intestinal dysmotility) and muscle

Neurology Education

The three shields of Mayo Clinic represent patient care supported by education and research. From the beginning, the Mayo brothers recognized the importance of education in providing optimal and informed care. The Department of Neurology exemplifies the best of that tradition and commitment. One of the department's distinguishing features is that it has a Section of Education, which stands on equal footing with its other subspecialty sections—a departmental arrangement that is unique among comparable academic medical centers.

Composed of 12 members, each with subspecialty interests, the Section of Education principally oversees resident rotations and participates in didactic courses for residents and students from Mayo Medical School. Members also serve as instructors for the first-year neurosciences course. Neurology residents thus have the benefit of instruction from premier practicing neurologists who not only have national and international reputations for research, scholarly publications, and leading textbooks, but also have daily hands-on clinical experience.

In 1919, a neurology resident at Mayo Clinic spoke of the team spirit that fostered the development of individual talents and promoted reciprocal development of staff and residents. That collaborative relationship between staff and trainees continues today across Mayo's three



campuses in Arizona, Florida, and Minnesota. Regardless of the campus chosen, residents have the advantage of an integrated curriculum, shared resources, state-of-the-art facilities, and the option of subspecialty rotations at each of the other campuses. The mix of patients with routine and uncommon problems, the depth of clinical expertise and dedication among its staff to patient care, and the advancement of clinical and basic research ensures that residents come away prepared for their career—be it in general practice or an academic medical center and as a clinician, investigator, or clinician educator.

A distinctive and innovative feature of resident training is the use of video recording. Every beginning resident in the Department of Neurology spends a month with members of the Section of Education learning patient history and examination skills from master clinicians. In most institutions, residents conduct the clinical visit and review their findings afterward with the staff member. At Mayo Clinic, these initial clinical consultations are recorded while the staff member observes. At the end of the month, the resident is again recorded for examination of growth in clinical skills. Video review sessions between staff member and resident provide an experiential teaching tool that addresses the entire physician-patient interaction, as well as the resident's diagnostic skills. It is a labor-intensive process emblematic of the priority Mayo's Department of Neurology places on education, through its dedication of staff time and resources to this endeavor.

In their fourth year of neurology subspecialty training, residents return for a final one-month rotation with members of the Section of Education to evaluate and treat general neurology patients who typically have undefined, symptom-based problems. It is in this last rotation, colloquially referred to as the "Finishing School," that they revisit the refinements of diagnosis and patient care—the art, as well as the science, of neurology.

The Department of Neurology is housed in an institution renowned for putting the patient first, for the highest standards of practice, for its academic and research contributions, and for being an academic center in which physician education is considered integral to patient care. Mayo Clinic's neurology residents and fellows come from all over the world, with more than 500 residency alumni to date, to participate in a program that focuses on developing the whole physician and caring for the whole patient—a department in which every member views education not as a burden, but as a privilege.

Mayo's neurology residents and fellows come from all over the world...

Neuromuscular Disorders

Mayo Clinic has a long-standing reputation for excellence in the study and management of neuromuscular disorders. Ground-breaking work at Mayo expanded the understanding of EMG findings in neurologic disorders. The first epidemiologic studies on amyotrophic lateral sclerosis (ALS) were conducted at Mayo and became the foundational studies of the Rochester Epidemiology Project, a vast database from which have come more than 1,000 epidemiologic publications on a wide range of diseases.

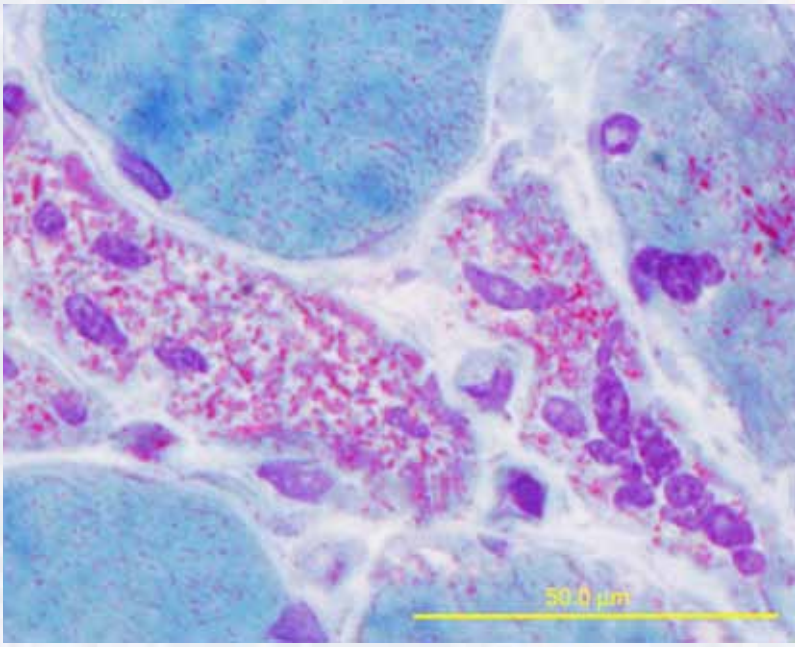
A unique feature of Mayo's practice is that peripheral nerve and neuromuscular disorders are separated into two divisions within the Department of Neurology (see Peripheral Nerve Disorders on pages 36-37). This separation allows for specialized concentration across diverse areas of disease type, neurophysiology, and pathology. The neuromuscular practice at Mayo includes members with specialized expertise in the following areas:

- Neurophysiology of muscle disorders
- Inherited and acquired neuromuscular and neuromuscular junction diseases
- Genetics of congenital myopathies and adult-onset neuropathies
- Muscle physiology and pathology
- Nerve physiology and pathology

This degree of specialization provides unusual depth to the collaborative practice. Faced with a particularly unusual muscle problem, physicians have ready access to in-house experts in muscle or nerve pathology, for example, or the latest genetic testing.

Mayo Clinic conducts more than 20,000 EMG studies each year at its three campuses. Tests rarely performed at other institutions, such as repetitive stimulation for neuromuscular junction diseases and single-fiber EMG,

Tests rarely performed at other institutions, such as single-fiber EMG, are done daily by Mayo Clinic electromyographers.



Late-onset myopathy with rod-like inclusions in the muscle fibers.

are conducted daily by Mayo electromyographers.

"Awake" anesthesia has made EMG in children feasible. Pediatric patients are sedated enough to minimize discomfort, but conscious enough for voluntary movement. Pediatric anesthesiologists and neurologists experienced in pediatric EMG help ensure that the tests are completed in the shortest time possible with minimal discomfort.

The Muscle Research Laboratory on Mayo's Rochester, Minnesota, campus conducts more than 1,500 muscle biopsies a year. Using specialized techniques for tests of the neuromuscular junction and muscle pathology and physiology, the laboratory sets the standard for muscle pathology and physiology laboratories throughout the world.

Mayo Clinic has identified and described numerous neuromuscular disorders. For example, its pioneering work in myasthenia gravis distinguished the mechanisms of this disease from those of related neurologic autoimmune disorders and generated many of the specialized diagnostic tests and clinical tools to manage it. Today, investigations in Mayo's Muscle Research Laboratory continue to make breakthrough discoveries. Recently, for example, studies of malfunctioning genes and gene products in muscle disease have led to the identification of specific subtypes of childhood myofibrillar myopathy.

The depth and breadth of Mayo Clinic's specialization in practice and in research expertise and resources, combined with collegial working relationships, ensure Mayo's continued leadership in neuromuscular disease.

Common Conditions for EMG Testing Include:

- Brachial and lumbar plexopathies
- Carpal tunnel and ulnar neuropathies or cubital tunnel syndrome
- Cranial nerve disorders
- Motor neuron disease
- Muscle cramps or hyperexcitable nerve syndrome
- Myopathies (congenital and acquired)
- Neuromuscular junction disorders (eg, congenital and acquired myasthenia gravis, Lambert-Eaton myasthenic syndrome)
- Nerve terminal disorders
- Peripheral neuropathy
- Pediatric muscular dystrophies, inherited neuropathies, metabolic myopathies, congenital myasthenia syndromes
- Radiculopathies

Neuro-oncology

With high patient volumes and the necessary infrastructure and institutional support, Mayo Clinic is uniquely positioned to translate basic science research into cancer treatment. For example, Mayo brought the attenuated measles virus therapy (MVT) from animal studies to human trials in just three years.

Mayo Clinic's translational research in neuro-oncology is funded by the National Cancer Institute (NCI) and the National Institutes of Health (NIH) under the following programs:

- Mayo Clinic Cancer Center, a three-site NCI-designated cancer center, one of the largest in the country and the only one that accommodates three geographic locations
- Brain Cancer Specialized Program of Research Excellence (SPORE), an NCI-funded program focused on translational research
- Center for Translational Science Activities, funded by NIH
- North Central Cancer Treatment Group, a cooperative clinical research group for the development, execution, and review of high-priority NCI-funded trials, expediting novel treatments into clinical trials

Mayo's Brain Cancer SPORE is one of 67 SPORE grants around the country and one of only three devoted to brain cancer. It is also the only SPORE led by a neurologist. Through the SPORE grant, clinical researchers and basic scientists in molecular and stem cell biology, neuroimmunology, imaging science, pharmacology, epidemiology, neuropathology, and radiology collaborate across Mayo's three campuses and with other institutions. Their investigations focus on:

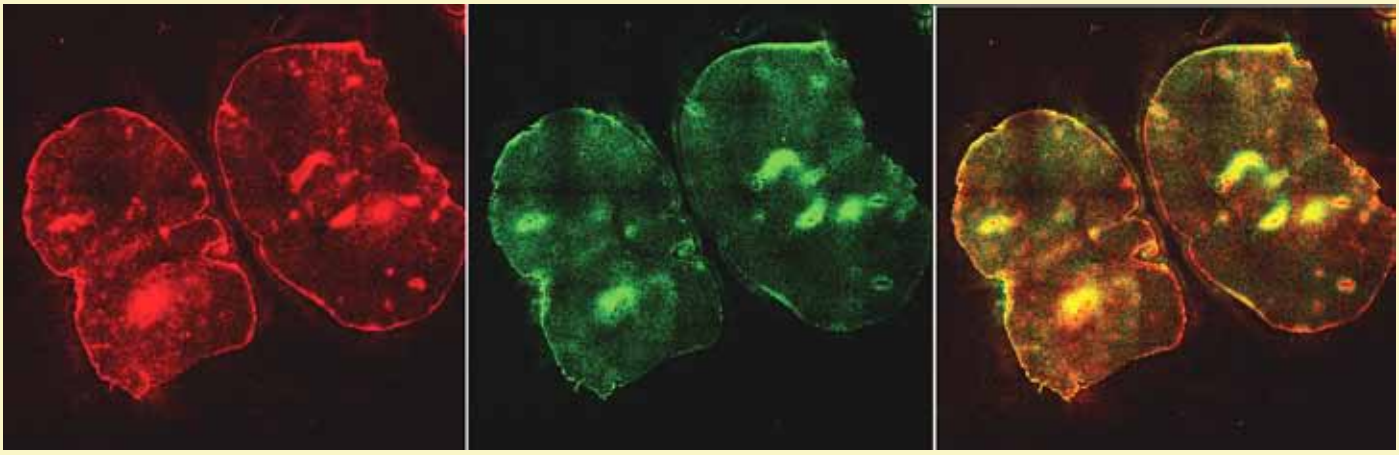
- Identifying mechanisms of glioma initiation and progression
- Identifying diagnostic, prognostic, and predictive biomarkers
- Identifying targets for intervention and germline regions associated with susceptibility
- Developing novel therapies, such as the oncolytic measles virus

