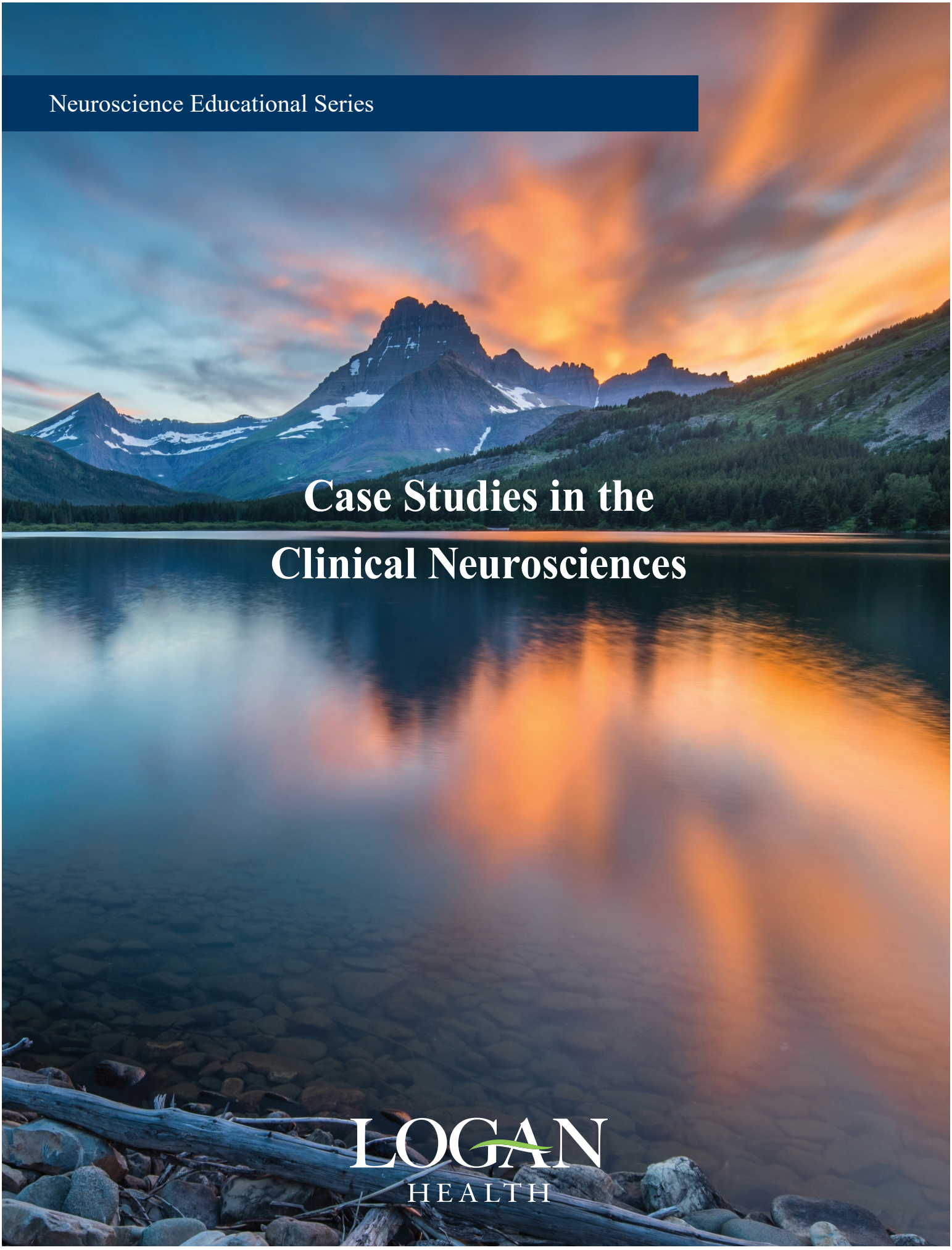
Neuroscience Educational Series



Case Studies in the Clinical Neurosciences

LOGAN HEALTH

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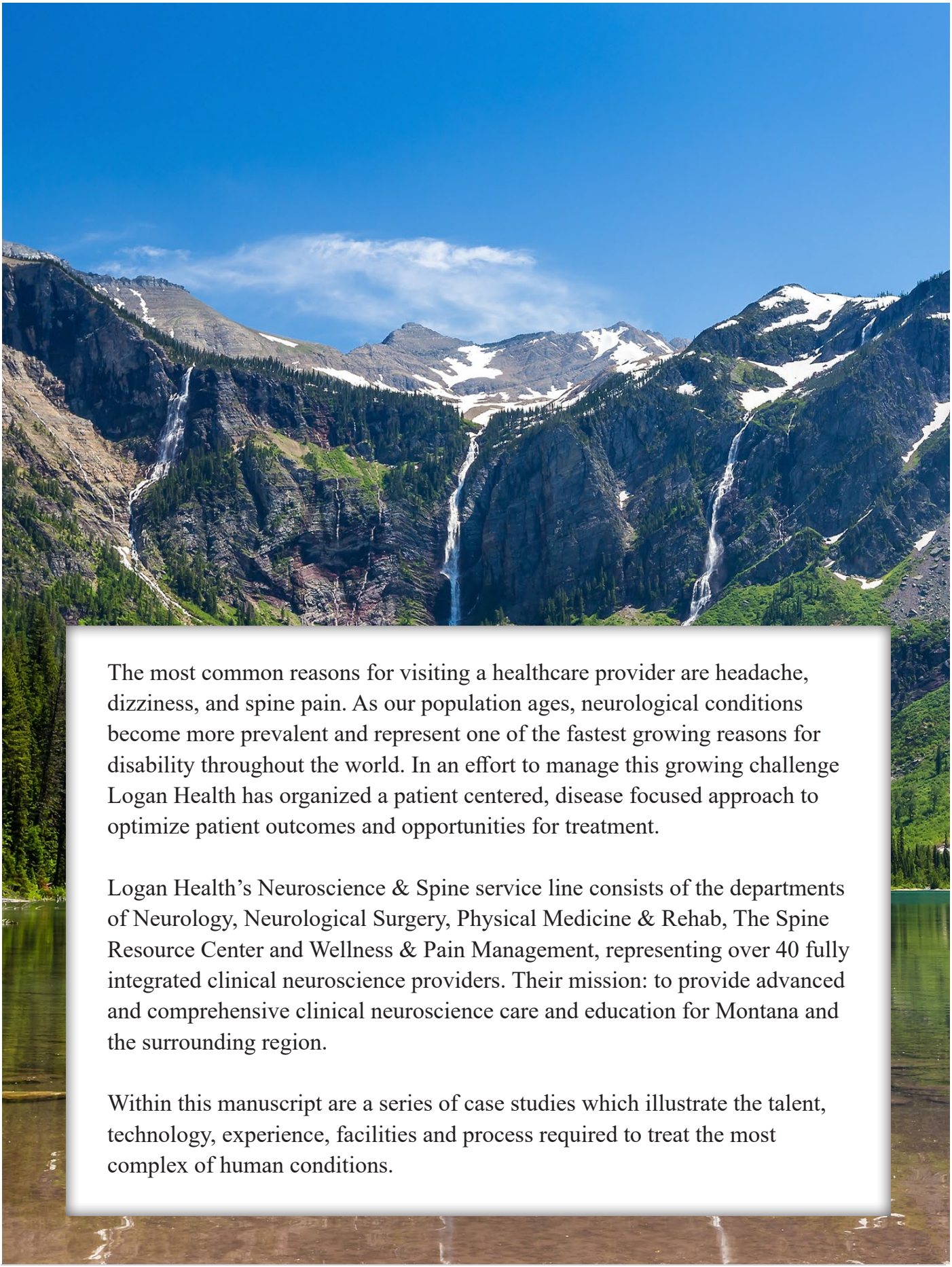


The most common reasons for visiting a healthcare provider are headache, dizziness, and spine pain. As our population ages, neurological conditions become more prevalent and represent one of the fastest growing reasons for disability throughout the world. In an effort to manage this growing challenge Logan Health has organized a patient centered, disease focused approach to optimize patient outcomes and opportunities for treatment.

Logan Health's Neuroscience & Spine service line consists of the departments of Neurology, Neurological Surgery, Physical Medicine & Rehab, The Spine Resource Center and Wellness & Pain Management, representing over 40 fully integrated clinical neuroscience providers. Their mission: to provide advanced and comprehensive clinical neuroscience care and education for Montana and the surrounding region.

Within this manuscript are a series of case studies which illustrate the talent, technology, experience, facilities and process required to treat the most complex of human conditions.

Case Study One

Headache Followed by a Swiftly Declining Examination

By TC Origitano, MD, PhD, and Joshua Krass, DO

The patient is a 46 year old male who presented to an outside hospital with a progressive headache, confusion and increasing difficulty with speech and walking. His medical history is significant for being COVID-19 positive and a remote history (greater than 15 years ago) of