As a fully integrated and multidisciplinary center, Mayo Clinic provides comprehensive care for people with spinal tumors. All three Mayo Clinic campuses have expertise with the range of treatments for primary and metastatic disease.

“We take a holistic approach to spinal oncology,” says Maziyar A. Kalani, M.D., a neurosurgeon at Mayo Clinic in Phoenix/Scottsdale, Arizona. “In addition to surgery, we use decompression, stabilization, various ablation technologies and minimally invasive cement augmentation. We offer the gamut of available treatments to meet whatever needs an individual patient has.”

That capability rests upon Mayo’s enterprisewide, multidisciplinary expertise. Neurosurgeons collaborate with neuroradiologists, oncologists, radiation oncologists, and specialists in physical medicine and rehabilitation (PM&R).

“We have a high-volume practice in both primary and metastatic tumors, and a number of specialists in each department at each site who are experts in spinal oncology,” says Mohamad Bydon, M.D., a neurosurgeon at Mayo Clinic in Rochester, Minnesota.

Coordinating care in these complex cases requires strong communication among medical services. Neurosurgeons, neuroradiologists and radiation oncologists routinely confer on challenging cases.

“Our ability to communicate with providers from different specialties who are all on one campus — as well as to obtain input from colleagues from the other two campuses — allows us to maximize the benefits of team management for our patients,” says Kingsley Abode-Iyamah, M.D., a neurosurgeon at Mayo Clinic in Jacksonville, Florida. “That ability is especially important when we deal with rare and technically challenging spinal tumors. Our combined experience helps us to better benefit each patient.”

Figure 1. T2-weighted image shows an extensive syrinx associated with an intramedullary hemangioblastoma in a 19-year-old woman with von Hippel-Lindau disease.
**Blending technology and patient-focused care**

Mayo Clinic uses the latest technology for the expeditious diagnosis and treatment of spinal tumors. “Our ability to get high-resolution MRI scans and radionuclotide studies, such as positron emission tomography and single-photon emission computerized tomography, helps with both diagnostic quandaries and pre-surgical planning,” says Selby G. Chen, M.D., a neurosurgeon at Mayo Clinic’s campus in Florida.

Proton beam therapy, which allows radiation delivery to conform more closely to the tumor, is available at Mayo Clinic’s campuses in Arizona and Minnesota. The pencil beam technology used at Mayo offers added precision by delivering protons in a raster pattern at different specific depths, to better conform to the volume of the tumor.

Mayo Clinic also uses recently approved carbon fiber implants, which can allow for lower radiation doses than traditional titanium hardware. “Titanium is so dense that the protons can bounce off when it’s implanted in patients,” Dr. Kalani says. “To compensate, radiation oncologists have to increase the depth of penetration and the proton dosage. Carbon fiber is a composite, not a metal, so it avoids that issue.”

Decisions about the use of technology are based on each patient’s needs. Mayo Clinic’s multidisciplinary approach is aimed at devising the optimal individualized treatment plan — avoiding unnecessary surgery and employing complementary treatment modalities when they can help improve treatment outcome and survival.

“We try to adopt minimally invasive approaches whenever appropriate, to help speed recovery and decrease postoperative pain,” Dr. Chen says. “However, when larger surgeries are needed, we don’t hesitate to do a more extensive operation that may involve multiple spinal surgeons as well as vascular surgeons, general surgeons or orthopedic surgeons.”

Decision-making is enhanced by Mayo Clinic’s high-volume practice in spinal oncology. “We have enough patient volume to continuously follow our metrics and improve patient care. We have the numbers to drive change,” says Michelle (M.J.) J. Clarke, M.D., a neurosurgeon at Mayo Clinic in Rochester, Minnesota.

Technology and the commitment to patient-focused care allow Mayo Clinic to manage even the most complex spinal tumors. Dr. Bydon cites the recent case of a 19-year-old woman with von Hippel-Lindau disease who was successfully treated at Mayo Clinic’s campus in Minnesota. The patient had an intramedullary hemangio-blastoma with extensive syrinx (Figure 1, page 1).