As an example, Mayo Clinic's basic science investigators have generated a premier primary xenograft animal model that is transforming the study of tumor characteristics and response to treatment. Unlike established cell lines, used for the past 30 years and cultured in vitro, Mayo's xenograft model transfers tumor cells from humans directly into mice. It is an in vivo platform that more closely represents tumor growth and behavior in human patients than previous cell lines. Xenograft modeling is now required by many grant-funding sources, and Mayo has shared its well-described xenograft cell lines with researchers around the world. The model has accurately predicted the effects of a trial of drug and radiation dosage manipulations. Mayo scientists are now using it to investigate drug penetration across the blood-brain barrier and failure of common drugs, such as temozolomide, to overcome protein-based tumor sensitization (eg, poly [adenosine phosphate-ribose] polymerase inhibitors). Mimicking human glioblastoma (GBM) tumor growth, this model has much to offer in understanding the fundamental biology of GBMs, their resistance to standard treatment, and the development of novel therapies.

Other examples of Mayo Clinic's ongoing neuro-oncology research include:

- Reengineering the measles virus, a Mayo-developed technique, into virotherapy, to improve its target specificity, efficacy, and safety for human GBM trials
- Investigating the role of the MMSET protein in DNA damage and response and resistance of GBM to chemotherapy

Treating more than 20,000 patients with cancer a year, Mayo is committed to patient care...



Glioblastoma tumor–bearing animals were administered Texas-red dextran (red) and fluorescein (green) before euthanasia. The staining with these dyes in the tumor region (outlined on the hematoxylin-eosin stain on the left) reflects partial penetration of these compounds across the blood-brain barrier, similar to many drugs used for current brain tumor therapies.

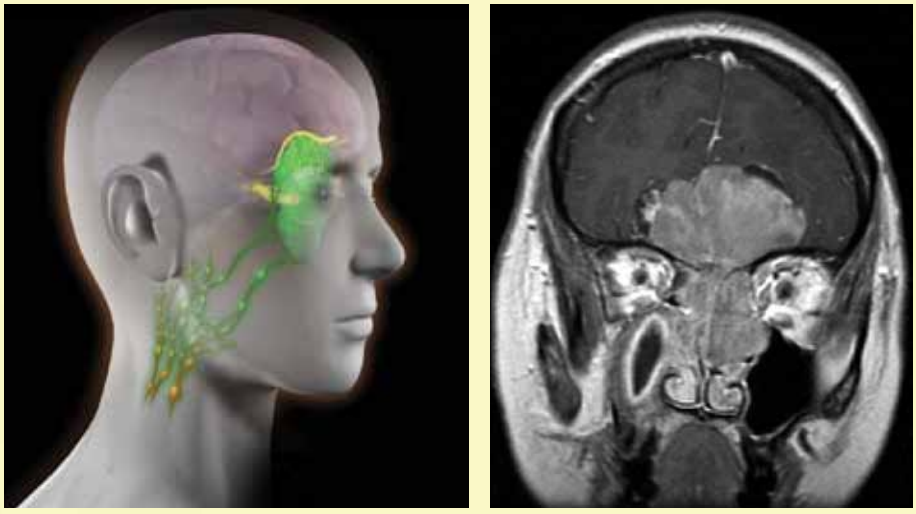
Architect's rendering of new proton beam therapy facilities in Arizona and Minnesota.

Treating more than 20,000 patients with cancer a year, Mayo Clinic is committed to patient care as a destination cancer center. To that end, Mayo is establishing a proton beam therapy program at both its Minnesota and Arizona campuses. Proton beam therapy allows greater control, higher doses, shorter treatment times, fewer adverse effects, and more precise targeting with less damage to surrounding tissue than standard radiation delivery systems. With its tight links between cancer treatment and research, Mayo is able to efficiently deliver translational medicine and move toward the highly individualized therapies of the future.

Skull Base Tumor Management

Mayo Clinic has an active skull base tumor practice for both children and adults. Among the most common skull base tumors are meningiomas, acoustic neuromas, pituitary tumors, clival chordomas, sinonasal tumors, chondrosarcomas, and craniopharyngiomas. Because such tumors involve anatomy within the purview of several surgical specialties, resection may require an otorhinolaryngologist, ophthalmologist, oromaxillofacial surgeon, or plastic surgeon, in addition to a neurosurgeon. Postsurgical care may involve radiation or medical oncology, or both, as well as medical and rehabilitation services. For children, the Mayo Clinic team in Rochester, Minnesota, includes specialists from pediatric neurology and neurosurgery, pediatric neuro-oncology, pediatric endocrinology, and radiation oncology, as well as anesthesiologists with expertise in pediatric surgery.

At many institutions, coordinating a multidisciplinary team for a single procedure can take time. Mayo Clinic can assemble such surgical teams with speed and efficiency. Mayo has an operating room staff with long experience in managing multiple surgical teams for a single procedure and radiation oncologists with specialized expertise in treating patients after surgery.



Esthesioneuroblastoma stage IV tumor.

Typically, patients see all specialists involved in their care over two to five days, and the surgery can be scheduled within two weeks of their visit. Participating physicians review the history together to decide on treatment options and meet with the patient as a team in a single visit to present their recommendations and answer questions. The patient is thus spared what can be a confusing and time-consuming effort of gathering information from a series of separate physician consultations.

The surgical approach taken may be an endoscopic or an open procedure. Endoscopic surgery for skull base tumors has received increased attention in the past few years, with the promise of a less invasive procedure and shorter recovery times. For example, many pituitary surgeries at Mayo Clinic are performed endoscopically. Two physicians who will soon join the Mayo Clinic staff—one in otorhinolaryngology and one in neurosurgery—are obtaining additional training in endoscopic surgery and will partner together at Mayo's Rochester campus to further expand the endoscopic skull base program.

Mayo Clinic is fortunate to have the resources and the depth and breadth of experience and expertise among its skull base surgeons to consider all options in an unbiased decision-making process. That process takes into account the nature, size, and location of the tumor and the patient's individual anatomy and history. The best approach to skull base tumors—and the one to which Mayo surgeons adhere—is one that is individualized, impartial, and flexible enough to ensure the best care for the patient.

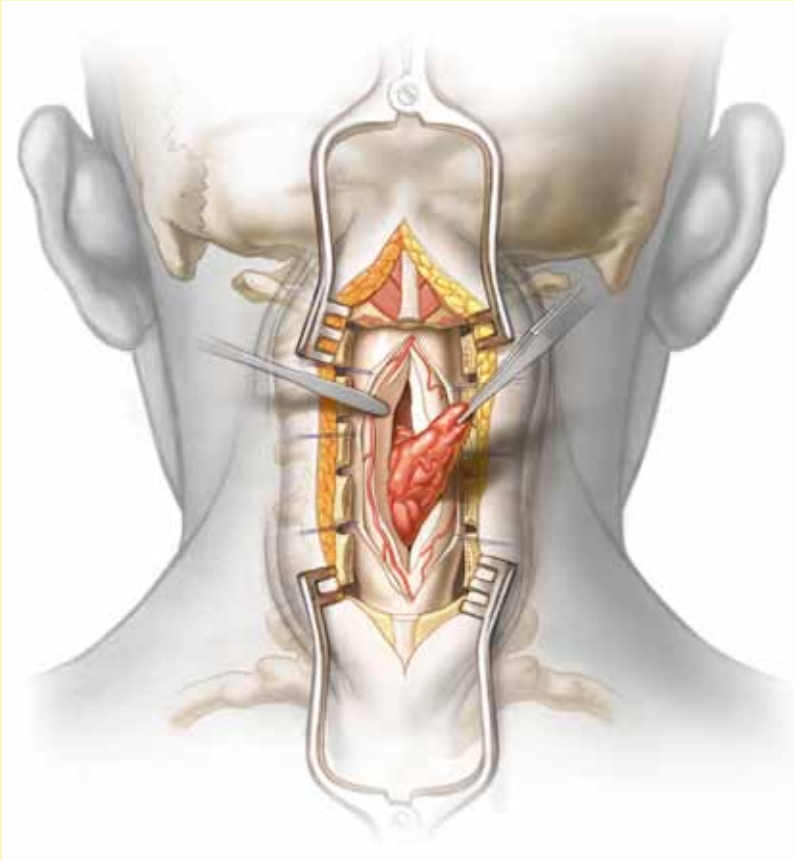
Spinal Cord Tumor Surgery

Mayo Clinic's neurosurgeons operate on three or four spinal cord tumors a week, making the spinal cord tumor practice one of the largest in the country. Patients are cared for by an interdisciplinary team, anchored by a neuro-oncologist who conducts the evaluation and guides patient care following surgery. Neurologists conduct motor and somatosensory evoked potential monitoring during surgery. Physical Medicine and Rehabilitation specialists provide any necessary therapies after surgery. Follow-up treatment may include radiation therapy or other neuro-oncology therapies.

A distinguishing feature of Mayo's spinal cord tumor practice is its proactive approach to the prevention of spinal deformity. The development of spinal deformities is a common consequence of tumor resection. To spare the patient another major surgical procedure several years later, Mayo's neurosurgeons conduct spinal reconstruction, when appropriate, within days of removing the tumor.

Mayo Clinic in Rochester, Minnesota is fortunate to have an in-house rehabilitation unit with therapists who are experienced in treating patients with spinal cord tumors. Because the rehabilitation facilities are located within the same building as the surgical unit, patients can begin rehabilitation very early after surgery. The neurosurgeon continues to be immediately available if postoperative issues arise.

The advantage of the practice at Mayo Clinic is that every aspect of the care of patients with spinal cord tumors is addressed in one location by interdisciplinary teams with experience and expertise. Care is provided as a coordinated, collaborative intervention strategy from diagnosis through long-term follow-up services.



Posterior approach to spinal cord tumor in the cervical spine.