Renal Cell Carcinoma (RCC). He underwent a CT scan of his head which demonstrated a large blood clot in the inferior posterior part of his brain (cerebellum) plus multiple, suspicious masses in the upper part of his brain consistent with metastatic tumors. The bleed in the cerebellum was causing obstruction to the spinal fluid flow leading to increased pressure on the brain. A telephone consultation was carried out with Logan Health (LH) neurosurgery with recommendation for intubation (placement of a breathing tube) and rapid transport to the intensive care unit.

Upon arrival to the ICU the patient was evaluated and stabilized by the intensive care physician. Neurosurgery performed an external ventricular drain placement (a small tube that goes to the hollow part of the brain filled with spinal fluid) at the bedside to control and monitor intracranial pressure. The patient was readied and subsequently taken to the operating room for definitive removal of the blood clot. The blood clot was removed through a suboccipital craniotomy (a hole made through the inferior-posterior skull). During the operation it was found the clot was the result of a metastatic tumor which had bled. The entirety of the tumor was removed.

He made a slow but steady recovery over the course of the next several weeks. Due to the hemorrhage location in proximity to the brainstem, the centers for breathing, coordination and swallowing were affected. To optimize his nutrition and protect his airway, a feeding tube and tracheostomy were placed. This also allowed for safe mobilization of the patient with speech, occupational and physical therapies.