“The tumor was large,” Dr. Bydon says. “It encompassed the patient’s spine and resulted in an accumulation of fluid that was damaging the spinal cord. The patient experienced weakness in her legs and symptoms of myelopathy.

The surgical treatment, which included laminectomy and tumor resection, was complicated by the tumor’s size and location in the spinal cord. “We had to navigate around the spinal cord and very carefully dissect the blood vessels, to avoid removing any vessels important to the spinal cord,” Dr. Bydon says.

The patient emerged from tumor resection (Figure 2, page 2) with improvement in her legs and was able to leave the hospital two days later. “The tumor has been removed in whole, and the syrinx is resolving,” Dr. Bydon says.

Surgery is only one aspect of the comprehensive care that patients with spinal tumors need. Mayo Clinic’s specialists in PM&R provide extensive rehabilitation after spinal operations. In addition, patients with a genetic condition such as von Hippel-Lindau disease can be followed by medical geneticists and other specialists as needed.

“When patients are referred to Mayo, we look after all their needs,” Dr. Kalani says. “If patients are too sick for surgery, we don’t have to operate. But we can provide other treatment to ease their symptoms. We can help preserve quality of life.”

---

**Figure 2.** Postoperative MRI demonstrates no residual tumor and resolution of the syrinx in the patient with von Hippel-Lindau disease.
Autoimmune Neurology: Evolving Care for Immune-Inflammatory Diseases of the CNS

Alfonso (Sebastian) S. Lopez Chiriboga, M.D., and Iris (Vanessa) V. Marin Collazo, M.D., neurologists in Multiple Sclerosis and Autoimmune Neurology at Mayo Clinic in Jacksonville, Florida, discuss autoimmune neurology, one of neurology’s most rapidly evolving subspecialties.

Q: What is autoimmune neurology?
Autoimmune neurology encompasses immune-inflammatory diseases of the central nervous system (CNS) other than multiple sclerosis (MS). The autoimmune neurology subspecialty is driven by recent discoveries of multiple autoantibodies that target proteins expressed in the CNS. Those discoveries helped to increase recognition of autoimmunity as the cause of neurological conditions misdiagnosed as primarily psychiatric disorders, degenerative diseases such as dementia or infections.

Autoimmune neurology interacts with many other subspecialties, including behavioral neurology, epilepsy and movement disorders, as well as other medical specialties, including rheumatology, gastroenterology, oncology and psychiatry.

Q: What types of conditions are seen in patients at Mayo’s MS/autoimmune clinic?
Most patients have antibody-mediated CNS disorders such as autoimmune encephalitis or autoimmune epilepsy, or an autoimmune movement disorder such as stiff person syndrome or ataxia. The clinic team also evaluates and provides care to patients with neuromyelitis optica spectrum disorder (NMOSD), optic neuritis, transverse myelitis and neurosarcoidosis, in addition to MS. The multidisciplinary clinic offers integrated care in a one-time visit.

Q: When should a physician refer a patient to the MS/autoimmune clinic?
Patients who would benefit from referral include those with suspected or confirmed autoimmune encephalitis, NMOSD, optic neuritis, transverse myelitis or neurosarcoidosis.

In addition, physicians should consider referral for patients with:
• Neurological symptoms in the setting of a diagnosis of cancer
• New-onset epilepsy with no clear explanation, especially if seizures have been refractory to more than one anti-epileptic medication
• A history of autoimmunity — such as lupus, Sjögren’s disease, Crohn’s disease, rheumatoid arthritis or sarcoidosis — and the development of new neurological symptoms suspicious for CNS involvement

Q: At Mayo Clinic, these patients are seen by autoimmune neurologists. Why is that distinction important?
The complexity of the clinical presentations, the longitudinal follow-up and the medications used for these disorders require expertise in the optimal management of these conditions. Mayo Clinic’s autoimmune neurologists have formal fellowship training in their subspecialty.

Many disorders can be mistaken as autoimmune encephalitis. Use of unnecessary immunotherapy in patients can have serious adverse effects, including the potential risk of severe infections or cancer. Mayo Clinic noted, in research published in Neurology in 2017, the importance of being evaluated by an autoimmune neurologist subspecialist to avoid these problems.