Stereotactic Radiation

Mayo Clinic has been conducting stereotactic radiosurgery since 1990 at its Rochester, Minnesota, campus. With more than 5,250 patients treated to date, it is one of the busiest radiosurgery practices in the world.

Radiosurgery is also available at Mayo's Arizona and Florida campuses. At all three sites, the treatment teams include neurosurgeons, radiation oncologists, and medical physicists with specialized training in radiosurgical case management. Patients range in age from toddlers to elderly persons. Radiosurgery can be a particularly good option for patients unable to tolerate an open procedure. At Mayo, the benefits of radiosurgery are carefully weighed against the risks by neurosurgeons with expertise in both open procedures and stereotactic radiosurgery. Approximately 65% of the tumors treated at Mayo are benign and 35% are malignant. Of the former, tumor control has been achieved in 95% of patients.

Used as an alternative to or in conjunction with traditional neurosurgery, radiosurgery can be an excellent minimally invasive option.

Radiosurgery Can Be an Excellent Noninvasive Option for:

- Arteriovenous malformation
- Dural arteriovenus fistula
- Metastatic brain tumor
- Malignant skull-base tumor
- Vestibular schwannoma (acoustic neuroma)
- Other cranial nerve schwannomas
- Meningioma
- Pituitary adenoma

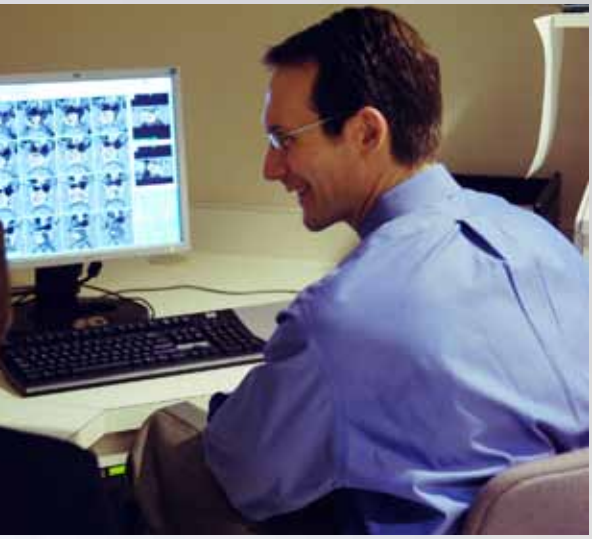
At Mayo, the benefits of radiosurgery are carefully weighed against the risks by neurosurgeons with expertise in both open procedures and stereotactic radiosurgery.

Radiosurgery delivers radiation to an image-defined target in highly conformal dose plans with steep fall-off, allowing for safe delivery of high doses of radiation received in a single session. In some cases, such as a large arteriovenous malformation or large skull-base tumor, the surgery may be staged over several months.

At Mayo's Arizona and Florida sites, radiosurgery is conducted using a linear accelerator with an image-guided targeting system. Mayo's practice in Rochester has been using a Leksell Gamma Knife Perfexion delivery system since 2007. The size of the unit and the nature of the radiation delivery allow treatment of more lesions on the periphery of the brain, the skull base, and the spine, including:

- Head and neck cancers
- Ocular neoplasms
- Peripheral skull-base carcinomas
- Tumors of the upper cervical spine.
- Paragangliomas (glomus tumors)

Since the inception of the practice, Mayo has maintained a continuous database that includes patient characteristics, radiosurgical dosimetry, and surgical outcomes. The database has contributed to both the research and the practice of neurosurgery and radiation oncology with more than 125 publications on radiosurgery.

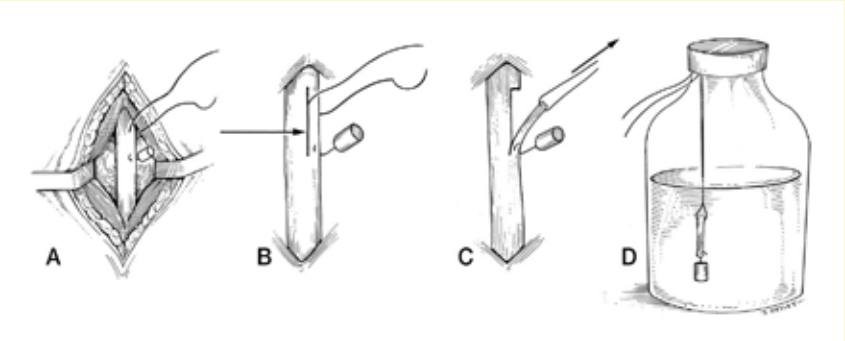


LEKSELL GAMMA KNIFE
PERFEXION
ELEKTA

Peripheral Nerve Disorders

In the 1960s, Mayo Clinic did something that few, if any, institutions have done before or since. It established a free-standing clinical peripheral nerve laboratory. This laboratory pioneered methods for harvesting and processing nerve biopsy specimens. Today, it is one of the largest nerve biopsy services in the world, and its innovation continues in the identification of previously unrecognized conditions, new understanding of the mechanisms of peripheral nerve disease, and improved diagnosis and treatment of peripheral neuropathies.

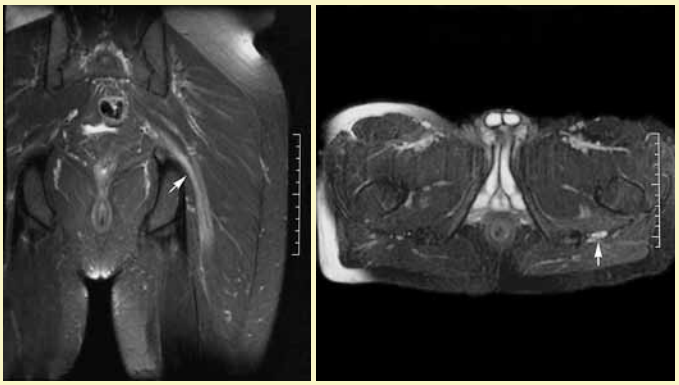
Many major medical centers also conduct nerve biopsies, but often in the setting of a general pathology laboratory rather than a specialized peripheral nerve laboratory. With the application of labor-intensive, varied, and novel preparations, Mayo's peripheral nerve laboratory can change an uncertain diagnosis to a disease-specific one. In addition to the hundreds of biopsies conducted for Mayo patients each year, Mayo interprets an even greater number of specimens that are sent to the laboratory in the form of prepackaged kits with fixatives and detailed processing instructions.



A-D, Sequential steps in performance of fascicular nerve biopsy (modified from Dyck PJ, Lofgren EP. Method of fascicular biopsy of human peripheral nerve for electrophysiologic and histologic study. Mayo Clin Proc *1966;41[11]:778-84).*

In the 1960s, Mayo also described the technique of fascicular nerve biopsy in which part of the nerve was harvested and part was left intact. For many years, this was a seldom-used technique. Ten years ago, Mayo combined the expertise of peripheral nerve neurology, radiology, neurosurgery, and pathology and began a systematic program of frequent targeted fascicular nerve biopsies. This highly specialized technique allows examination of nerve fascicles or bundles, sometimes as small as a single fascicle, thus preserving function in the parent nerve. While most nerve biopsies are taken from distal cutaneous sites, fascicular nerve biopsies are conducted from major proximal nerves. Such a procedure requires not only rare surgical skill, but also customized imaging protocols and a laboratory with the expertise and experience to correlate findings on high-resolution MRI with the exact histology.

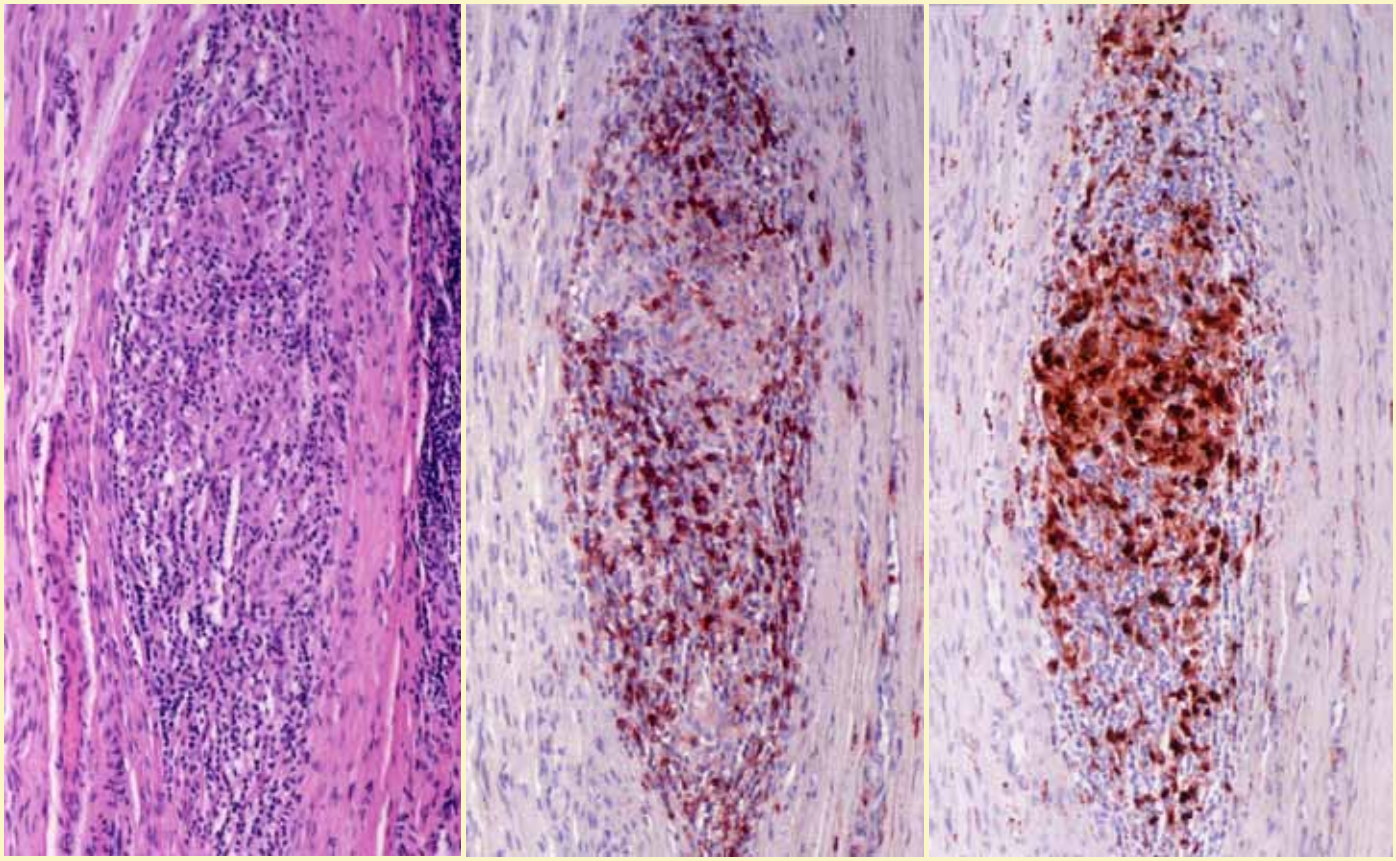
The robust clinical value of such studies is apparent in the ability to diagnose previously undiagnosed, idiopathic conditions. For example, of 119 patients at Mayo with unexplained neuropathy, targeted fascicular biopsy revealed that 85% of them had biopsies with meaningful pathology, of which 76% were treatable conditions. The most common postbiopsy diagnoses not only included such disorders as inflammatory demyelination, perineuroma, lymphoma, metastatic tumor, but other rarer pathologies were detected, including amyloidoma. Accurately targeted biopsy depends on the quality of the diagnostic imaging. Mayo's enhanced MR techniques, such as dedicated radiofrequency coils custom made for Mayo, optimal image reformatting, and 3-D reconstruction are transforming diagnosis. Combined with detailed clinical findings and electrophysiologic studies, these unique imaging methods



T2-weighted fast spin echo images with fat suppression from a 30-year-old man with a two-year history of progressive left foot drop and pain showing areas (arrows) of nerve enlargement and increased signal of the sciatic nerve on coronal (left) and axial (right) planes (modified from Dyck PJB, et al. MRI-Targeted Fascicular Nerve Biopsies of Proximal Nerves: Historic Reports and Illustrative Case Reports. In Companion to Peripheral Neuropathy – Illustrated Cases and New Developments, *Dyck PJ, Dyck PJB, Engelstad JK, Low PA, Amrami KK, Spinner RJ, Klein CJ, Editors, Saunders, Philadelphia, Chapter 1:3-14,2010).*

enable highly individualized protocols that provide strategic precision in localizing focal nerve lesions.

Few institutions can match the depth and breadth of subspecialization in Mayo's division of peripheral nerve disease. Its members are recognized as leaders in the field with major textbooks, publications, and research that identifies new syndromes and is generating novel diagnostic techniques. Ongoing investigations include designer genetic evaluations, next-generation gene sequencing, and the application of autologous mesenchymal stem cell for neural regeneration (see Regenerative Medicine, pages 38-39). Mayo's 50-year legacy of advances in peripheral nerve disease continues to make a difference for patients with known and unknown peripheral neuropathies.



Serial longitudinal paraffin sections from a sciatic nerve fascicular biopsy, the site of which was selected from the MRI images shown above. The biopsy shows a large nerve granuloma (left, hematoxylin-eosin; middle, CD45 [leukocytes]; and right, CD68 [macrophages]). The patient received a diagnosis of sciatic nerve sarcoidosis (modified from Dyck PJB, et al. MRI-Targeted Fascicular Nerve Biopsies of Proximal Nerves: Historic Reports and Illustrative Case Reports. In Companion to Peripheral Neuropathy – Illustrated Cases and New Developments, *Dyck PJ, Dyck PJB, Engelstad JK, Low PA, Amrami KK, Spinner RJ, Klein CJ, Editors, Saunders, Philadelphia, Chapter 1:3-14,2010).*

Regenerative Medicine

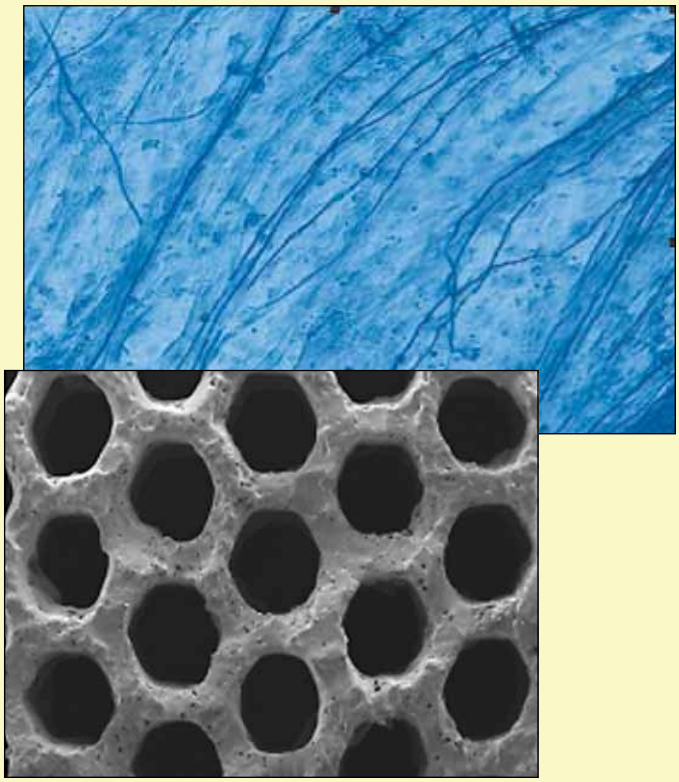
Mayo Clinic scientists are using advanced biomedical technology, recombinant forms of naturally occurring autoantibodies patented by Mayo, and novel methods of tissue engineering to prevent cell death and promote neural regeneration in the brain, spinal cord, and limbs. Three of these projects, described below, are about to enter clinical trials.

1. Large-gap peripheral nerve repair

Although peripheral nerves can regenerate across small gaps, an array of inhibitory factors prevents them from bridging gaps larger than 5 cm. Early work centered on creating antibodies to counteract inhibitory factors. Mayo Clinic took a different approach and pioneered ways to reengineer stem cells to become delivery vehicles for neural growth factors. The next step was developing a permissive cellular environment that could sustain growth and enable axons to find and connect with targets across large gaps. Mayo has now developed such an environment. It takes the form of a novel synthetic tubing that provides a biodegradable scaffold between severed axons and within which neural growth factors, signaling molecules, and guidance cues sustain new growth and axonal projections. This work has been led by two Mayo physician-scientists. One is a neurologist and molecular neuroscientist and the other is an orthopedic surgeon and biomedical engineer. Both are codirectors for nerve injury research in the Armed Forces Institute of Regenerative Medicine, a Department of Defense–funded consortium of 16 institutions to generate new treatments for persons injured in military activities. In collaboration with a peripheral nerve surgeon, the team is now conducting the first human clinical trials of polymer scaffold implants at Mayo Clinic in Rochester, Minnesota, to repair large-gap nerve wounds.

2. Neuronal regeneration in amyotrophic lateral sclerosis

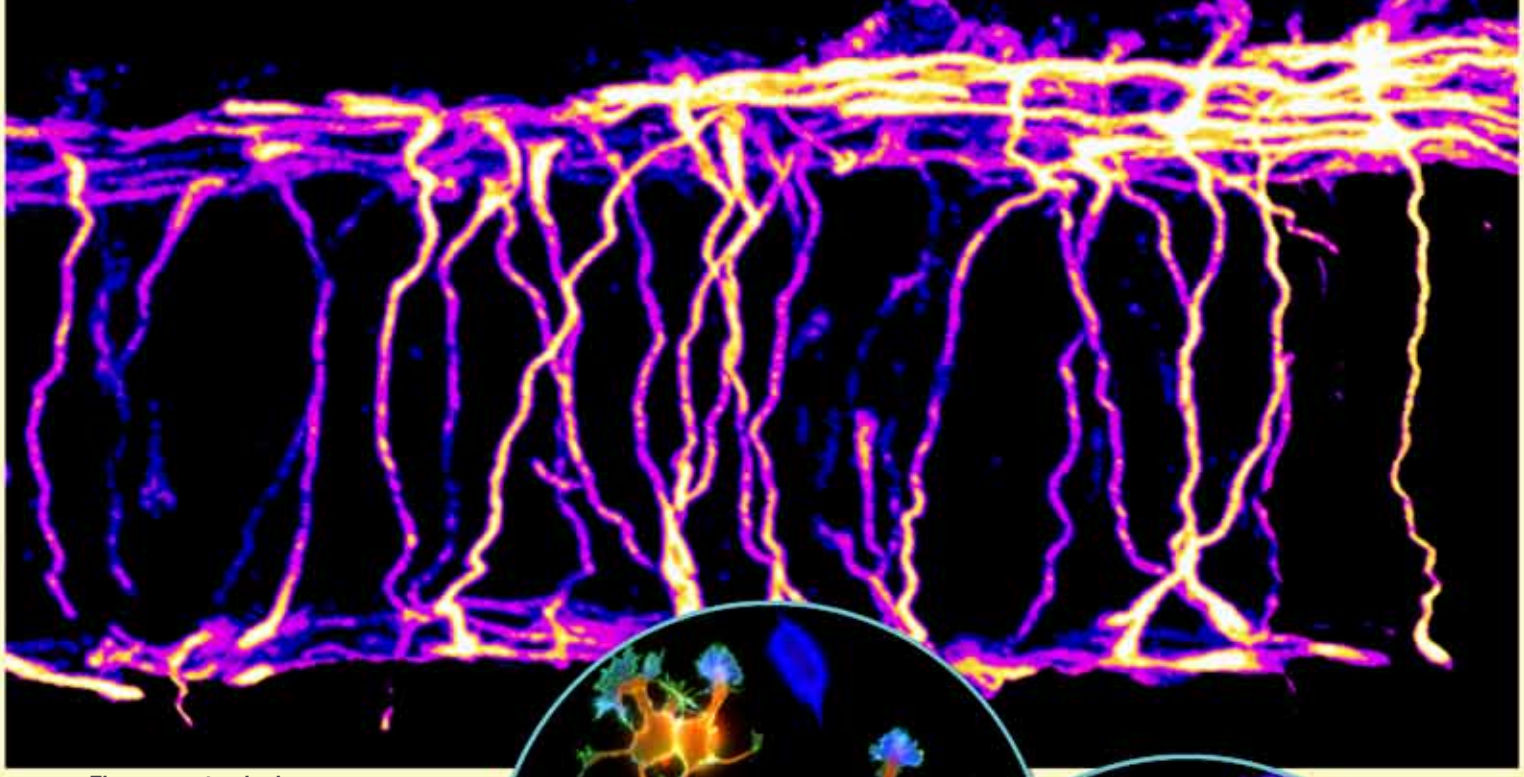
Using autologous mesenchymal stem cells to supply growth factor to neurons, Mayo investigators have completed the safety trials on 15 patients with amyotrophic lateral sclerosis. They are now ready to take their work to clinical trial. This work has regenerative implications for other neurodegenerative diseases.