Additional research indicates that autoimmune encephalitis is more common than previously known. In the Annals of Neurology in 2018, Mayo Clinic published results of the first population-based comparison study of autoimmune encephalitis and infectious encephalitis. Our study found that the prevalence and incidence of autoimmune encephalitis are comparable to infectious encephalitis, and the detection of autoimmune encephalitis is increasing over time.

Q: What is Mayo Clinic’s approach to the diagnosis and treatment of autoimmune neurological conditions?
Patients are seen by physicians with expertise in diagnosing and managing the sequelae of CNS autoimmunity — not only neurologists but also psychiatrists, rheumatologists and neuropsychologists. In addition, patients are in close contact with nursing staff with expertise in managing symptoms and monitoring immunotherapy. Under Mayo Clinic’s multidisciplinary approach, patients may also be seen by specialists in epilepsy, behavioral neurology or movement disorders, to ensure the best possible care and recommendations.

Autoimmune neurological disorders require expert evaluation to provide an accurate diagnosis. Mayo Clinic’s state-of-the-art resources (Figure, page 4) include high-field MRI and a dedicated immunology laboratory for the diagnosis, treatment, rehabilitation and longitudinal care of patients with these disorders. Test results and treatment plans are typically generated in less than two weeks.
There are no FDA-approved medications for most autoimmune neurological diseases. But Mayo Clinic is at the forefront of studying new therapies and treatment protocols. Patients benefit from the most current therapeutic options.

For more information


Spinal Dural AVF: A Potential Cause of Syringomyelia

Syringomyelia is characterized by the formation of a fluid-filled cyst or syrinx in the spinal cord. The syrinx can expand over time, compressing or damaging neuronal tissue. Syringomyelia is most commonly associated with Chiari malformation type I, trauma, spinal cord tumors or inflammatory disease; however, some cases are idiopathic.

Mayo Clinic recently identified a spinal dural arteriovenous fistula (AVF) in a patient referred to Mayo with a diagnosis of idiopathic syringomyelia. The spinal dural AVF was successfully treated at Mayo Clinic, and the patient made a strong recovery (Figure, page 5).

“We believe that idiopathic syringomyelia shouldn’t be diagnosed without serious consideration of spinal dural AVF, especially if the syrinx is growing,” says Christopher J. Klein, M.D., a neurologist at Mayo Clinic in Rochester, Minnesota. “We don’t know how common this association might be or how many of these cases are missed. But we have seen rapid progression of neurological symptoms when an idiopathic syrinx is expanding. Early diagnosis can help prevent permanent myelomalacia and nerve root damage.”

The patient referred to Mayo Clinic was a 68-year-old man who experienced three years of progressive, painless lower extremity weakness. Formerly an avid hiker, he required assistance from two people to stand and walk. Before referral to Mayo Clinic, the patient had an MRI scan that showed a large cervicothoracic syrinx associated with cervical stenosis. He then underwent cervical decompression and fusion, but continued to worsen.

A subsequent MRI with contrast showed enlargement and enhancement of the patient’s nerve roots. Electromyography and nerve conductions identified an axonal predominant chronic-active polyradiculopathy; analysis of the patient’s cerebrospinal fluid found elevated protein. A diagnosis of inflammatory myelopolyradiculopathy with syrinx was postulated, but the patient didn’t respond to six months of anti-inflammatory treatment.

“When the patient came to Mayo, we looked very carefully at his MRI scans and saw flow voids,” Dr. Klein says. “Angiogram confirmed the abnormal connection between the vein and artery that leads to the pressure differential and spinal dural AVF.”

The spinal dural AVF was treated with transarterial embolization. Three months after the procedure, imaging of the patient’s spine showed that the cervicothoracic syrinx had resolved, and the nerve roots were no longer enlarged. The patient had normal power and near normal gait. “He’s hiking again,” Dr. Klein says.

Dr. Klein notes that the edema in the nerve roots makes this case unique. “We don’t yet understand the implications,” he says. “Because this type of syringomyelia is a new entity, we need further investigations.”