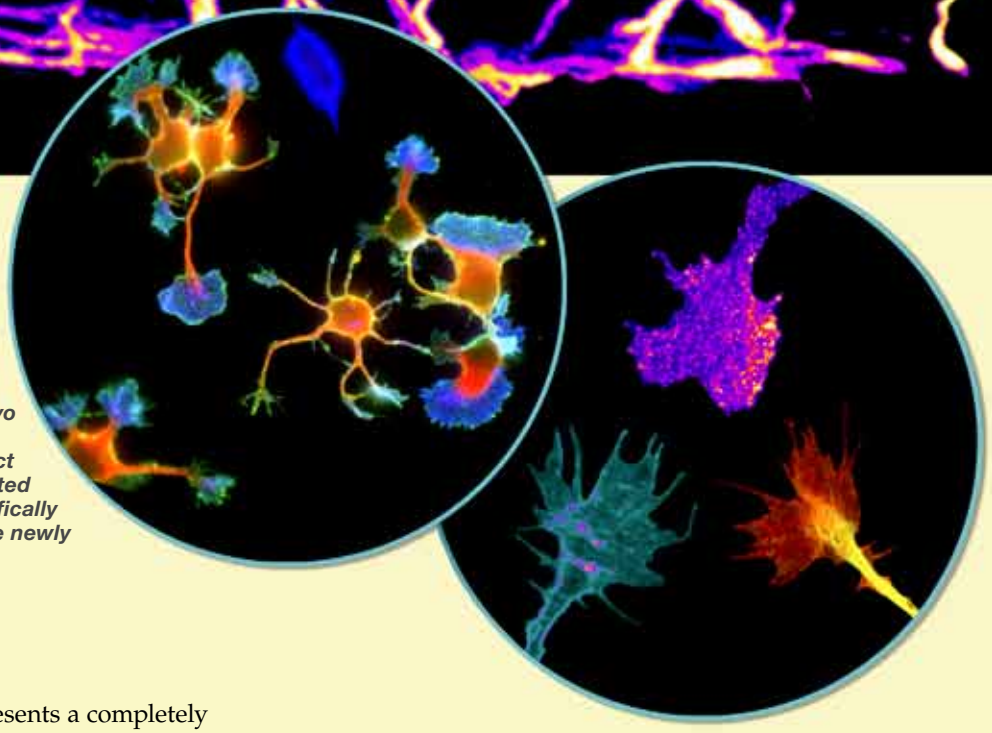
Close-up views of the synthetic polymer scaffolds, with an image (top) of myelinated nerve fibers that have grown in the scaffolds.

3. Central nervous system autoantibody treatment for stimulating axonal outgrowth and remyelination

In the late 1980s, Mayo Clinic investigators discovered and isolated the human autoantibody HIgM2, a naturally occurring immunoglobulin molecule that is the body's first and most rapid response, often referred to as the innate immune response. Having developed a recombinant form and manufactured it in conjunction with the University of Minnesota, they are ready to take the drug to clinical trial as a remyelination treatment for multiple sclerosis



Fluorescent spinal neurons projecting within the spinal cord.



Nerve growth and regeneration (inserts at right). Neurons are labeled with an antibody called* recombinant human ab 12 (rHigM12), *developed at Mayo Clinic. This antibody causes neurons to grow and connect with other neurons. Stimulated neurons show growth specifically in the "growth cones" — the newly developing tips of neurons.

(MS). Recombinant HIgM22 represents a completely unique approach to MS treatment in particular and to restorative central nervous system therapy in general.

In other ongoing work, Mayo neuroscientists are testing biodegradable scaffolding in spinal cord regeneration in animals. Axonal regrowth in the spinal cord presents particular challenges. For example, it must be bidirectional (both toward and away from the brain). To stimulate this regrowth and overcome extrinsic inhibitory factors, this research involves novel use of second messengers, elevating their influence to reprogram nerve growth cones. Future regeneration projects include using adult neural stem cell biology for neurogenesis in the hippocampus, work that is focused on how neurons are generated and form functional circuits.

Regenerative medicine requires extensive collaboration from neurology, neurosurgery, orthopedic surgery, biomedical engineering, molecular neuroscience, immunology, and physiology. By integrating these in-house areas of expertise, Mayo Clinic research teams have made substantial progress toward the regeneration of nerves once considered impossible to save.

Speech Pathology

Speech and language disorders can be the first signs of neurologic disease, and their identification can aid in neurologic differential diagnosis. For this reason, more than half a century ago, the practice of speech pathology at Mayo Clinic in Rochester, Minnesota, began and remains a subspecialty division within the Department of Neurology.

This uncommon administrative arrangement led to a close clinical and research collaboration between neurology and speech pathology that continues today. From it came a systematic classification system for motor speech disorders (ie, the dysarthrias and apraxia of speech). Refined over the years, the system continues to be used in clinical practice around the world. It has spurred influential studies that have improved the understanding of speech disorders associated with a wide range of neurologic diseases, including corticobasal degeneration, multiple systems atrophy, Parkinson's disease, progressive supranuclear palsy, Wilson's disease, primary progressive aphasia and apraxia of speech, and other degenerative conditions.

Mayo's Speech-Language Pathologists Are Active Participants on Many Interdisciplinary Teams, Including the Following:

- Amyotrophic lateral sclerosis clinic
- Cochlear implant program
- Craniofacial clinic
- Deep brain stimulation team
- Learning disorders assessment program
- Multidisciplinary dysphagia team
- Velopharyngeal inadequacy team
- Voice restoration postlaryngectomy team

The modern conceptualization of acquired and childhood apraxia of speech also grew out of work at Mayo Clinic. Today, Mayo is a recognized leader in refining the diagnosis and understanding of childhood apraxia of speech and in the study of innovative treatment approaches.

At Mayo's campus in Rochester, speech-language pathologists are collaborating with behavioral neurologists and imaging scientists in work that is revealing correlations between the clinical speech and language characteristics and biologic and imaging features of various types of neurodegenerative speech and language disorders. From this work, the identification of speech characteristics in conditions such as primary progressive aphasia and apraxia of speech is helping to predict underlying pathology (eg, tauopathy). Other examples of current research across Mayo's three campuses in Arizona, Florida, and Minnesota include investigations of various aspects of dysphagia.

Speech pathology plays an important role in the education of medical students, neurology residents, and students in other medical subspecialties. Clinical fellowships are offered for master's-level speech-language pathologists; a postdoctoral fellowship is offered on the Rochester campus and staff members who have a PhD are on the faculty of the Mayo Medical School.

Across Mayo's three campuses, there are more than 11,000 new patient visits in speech pathology each year. The practice is distinguished by the expertise of its clinicians in the management of a wide variety of rare and common

...the identification of speech characteristics in conditions such as primary progressive aphasia and apraxia of speech are helping to predict underlying pathology...

communication and swallowing disorders. Diagnostic and treatment services are provided in the outpatient, acute hospital, and rehabilitation settings to adults with speech, language, voice, cognitive-linguistic, and swallowing disorders, as well as nonorganic communication disorders that mimic organic conditions. Speech-language pathologists also provide intraoperative monitoring of speech and language function during neurosurgical procedures involving eloquent cortex. Pediatric services are provided at Mayo's campus in Rochester, serving children with speech, language, voice, or swallowing disorders in the outpatient, inpatient, and rehabilitation settings.

Committed to evidence-based practice, interdisciplinary team work, and clinically focused research, the Division of Speech Pathology continues its legacy of providing patients with the highest standards of care.

Spine Disorders: Evaluation and Management

Spine surgery is usually reserved for patients who have refractory pain, loss of neurologic function, or invasive or progressive tumors. At Mayo Clinic, spine surgery is conducted by neurosurgeons, as well as orthopedic surgeons.

Mayo's surgeons take a measured approach to spine care, believing it serves the patient's best interest to proceed from conservative treatment to more aggressive therapy. Across Mayo's three campuses in Arizona, Florida, and Minnesota, Mayo's collaborative practice fosters this approach. Treatment may start with physical therapy or pain medication and injections, or both, as well as acupuncture and behavioral interventions, such as relaxation training and biofeedback. Intervention may include surgery and always includes patient education and counseling.

Referrals that come directly to Mayo's neurosurgical service are managed by an interdisciplinary team that includes neurologists, physiatrists, and pain anesthesiologists. Unlike at other institutions, all patients who have been referred directly to neurosurgery for spine care are first seen by a neurologist or a physiatrist. Close collaboration helps to ensure an accurate diagnosis and appropriate patient selection for surgical intervention. For example, although degenerative changes may be present on an imaging study, numbness and tingling in the hands could be related to multiple sclerosis or due to carpal tunnel syndrome confirmed with neurophysiologic testing (nerve conduction studies and electromyography).

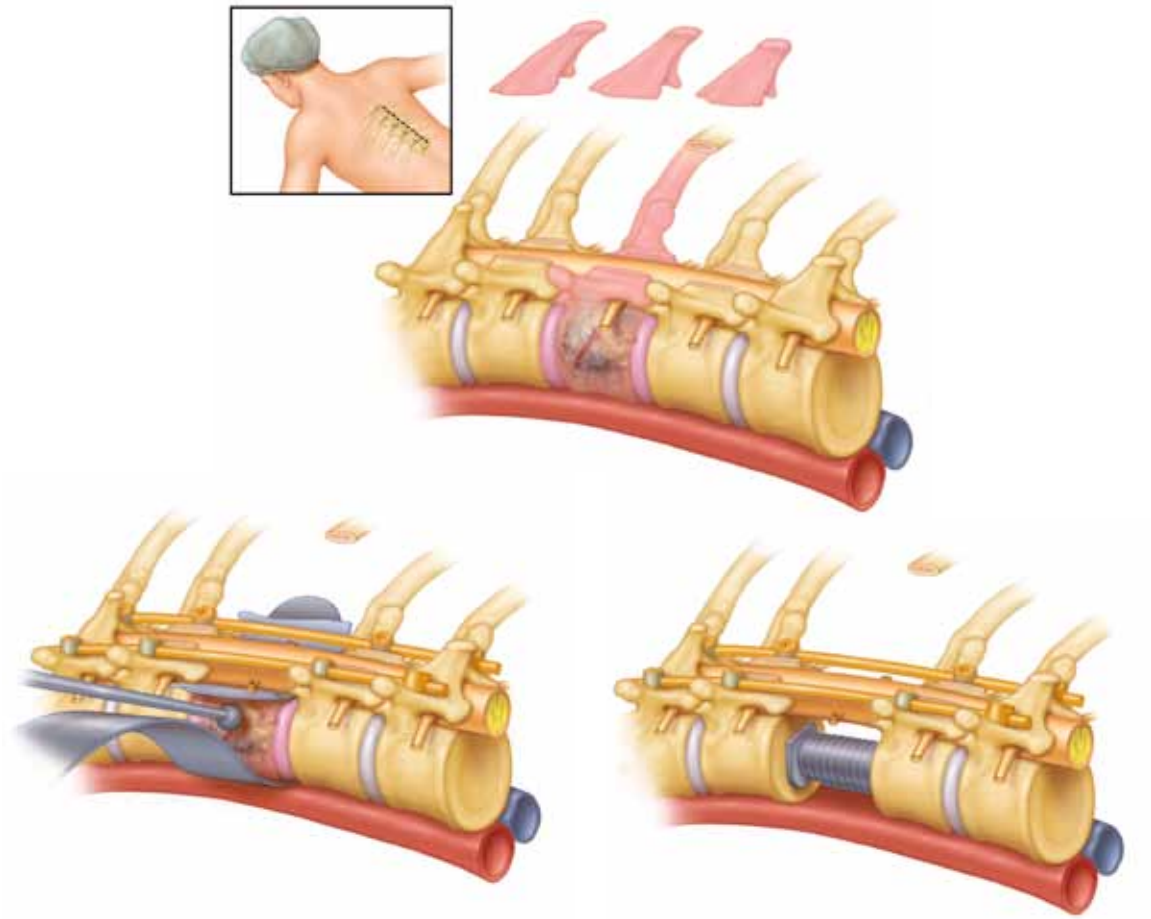
Mayo Clinic evaluates and treats patients with spinal conditions through its Spine Center. In addition, across its three campuses, interdisciplinary physician teams meet to review patient medical records, imaging studies, and other patient-provided data in cases where the potential benefits of further evaluation or treatment are complicated or equivocal. This prereview has saved many patients a trip to Mayo and has expedited the evaluation and treatment for numerous others whom Mayo can help.