Expertise that facilitates diagnosis
Mayo Clinic’s diagnostic capabilities rest upon technical expertise and a team approach. Spinal dural AVFs are often overlooked, due to their heterogeneous clinical and radiologic features. Mayo Clinic has experience with the unusual radiographic findings that indicate a spinal dural AVF and warrant further testing with spinal cord angiogram.

“A decision to move to angiogram can be assisted by observing flow voids on T2 MRI. Flow voids are most commonly seen on sagittal images,” Dr. Klein says.

Spinal cord angiogram, a tool critical for
Two novel glial autoantibodies discovered in the past 15 years enable recognition of patient subsets with antigen-specific central nervous system inflammatory demyelinating autoimmunity manifesting as optic neuritis. Since introduction of live transfected cell-based assays, myelin oligodendrocyte glycoprotein immunoglobulin G (MOG-IgG) has emerged as a reproducible marker for a subset of patients with optic neuritis, aquaporin-4 immunoglobulin G (AQP4-IgG)-seronegative inflammatory central nervous system demyelinating disorders with neuromyelitis optica spectrum disorder (NMOSD)-like phenotype, and acute disseminated encephalomyelitis (predominantly in children).

Recent studies suggest the association of MOG-IgG seropositivity with recurrent optic neuritis attacks can lead to significant visual morbidity. Because there are few large studies of MOG-IgG-seropositive optic neuritis, however, the clinical phenotype is poorly defined.

To better define the clinical entity and anticipate visual outcomes, John J. Chen, M.D., Ph.D., a neuro-ophthalmologist at Mayo Clinic in Rochester, Minnesota, Mayo neuroimmunologists including Eoin P. Flanagan, M.B., B.Ch., and Sean J. Pittock, M.D., and a team of researchers conducted a multicenter, observational case series to determine the presenting signs and symptoms, radiologic abnormalities, accompanying neurological deficits, and visual outcomes of a large cohort of patients with MOG-IgG-seropositive optic neuritis. Study results were published in the American Journal of Ophthalmology in 2018.

Characteristics and visual clues
Researchers identified 87 patients seen at Mayo Clinic between 2001 and 2017, or elsewhere in 2016 and 2017, who had a clinically documented
Patients were classified as having a single episode of optic neuritis, recurrent optic neuritis, chronic relapsing inflammatory optic neuropathy, neuromyelitis optica spectrum disorders-like phenotype, acute disseminated encephalomyelitis, multiple sclerosis, or “optic neuritis plus” for patients with additional neurological symptoms.

Patients’ medical records were reviewed for presence of pain, fundus appearance at onset, visual acuity at the worst optic neuritis attack nadir and at last follow-up, number of attacks, other neurological symptoms, magnetic resonance imaging (MRI) findings, and immunotherapy and outcome.

Characteristics of the cohort include:

• Females comprised 57%.
• Median age at onset was 31 (range 2 to 79) years.
• Median number of optic neuritis attacks was 3 (range 1 to 8), median follow-up was 2.9 years (range 0.5 to 24 years), and annualized relapse rate was 0.8.
• Average visual acuity at nadir of worst attack was count fingers. Average final visual acuity was 20/30; for five patients (6%), average final visual acuity was less than or equal to 20/200 in either eye.
• Optic disk edema (Figure) and pain each occurred in 86% of patients
• MRI showed perineural enhancement in 50% and longitudinally extensive involvement in 80%.
• Twenty-six patients (30%) had recurrent optic neuritis without other neurological symptoms, 10 (12%) had a single episode of optic neuritis, 14 (16%) had chronic relapsing inflammatory optic neuropathy, and 36 (41%) had optic neuritis with other neurological symptoms (most often neuromyelitis optica spectrum disorder-like phenotype or acute disseminated encephalomyelitis).
• Only one patient was diagnosed with multiple sclerosis; that patient had a low MOG-IgG titer.
• Persistent MOG-IgG seropositivity occurred in 61 of 62 patients (98%).
• A total of 61% received long-term immunosuppressant therapy.

“Our team identified five major findings in our review of visual outcomes and characteristics in this cohort,” says Dr. Chen. Those findings are as follows:

• The inflammatory course is diverse; in most cases optic neuritis is recurrent, with or without additional neurological features.
• Despite recurrence of attacks, most patients retain functional vision.
• Optic disk edema and bilateral disease are common.
• MRI evidence of optic nerve sheath and periorbital tissue involvement is common in the acute attack.
• MOG-IgG-positive neuroinflammation is a distinct entity from multiple sclerosis and AQP4-IgG-seropositive NMOSD.