3-D image guidance is used to accurately direct implantation of instrumentation, greatly improving screw placement accuracy and patient safety.

In addition to traditional reconstructive surgery, Mayo Clinic has neurosurgeons who specialize in degenerative conditions, such as scoliosis, kyphosis, and tumors of the bony spine, including chordomas. Pediatric spine surgery is also available at Mayo Clinic in Rochester, Minnesota, for various conditions in appropriately selected patients.

Mayo neurosurgeons use the latest surgical techniques, instrumentation, and technologies. For example, 3-D image guidance is used to accurately direct the implantation of instrumentation, greatly improving screw placement precision and patient safety.

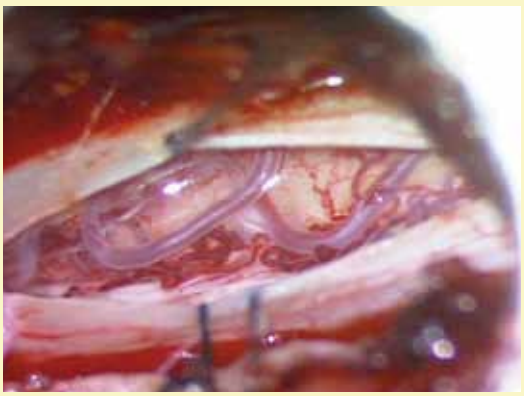
Judicious application of innovative surgical techniques and other nonsurgical forms of treatment provide Mayo Clinic's patients with reasonable expectations and optimal outcomes.



Tumor removal and spine reconstruction.

Minimally Invasive Spinal Surgery is Also Performed at all Three Campuses for Conditions Such as:

- Single-level, focal herniated disks (microdiskectomy)
- Cervical and lumbar spinal stenosis (laminectomy)
- Spinal fusion for one- and two-level disk degeneration



Dural arteriovenous fistula seen through a microendoscopic tubular retractor.

Selected Awards, Appointments, and Recognitions

Minnesota

Neurology

J. Eric Ahlskog, MD, PhD
American Parkinson's Disease Association, Fred Springer Award, 2007.

Allen J. Aksamit Jr, MD
American Academy of Neurology, Section of Neuro-Infectious Diseases, Founding Chair, 2002-2003, Chair-Elect, 2005-2006, Chair, 2006-2009; A.B. Baker Teacher Recognition Award, 2009.

Kimberly K. Amrami, MD
Carman Award, Citizenship Award, 2004. National Institutes of Health, Quick Trials Study Section, Chair, 2010-Present.

J. D. Bartleson Jr, MD
American Academy of Neurology, Spine Section, Chair, 1998-2000 and 2010-2012; Executive Committee Chair, 1998-2000 and 2010-2011; Practice Improvement Subcommittee, Chair, 1999-2005. Minnesota Health Data Institute, Vice-Chair, 2002. Minnesota Society of Neurological Sciences, President, 2002. American Academy of Neurology Pocket Guidelines, Editor, 2003-2007.

Eduardo E. Benarroch, MD
American Academy of Neurology, A.B. Baker Teacher Recognition Award, 2008. Shy Drager Syndrome/ Multiple System Atrophy Research Award, 2005. American Autonomic Association, President, 2002-2004.

Christopher J. Boes, MD
American Academy of Neurology, A.B. Baker Teacher Recognition Award, 2011; Councilor, History of Neurology Section, 2008-Present. *Neurology*, Book Review Editor, 2006-Present. *Headache Currents*, Contributing Editor, 2004-Present.

Bradley F. Boeve, MD
American Academy of Neurology, Councilor, Behavioral Neurology Section, 2007-2009. Association for Frontotemporal Dementias, Chair, 2007-2011. Alzheimer's Association, Minnesota-North Dakota Chapter, Board of Directors, 2002-2008.

John B. Bodensteiner, MD
Child Neurology Society, President-Elect, 2006-2007; President, 2007-2009; Chair, Nominating Committee, 2009-2011. *Journal of Child Neurology*, Senior Associate Editor, 1985-Present.

Andrea J. Boon, MD
American Association of Neuromuscular and Electrodiagnostic Medicine, Annual Meeting, Best Abstract Award, 2010.

Jeffery W. Britton, MD
Society of Clinical Neurologists, Program Chair, 2011.

Michael C. Brodsky, MD
American Association for Pediatric Ophthalmology and Strabismus, Honor Award, 2004. American Academy of Ophthalmology, Senior Achievement Award, 2010. *American Orthoptic Journal*, Associate Editor, Editorial Board, Present. *Binocular Vision and Strabismus Quarterly*, Associate Editor. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, Editorial Board Member, 2001-2010.

Robert D. Brown Jr, MD
American Academy of Neurology, Vascular Neurology Section, Education Workgroup, Chair, 2005-2006. American Heart Association, Stroke Leadership Award, 2001. American Neurological Association, Chair, Education Committee, 2006-2009; Member, Executive Council, 2009-2012. Brain Aneurysm Foundation, Scientific Advisory Board and Research Grant Review Group, Member, 2002-Present.

Melinda S. Burnett, MD
Movement Disorder Society, First Melvin Yahr International Young Scientist Award for Outstanding Work in the Field of Brain and Movement Disorders Research, 2007.

Gregory D. Cascino, MD
American Academy of Neurology, Board of Directors, 2011-Present; President, Section on Epilepsy, 2001-2004; Chair, Membership Committee, 2005-2010; Chair, Nominating Committee, 2006-2011; Topic Chair, Epilepsy, 2000-2003. *Epilepsy Currents*, Contributing Editor, 2001-2004. *Neurology*, Associate Editor, 2009-Present. American Epilepsy Society, Chair, Neuroimaging Special Interest Group, 2001-2004.

Terrence L. Cascino, MD
American Academy of Neurology, Treasurer, Board of Directors, 2009-Present, Secretary, Board of Directors, 2007-2009. American Academy of Neurology Enterprises, Inc, Chair, 2011-Present. American Board of Psychiatry and Neurology, Director, 2012-Present. American Neurological Association, Councilor, 1998-2000. United Council for Neurologic Subspecialties, Chair, 2003-2004.

Shelley A. Cross, MD
North American Neuro-Ophthalmology Society, Chair, By-Laws Committee, 1999-2003.

F. Michael Cutrer, MD
Cephalalgia, Associate Editor, 1999-Present. *Current Opinion in Neurology*, Headache Section, Editor, 2002-Present.

Jasper R. Daube, MD
American Academy of Neurology, Treasurer, 1997-2001. *Annals of Neurology*, Editorial Board Member, 1993-Present. *Electroencephalography and Clinical Neurophysiology*, Editorial Board Member, 1986-Present. *Muscle and Nerve*, Editorial Board Member, 1981-Present.

Joseph R. Duffy, PhD
American Speech-Language-Hearing Association, Honors of the American Speech-Language-Hearing Association, 2006; Chair, Speech Disorders Liaison Group, 1996-2010; Executive Board Member, Communication Sciences and Disorders Clinical Trials Research Group, 1996-2010; Publication Board Member, 2010-Present. *Journal of Medical Speech-Language Pathology*, Editorial Consultant Board, 1992-Present. *International Journal of Language and Communication Disorders*, Executive Editorial Board, 1992-Present.

P. James B. Dyck, MD
American Academy of Neurology, Co-editor, *Continuum of Peripheral Nerve Disorders*, 2001-2003. Society of Clinical Neurologists, President-Elect, 2009-Present, Council Member, 2002-2004 & 2006-2009. United Council for Neurologic Subspecialties, Clinical Neuromuscular Pathology Section, Director, 2006-Present; United Council for Neurologic Subspecialties (UCNS), Clinical Neuromuscular Pathology Subspecialty (CNMP), Director, 2006-Present, Board Member, 2005-2008; Clinical Neuromuscular Pathology Examination Committee, Chair, 2005-Present. Centers for Disease Prevention and Control, Charles C. Shepard Science Award for Assessment and Epidemiology, 2011.

Peter J. Dyck, MD
Quantitative Sensation Testing Society, President and Founding Member, 2004-Present. *Diabetes*, Associate Editor, 2011-Present; Editorial Board Member, 2010-Present. *Muscle and Nerve*, Editorial Board Member, 1998-2004. *Journal of Neurology, Neurosurgery and Psychiatry*, Editorial Board Member, 2004-2009. *Journal of the Peripheral Nervous System*, Editorial Board Member, 2007-2010. *BMJ Case Reports*, 2008-Present.

Scott D. Eggers, MD
American Association of Electrodiagnostic Medicine, Junior Member Recognition Award, 2002.

Andrew G. Engel, MD
Neuromuscular Disorders, Associate Editor, 1997-Present. *Neurology*, Associate Editor, 2007-Present.

Kelly D. Flemming, MD
American Academy of Neurology, A.B. Baker Teacher Recognition Award, 2010.

Keith A. Josephs, MD
American Academy of Neurology, Research Award in Geriatric Neurology, 2008; Norman Geschwind Prize in Behavioral Neurology, 2010. American Philosophical Society, Judson Daland Prize for Outstanding Achievement in Clinical Investigation, 2009. *Frontiers of Dementia*, Review Editor, 2010. Foundation Scholarship to the Queen Square, London, United Kingdom, 2002. Ohio State University Medical Center, Harold Brenner Pepinsky Early Career Award in Neurobehavioral Science, 2009.