“Our study indicates that MOG-IgG seropositivity predicts a relapsing inflammatory disease process with recurrent optic neuritis as a common feature. MOG-IgG positivity should be suspected if optic disk edema is moderate to severe at onset or if MRI shows optic nerve sheath involvement,” says Dr. Chen. “Despite optic neuritis attacks being severe and recurrent, however, most patients retain good functional vision. It remains to be determined whether MOG-IgG serostatus in the remission phase of optic neuritis will predict future attacks.”

For more information
Research Highlights in Neurology and Neurosurgery

**Intrathecal Injection of Stem Cells for MSA**
Multiple system atrophy (MSA) is a progressive and invariably fatal neurodegenerative disorder. Its pathologic hallmark is a modified form of the alpha-synuclein protein, with associated neuronal loss. Although the precise mechanisms leading to neuronal loss aren’t entirely understood, there is increasing evidence that deprivation of neurotrophic factors plays an important role. Mesenchymal stem cells are known to be capable of secreting neurotrophic factors with neuroprotective effects. A previous trial of stem cell therapy for MSA showed significantly slower disease progression in patients but raised safety concerns, with intra-arterial injections of stem cells resulting in ischemic lesions. In a phase I/II study, Mayo Clinic researchers found that intrathecal stem cell administration in patients with MSA is safe and well tolerated, although associated with a painful implantation response at high doses. Using a dose-escalation study design, the researchers administered adipose-derived autologous mesenchymal stem cells intrathecally to 24 patients with early MSA. There were no attributable serious adverse events, and injections were generally well tolerated. At the highest dose tier, three of four patients developed low back and posterior leg pain but experienced no neurological deficits. Six of 12 patients in the medium dose tier developed similar but milder and transient discomfort. The rate of disease progression was markedly lower compared with a matched historical control group. Research continues to define the optimal timing of repeated injections, explore long-term efficacy and further define the mechanism of action. (Singer W, et al. Intrathecal administration of autologous mesenchymal stem cells in multiple system atrophy. *Neurology*: 2019;93:e77.)

**Insights Into Surgical Treatment of Cervical Spondylotic Myelopathy**
Cervical spondylotic myelopathy (CSM) is the most common cause of myelopathy in patients over age 55. The disease can lead to spinal cord injury, impaired quality of life and significant neurological disability. After conservative therapy has failed, surgical treatment might include decompression, anterior column reconstruction or fusion procedures. Anterior cervical disectomy and fusion (ACDF) is the most common procedure for single-level CSM. However, for multilevel CSM, some patients might also undergo anterior cervical corpectomy and fusion (ACCF). The best approach for multilevel CSM is controversial, due to a lack of adequate data comparing post-operative outcomes of the two techniques. A Mayo Clinic analysis indicates that ACCF might be associated with worse clinical outcomes following multilevel treatment for CSM. Using the National Surgical Quality Improvement Program database from 2007-17, the researchers identified 3,708 patients who had single-level ACCF or two-level ACDF. Propensity scoring was used to match patients undergoing the procedures. On multivariable regression, single-level ACCF as compared with two-level ACDF was significantly associated with longer hospital stay, longer operative time, decreased odds of readmission and increased odds of complications. The researchers also identified 939 patients who had two-level ACCF or three-level ACDF. On multivariate regression, comparisons of those groups indicated that ACDF was significantly associated with longer hospital stays and increased odds of complications. (Banno F, et al. Anterior cervical corpectomy and fusion versus anterior cervical disectomy and fusion for treatment of multilevel cervical spondylotic myelopathy: Insights from a national register. *World Neurosurgery*: In press.)