David F. Kallmes, MD
Society of Cardiovascular and Interventional Radiology, Dr. Gary J. Becker Young Investigator Award, 2001. Society of NeuroInterventional Surgery, Chair, 2004-Present. *Neuroradiology*, Editor/Reviewer. *Radiology*, Deputy Editor, 2009.

Orhun H. Kantarci, MD
American Academy of Neurology, Founders Award, 2005.

Gesina F. Keating, MD
Society for Neuro-Oncology and Sontag Foundation Award for Excellence in Quality of Life Research, 2003.

B. Mark Keegan, MD
Neurology, Section Editor, 2007-Present.

Christopher J. Klein, MD
Cochrane Updates in Neuromuscular Treatment Trials, Co-editor, 2004-Present. *Journal of the Peripheral Nervous System*, Co-editor, 2006-Present.

David S. Knopman, MD
Neurology, Deputy Editor, 2009-Present; Associate Editor, 2007-2009. National Institute on Aging/Alzheimer's Association, Co-chair, Workgroup for the Revision of the Diagnosis of Dementia, 2010-2011. Association for Frontotemporal Dementias, Board Member, 2010-Present.

Suresh Kotagal, MD
US Food and Drug Administration, Consultant, Neurological Devices Section, 2010-Present. Child Neurology Society, Councilor, Midwest Region, 2011-Present; Board of Directors, 2011-Present. Professors of Child Neurology, Secretary/Treasurer, 2011-Present.

Ruple S. Laughlin, MD
Society of Clinical Neurologists, Board of Councilors, 2011-2013.

Vanda A. Lennon, MD, PhD
American Academy of Neurology, Frontiers in Clinical Neuroscience Lecturer, 2006. American Association of Neuromuscular and Electrodiagnostic Medicine, Annual Meeting Edward Lambert Lecturer, 2006.

Philip A. Low, MD
Journal of the Autonomic Nervous System, Associate Editor, 1995-Present.

Claudia F. Lucchinetti, MD
American Academy of Neurology, Frontiers in Neuroscience Lecture, Beyond the Decade of the Brain, 2002. The Teva Neuroscience Parisi Research Lectureship, 2008.

Kenneth J. Mack, MD, PhD
eMedicine Child Neurology, Chief Medical Editor, 2000-2005.

Michelle L. Mauermann, MD
American Association of Neuromuscular and Electrodiagnostic Medicine, Editorial Board Member, 2009-Present.

Irene Meissner, MD
American Heart Association, Bugher Foundation Award, 2001-2004.

Bahram Mokri, MD
American Headache Society, John R. Graham Senior Clinician's Forum Award, 2004.

John H. Noseworthy, MD
American Academy of Neurology, Board of Directors, 2007-Present; Science Committee, Chair, 2003-2006; Awards Committee, Chair, 1999-2001. Sylvia Lawry Multiple Sclerosis Research Center, Publication Committee, Chair, 2002-Present; Scientific Oversight Committee, Chair, 2001-Present. *Neurology*, Editor-in-Chief, 2007-2009; Editorial Board Member, 1997-2006. *Canadian Journal of Neurological Sciences*, Editorial Board Member, 1995-2004. *Journal of Neurology*, Editorial Board Member, 2000-2005.

Brian P. O'Neill, MD
American Academy of Neurology, Councilor, 2006-Present. Sontag Foundation, Scientific Advisory Board, Founding Member, 2003-Present. *Journal of Neuro-Oncology*, Editorial Board Member, 2006-Present. *NeuroOncology*, Editorial Board Member, 2006-Present. *CNS Oncology*, Editorial Board Member, 2011-Present; Founding Member, 2011-Present.

Marc C. Patterson, MD
American Academy of Neurology, Councilor, Child Neurology Section, 2011-Present. Niemann-Pick Disease Type C (NPC) Registry, Chair, Scientific Committee, 2009-Present. Rose F. Kennedy Intellectual and Developmental Disorders Research Center, External Advisory Board Member, 2011-Present. American Board of Psychiatry and Neurology, Chair, Neurodevelopmental Disabilities Examination Committee, 2010. Stem Cells Inc, Chair, Data Monitoring Committee. World Health Organization International Advisory Group for the Revision of ICD-10 Diseases of the Nervous System, Leader, Child Neurology Group, 2009-Present.

Ronald C. Petersen, MD, PhD
American Academy of Neurology, Potamkin Prize for Pick's, Alzheimer's and Related Dementias, 2005. National Alzheimer's Association, Washington, DC, Ronald and Nancy Reagan Research Institute Award, 2004. MetLife Foundation, Award for Medical Research in Alzheimer's Disease, 2004. Alzheimer's Disease Centers Directors' Executive Committee, Advisory Panel, Chair, 2000. Alzheimer's Association, Chair, 2008-Present. Alzheimer's Association, Medical and Scientific Advisory Council, Chair, 2008-Present. US Department of Health and Human Services, Chair, Advisory Council on Alzheimer's Research, Care and Services, 2011. *Alzheimer's & Dementia*, Editorial Board Member, 2005-Present. *Alzheimer's Research & Therapy*, Editorial Board Member, 2008-Present. *Annals of Neurology*, Editorial Board Member, 1997-2002. *Continuum*, Editorial Board Member, 2003-Present.

Istvan Pirko, MD
American Neurological Association, Travel Fellowship Award, 2002 and 2004. *BioMedCentral Neurology*, Associate Editor, 2010-Present. *Nanomedicine: Nanotechnology, Biology and Medicine*, Clinical Editor, 2009-Present.

Sean J. Pittock, MD
Irish Neurological Association Meeting, Harold Miller Prize, 2006.

Alejandro A. Rabinstein, MD
American Heart Association, Vice-Chair, Stroke Guidelines Oversight Committee, 2010-Present.

Moses Rodriguez, MD
American Academy of Neurology, Frontiers in Neuroscience Award, 2008. Center for Multiple Sclerosis and Central Nervous System Demyelinating Diseases Research and Therapeutics, Director, 2011-Present.

Paola Sandroni, MD, PhD
American Academy of Neurology, Chair, Autonomic Nervous System Section, 2011-Present; Chair-Elect, Autonomic Nervous System Section, 2008-2010.

Duygu Selcen, MD
World Muscle Society, The President's Prize for the Young Myologist of the Year, 2007.

Michael H. Silber, MB, ChB
American Board of Sleep Medicine, President, 2000-2003. American Academy of Sleep Medicine, President, 2006-2007, Nathaniel Kleitman Award, 2010.

Wolfgang Singer, MD
American Academy of Neurology, Leader, Science Committee of Autonomic Nervous System Section, 2005-2008. National Institutes of Health, Building International Research Careers in Women's Health Award (K12 Program), 2011.

Elson L. So, MD
American Academy of Neurology, Chair, Clinical Neurophysiology Section, 2004-2006. Philippine Neurological Society, Gilberto Gamez Award, 2005. American Epilepsy Society, Vice President, 2011-2012; Board of Directors, 2008-2010; Chair, Special Interest Groups Oversight Committee of the Board of Directors, 2008-2010. American Epilepsy Society and Epilepsy Foundation of America Joint Task Force, Chair, 2007. *Journal of Clinical Neurophysiology*, Editorial Board Member, 2008-Present. *Epilepsy Research*, Editorial Board Member, 2006-Present. *Epilepsia*, Editorial Board Member, 2010-Present.

Eric J. Sorenson, MD
American Association of Neuromuscular and Electrodiagnostic Medicine, Chair, Research Committee, 2008-Present. National ALS Research Group, Board of Directors, 2011-Present.

Kathryn A. Stolp, MD
Association of Academic Physiatrists, President-Elect, 2010-Present. American Association of Neuromuscular and Electrodiagnostic Medicine, President, Board of Directors, 2006-2007; Chair, Finance Committee, 2002-2005; Chair, Disciplinary Committee, 2007-2008; Chair, Nominating Committee, 2008-2009 and 2011-Present. American Board of Electrodiagnostic Medicine, Treasurer, 2011-Present; Board Member, 2011-Present; Secretary, 2001-2002; Chair, Recertification Examination Committee, 2000-2002. *Archives of Physical Medicine and Rehabilitation*, Editorial Board Member, 1999-Present. *Journal of Clinical Neuromuscular Disease*, Editorial Board Member, 1999-Present; Associate Editor, Clinical Images, 1999-2005.

Joon H. Uhm, MD
Sontag Foundation, Distinguished Scientist Award, 2003-2006.

Brian G. Weinshenker, MD
American Academy of Neurology and National Multiple Sclerosis Society John Dystel Prize for Multiple Sclerosis Research, 2011.

Eelco F.M. Wijdicks, MD, PhD
American Academy of Neurology, Chair, Section of Critical Care and Emergency Neurology, 1989-Present. *Lancet Neurology Network*, Associate Editor, 2000-2001. *Neurocritical Care*, Editor-in-Chief, 2004-Present.

Elaine C. Wirrell, MD
Royal College of Physicians and Surgeons, Canada, Vice-Chair, Neurology Examination Committee, 2009-Present.

Gregory A. Worrell, MD, PhD
CURE Foundation, Chicago, Illinois, The Maggie Loeffel Award, 2005. Epilepsy Foundation of Minnesota, Board Member, 2008-Present. *Epilepsy Currents*, Associate Editor, 2010-Present.

Neurosurgery

John L. D. Atkinson, MD
American College of Surgeons, Chair, Advisory Council for Neurological Surgery, 2009-Present. Neurosurgical Society of America, Secretary, 2007-Present.

William E. Krauss, MD
World Neurosurgery, Editor/Reviewer, 2009.

Giuseppe Lanzino, MD
Minnesota Neurosurgical Society, President, 2011-Present. *Stroke*, Co–Section Editor, Neurosurgery, 2008-Present. *Journal of Neurosurgery*, Editorial Board Member, 2007-Present. *Neurocritical Care*, Editorial Board Member, 2008-Present.

Kendall H. Lee, MD, PhD
American Association of Neurological Surgeons, Philip Gildenberg Award, 2004. *Journal of Neural Engineering*, Editorial Board Member, 2011-Present. *Neuromodulation: Technology at the Neural Interface*, Editorial Board Member, 2010-Present.

Michael J. Link, MD
North American Skull Base Society, Director at Large, 2007-2010. Acoustic Neuroma Association, Medical Advisory Board Member, 2008-Present.

Fredric B. Meyer, MD
American Board of Neurological Surgeons, Director. Congress of Neurological Surgery, Drake Lecture, 2011. *Journal of Neurosurgery*, Editorial Board Chair, 2010.

Ian F. Parney, MD, PhD
Alberta Heritage Foundation for Medical Research, Research Prize, 2004-2008, Clinical Investigator, 2004-2008.