**Association of Tau and Cognition in Cognitively Unimpaired Adults**
As seen at autopsy, the relationship between cognitive decline and the distribution of beta-amyloid and tau is well defined. However, the relationship of these two pathologies and cognitive decline early in the disease process isn’t clearly understood. The Mayo Clinic Study of Aging found that tau deposition in medial temporal lobe regions is associated with poorer performance on memory tests completed by cognitively unimpaired study participants. Tau- and amyloid-PET imaging was performed in 579 cognitively unimpaired participants ages 50 to 98. The associations between test scores and tau-PET signals in 43 brain regions were analyzed. In additional models, study participants were classified by normal or abnormal global amyloid-PET signal, and normal or abnormal regional tau-PET signal. Higher tau-PET signal was associated with poorer memory performance in all medial temporal lobe regions as well as in the middle temporal pole and frontal olfactory regions. The largest association with tau-PET and memory scores was seen in the entorhinal cortex; tau-PET in that region was also associated with poorer global and language performance. The researchers found no synergistic effect in additional worsening of early memory impairment for participants with both amyloid and tau. The researchers note that these data support possible independent pathways for the initial development of Alzheimer’s disease, with either amyloid or tau pathology possibly occurring first. (Lowe VJ, et al. Cross-sectional associations of tau-PET signal with cognition in cognitively unimpaired adults. *Neurology*: In press.)

To read more about Mayo Clinic neurosciences research and patient care, visit www.MayoClinic.org/medical-professionals.
Education 2020 and 2021 Neurology and Neurologic Surgery Continuing Medical Education Programs

2020 courses

**March**

Multidisciplinary Neuro-Oncology Symposium: Updates in Medical and Surgical Management of Brain Tumors 2020
March 6-7, 2020
Wyndham Grand Orlando Resort Bonnet Creek, Orlando, Fla.

**April**

Advances in Brachial Plexus Reconstruction: A Surgical Skills Course 2020
April 23-25, 2020
Mayo Clinic, Rochester, Minn.

**July**

Neurology in Clinical Practice 2020
July 9-11, 2020
The Westin Grand Cayman Seven Mile Beach Resort, Seven Mile Beach, Cayman Islands

**October**

12th International Conference on Frontotemporal Dementias 2020
Oct. 7-10, 2020
Hilton Minneapolis, Minneapolis

**November**

Neuroradiology: Practice to Innovation
Nov. 9-13, 2020
The Ritz-Carlton, Grand Cayman, Cayman Islands

Mayo Clinic Multidisciplinary Spine Care Conference 2020
Nov. 13-14, 2020
The Ritz-Carlton, Amelia Island, Florida

2021 courses

**February**

Practical Neuroradiology: Excellence Through Evidence and Guidelines
Feb. 7-11, 2021
Four Seasons Resort and Residences, Whistler, British Columbia, Canada

**March**

4th Annual Mayo Clinic Advances and Innovations in Complex Neuroscience Patient Care: Brain and Spine 2021
March 4-6, 2021
Enchantment Resort, Sedona, Ariz.

Information and registration

Mayo Clinic in Rochester, Minnesota
Phone: 800-323-2688 (toll-free) or 507-284-2509
Email: cme@mayo.edu

Mayo Clinic in Jacksonville, Florida
Phone: 800-462-9633 (toll-free) or 904-953-0421
Email: cme-jax@mayo.edu

Mayo Clinic in Phoenix/Scottsdale, Arizona
Phone: 480-301-4580
Email: mca.cme@mayo.edu

Website: https://ce.mayo.edu/neurology-and-neurologic-surgery

Expedited Patient Referrals to Mayo Clinic Departments of Neurology and Neurologic Surgery

While Mayo Clinic welcomes appointment requests for all neurologic and neurosurgical conditions, patients with the following conditions are offered expedited appointments:

1. Cerebral aneurysms
2. Cerebral or spinal arteriovenous malformations
3. Brain, spinal cord or peripheral nerve tumors
4. Epilepsy with indications for surgery
5. Carotid disease

MAYO CLINIC | mayoclinic.org

4500 San Pablo Road | 200 First Street SW | 13400 East Shea Boulevard
Jacksonville, FL 32224 | Rochester, MN 55905 | Scottsdale, AZ 85259

©2020 Mayo Foundation for Medical Education and Research. All rights reserved.
MAYO, MAYO CLINIC and the triple-shield Mayo logo are trademarks and service marks of MFMER.