Bruce E. Pollock, MD
International Stereotactic Radiosurgery Society, Chair, Awards Committee, 1999-2007. Trigeminal Neuralgia Association, Medical Advisory Board Member, 2003-Present. American Association of Neurological Surgeons/Congress of Neurological Surgeons, Section on Tumors, Integra Foundation Award, 2005. Research Foundation of the American Association of Neurological Surgeons, Hunt-Wilson Young Clinician Investigator Award, 2000.

Robert J. Spinner, MD
American Association of Clinical Anatomists, Presidential Award, 2005. American Association of Neurological Surgeons/Congress of Neurological Surgeons, President, Joint Section on Disorders of the Spine and Peripheral Nerves, 2009-2011; President, Peripheral Nerve Task Force, 2009-2011. American Society for Peripheral Nerve, President, 2012-2013. Sigma Xi, The Scientific Research Society, President, 2011-2012. Sunderland Society, President, 2007-2008.

Arizona

Neurology

Charles H. Adler, MD, PhD
American Association of Neurology, Chair, Scientific Session, 2000-2005. Arizona Parkinson's Disease Consortium, Co-Principal Investigator.

Jonathan L. Carter, MD
Arizona Neurological Society, President, 2009-2011.

Richard J. Caselli, MD
Arizona State University, WP Carey School of Business, Board Member, Center for Services Leadership, 2010-Present. Flinn Foundation, Board Member, 2011-Present. Alzheimer's Association, Desert Southwest Chapter, Board Member, 2011-Present. Arizona Alzheimer's Disease Center, Clinical Core Director, 2000.

Brian W. Chong, MD
Western Neuroradiological Association, Chair, 2005-2006.

Bart M. Demaerschalk, MD
Arizona Department of Health Services, State of Arizona Cardiovascular Disease Program, Chair, Surveillance Workgroup, 2005-Present. Stroke Center for Excellence, A World Research Group Award, 2006. *The Neurologist*, Section Co-editor, Critically Appraised Topic and The Evidence-Based Neurologist, 2007-Present. *Journal of Brain Disease*, Founding Editor-in-Chief, 2008-Present. *Frontiers in Teleneurology*, Associate Editor, 2009-Present. *Journal of Stroke and Cerebrovascular Diseases*, Editorial Board Member, 2009. *Stroke*, Editorial Board Member, 2006-Present. *The Open Critical Care Medicine Journal*, Editorial Board Member, 2008-Present.

Joseph F. Drazkowski, MD
American Epilepsy Society, Vice-Chair, Membership Committee, 2011-Present. Arizona Epilepsy Foundation, Secretary, 2007-Present; Board of Directors, 2000-2009. Arizona Department of Transportation, Medical Review Program, Board Member, 1999-Present.

Erika D. Driver-Dunckley, MD
Arizona Neurological Society, Secretary, 2009-Present. *Parkinsonism and Related Disorders*, Book Review Editor, 2007-2008. MedInfoNow Book Review Service, Editor, Movement Disorder Section, 2009-Present.

David W. Dodick, MD
American Headache Society, President, 2010-2012. World Congress of Neurology Headache Research Group, Vice-Chair, 2010-Present. *Cephalalgia*, Editor-in-Chief, 2009-Present. *Headache Currents*, Editor-in-Chief, 2005-2009. *Lancet*, Editorial Board, 2010-Present. *The Neurologist*, Editorial Board, 2007-Present.

Yonas E. Geda, MD
American Neuropsychiatric Association, Chair, Awards Committee, 2011-Present. Academy of Psychosomatic Medicine, Chair, Neuropsychiatry Special Interest Group, 2008-Present. National Institutes of Health, Research Scientist Development Award, 2004-2009.

Rashmi B. Halker, MD
American Headache Society, Co-Editor, *Headache News*, 2010-Present.

Timothy Ingall, MD, PhD
American Stroke Association, Stroke Advocate of the Year Award, 2003. Arizona Stroke Initiative, Chair, 1998-Present. Arizona Cardiovascular Disease State Plan, Chair, 2006-Present.

Katherine H. Noe, MD, PhD
Epilepsy Foundation of Arizona, Board Member, 2009-Present.

Alyx B. Porter, MD
American Neurological Association, Minority Scholars Award, 2006.

Mark A. Ross, MD
American Clinical Neurophysiology Society, President, 2007. *Frontiers in Neuromuscular Diseases, Frontiers in Neurology*, Chief Editor, 2010-Present.

Joseph I. Sirven, MD
The Alliance for Continuing Medical Education: International Association of Continuing Medical Education Professionals, President's Award for Outstanding Leadership and Educational Contributions to Continuing Medical Education, 2006. Epilepsy Foundation of America, Chair, 2012-2013. Western Clinical Neurophysiology Society, President, 2007-2009. *Clinical Geriatrics*, Editor, 2005-2007. Epilepsy.com, Editor-in-Chief, 2010-Present. *Profiles in Seizure Management*, Editor, 2002-2004.

Neurosurgery

Mark K. Lyons, MD
Charles A. Dana Foundation, Patients' Choice Award, 2008-2010.

Naresh P. Patel, MD
IBC International Achievement Award, 2006.

Richard S. Zimmerman, MD
Health Services Advisory Group/Arizona Hospital and Healthcare Association, Arizona Partnership for Innovation in Patient Safety Award, 2007. Arizona State Regulatory Board for Physician Assistants, Vice-Chair, 1999-2001. National Trigeminal Neuralgia Association, Medical Advisory Board, 2004-Present. Neuropathy Action Foundation, Board of Directors, 2007-Present. *Clinical Neurology News*, Editorial Advisory Board, 2010-Present.

Florida

Neurology

Thomas G. Brott, MD
US Food and Drug Administration, Chair, Neurological Devices Panel, 2005-2008. National Stroke Association, Vice-Chair, 2000-2004, Board of Directors, 1993-2004. National Institute of Neurological Disorders and Stroke Advisory Council, Clinical Trials subcommittee, Co-Chair, 2009-2011; Chair, 2011-Present.

David J. Capobianco, MD
American Academy of Neurology, Chair, Consortium of Neurology Program Directors, 2011-2013, Program Directors Award, 2011.

William P. Cheshire Jr, MD
American Academy of Neurology, A.B. Baker Teacher Recognition Award, 2004; Chair, Autonomic Nervous System Section, 2002-2004; Chair, Autonomic Disorders Scientific Program, 2010-2012. Christian Medical and Dental Associations, Chair, Ethics Committee, 2011-Present. *Autonomic Neuroscience: Basic and Clinical*, Editorial Board, 2010-Present.

Dennis W. Dickson, MD
American Academy of Neurology, Potamkin Prize, 2011.

Elliot L. Dimberg, MD
Florida Society of Neurology, Board of Directors, 2011-Present, Co-Chair, Education Committee, 2011-Present.

Benjamin H. Eidelman, MD
American Academy of Neurology, A.B. Baker Teacher Recognition Award, 2008. National Multiple Sclerosis Society, Chair, National Council of Professional Advisory Committee Chairs, 1998-2001. International Society of Cerebral Blood Flow and Metabolism, Founding Member.

William D. Freeman, MD
Florida Medical Association, Distinguished Physician Award, 2005. Irene Madrak Award for Excellence in Pediatric Neurology, 2005. Robert H. and Clarice Smith/ M.L. Simpson Foundation Trust Research Fellowship, 2007-2008.

Kurt A. Jaeckle, MD
American Academy of Neurology, Chair, Section of Neuro-Oncology, 2000-Present; Chair, Preuss Award Committee, 2000-2008. North Central Cancer Treatment Group, Co-Chair, Neuro-Oncology Committee, 2001-2011. United Council on Subspecialty Certification, Board Member, 2005-2009. Society of Neuro-Oncology, Chair, By-Laws Committee, 1996-2010. Florida Center for Brain Tumor Research, Scientific Advisory Council, 2006-2008. National Cancer Institute, Chair, Special Emphasis Panel American Brain Tumor Consortium Grant Review, 2010.

Kathleen D. Kennelly, MD, PhD
American Academy of Neurology, A.B. Baker Teacher Recognition Award, 2010. American Association of Neuromuscular and Electrodiagnostic Medicine, Board of Directors, 2007-2010.

James F. Meschia, MD
Journal of Stroke and Cerebrovascular Diseases, Associate Editor, 2009-2010; Editorial Board Member, 2011-Present. *Stroke*, Section Editor, Genetics, 2011-Present.

Eric W. Nottmeier, MD
International Society for the Study of the Lumbar Spine, The ISSLS Award, 2005. Southern Neurological Society, Vice President, 2011.

Devon I. Rubin, MD
American Academy of Neurology, A.B. Baker Teacher Recognition Award, 2009. American Association of Neuromuscular Electrodiagnostic Medicine, Chair, Digital Media Education Committee, 2007-Present.

Jerry J. Shih, MD
Western Clinical Neurophysiology Society, President, 2002. National Association of Epilepsy Centers, Board Member, 2011.

Nilufer Taner, MD, PhD
Frontiers in Neurogenomics, Editorial Board Member. *The Scientific World Review*, Editorial Board Member.

William O. Tatum, DO
American Board of Registered EEG Technologists, Board of Directors, 2001-2007. American Clinical Neurophysiology Society, Board of Directors, 2005-Present, Council Member, 2009-2012. American Clinical Neurophysiology Society, Chair, Course Committee for Annual Meeting, 2010-2012.

Zbigniew K. Wszolek, MD
Duval County Medical Society, John A. Beals Award for Medical Research, 2004 and 2011. *Parkinsonism and Related Disorders*, Associate Editor for Reviews, 2005-2008. *Neurology*, Polish Edition, Co-Editor-in-Chief, 2003-2009. *European Journal of Neurology*, Regional Editor, 2007-Present.

Ryan J. Uitti, MD
World Federation of Neurology Association of Parkinsonism and Related Disorders, Executive Board Member, Secretary, 2009-Present. Duval County Medical Society, John A. Beals Award for Medical Research, 2005. University of Saskatchewan College of Medicine, Honorary President and Alumni Award Lecturer, 2008. *Neurology*, Associate Editor, 2006-Present.

Neurosurgery

Stephen Pirris, MD
Theodore Kurze Senior Prize in Clinical Neuroscience, 2002.

Robert E. Wharen Jr, MD
Neurosurgical Society of America, Vice President, 2011. Southern Neurological Society, President, 2008-2009, Treasurer, 2004-2007.

Mayo Clinic Health System

Neurology

Donn D. Dexter, MD
Wisconsin Medical Society, Council on Legislation, 2007-Present; University of Wisconsin Organ Procurement Organization, Certificate of Excellence Award, Star Recognition, 2009.

Neurosurgery

Douglas Chyatte, MD
Minnesota Neurosurgical Society, President, 2010-2011; Secretary/Treasurer, 2008-2010; Executive Committee, 2008-Present.

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