Attempts to wean the external ventricular drain were not successful. The patient then underwent an image guided, stereotactic placement of a ventricular peritoneal shunt. This would permit safe re-routing of the spinal fluid out of the brain while the swelling in the back of the brain resolved.

As his acute neurological condition began to stabilize, efforts were focused on the treatment of his recurrent, metastatic RCC. Detailed MRI imaging of his brain revealed multiple small metastatic lesions. Though pathology from his operation demonstrated RCC, full body imaging with CT scan of the chest, abdomen and pelvis failed to demonstrate any disease systemically. Oncology and radiation oncology consultations were obtained and the case discussed at the weekly cancer case conference/tumor board. It was decided that stereotactic radiosurgery (SRS) would be used to treat the five known brain lesions. SRS utilizes image based computer guidance to direct radiation in a tight geometrical configuration, placing the radiation only in the cancer and sparing the surrounding normal brain. These treatments, even to multiple lesions are given in a single sitting. They can provide tumor lethal doses of radiation without damaging adjacent brain. They can be applied repeatedly as need demands.

Over the course of time the patient's ability to eat and protect his airway recovered. The tracheostomy (breathing tube) and gastric tube (feeding tube) were removed. His recovery was managed by a LH skilled nursing facility, which provided him the necessary skilled nursing support, as well as speech, physical and occupational therapies. In this facility he learned to walk and talk again. He was discharged to home and independent living. Total course of his care from collapse to home was 77 days.

Figure 1. Initial scan demonstrating large hemorrhage in the cerebellum.

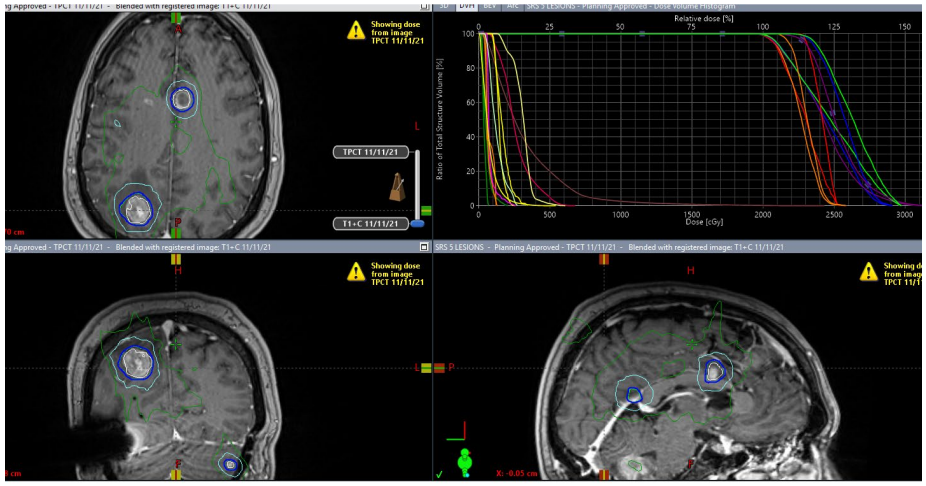


Figure 2. Example of dose planning and contouring of multiple metastatic lesions for single sitting stereotactic radiosurgery treatment.

Case Takeaways:

- Remote site direct consultation and the ability to remotely review imaging regionalizes the neurosurgery resources, rapidly providing care. TIME IS BRAIN.
- Rapid transfer to a tertiary center permits early, temporizing and definitive neurological care.
- Caring for high acuity patients takes teams of teams working together across multiple disciplines (ER, neurosurgery, neurology, critical care/pulmonology, hospitalist, radiology, anesthesiology, physical medicine and rehabilitation, palliative care, general surgery, oncology, radiation oncology and radiology).
- Multimodality therapies and advanced technologies are necessary to optimize outcomes (image guided intraoperative navigation, SRS, micro-neurosurgery and advanced imaging: MRI, PET, CT).
- Incident to recovery often occurs across a continuum of care facilities (ER to ICU to floor to skilled nursing facility to home).
- One patient, one plan, under one roof, being cared for by a team of teams, blending talent, technology, facilities and experience to optimize patient experience and outcomes.

Case Study Two

Caring for the Most Precious and Vulnerable of Montana

By Kelly Schmidt, MD

Often in pediatric neurosurgery, treatment of patients begins in the prenatal period when congenital brain anomalies of the fetus are identified. This patient was a 34-week gestation male fetus noted to have possible hydrocephalus on a routine prenatal ultrasound completed in Helena where the family lives. His mother had a fetal MRI to better evaluate the brain anatomy and was then set up for a prenatal consultation with pediatric neurosurgery. These prenatal visits allow parents to learn more about their child's condition and learn what to expect after birth in terms of imaging or possible surgery.

Given the possibility this infant could need neurosurgical treatment after birth, he was delivered full term at Logan Health. He required a one month stay in the neonatal ICU and while he didn't immediately require any neurosurgical treatment for the hydrocephalus, he was diagnosed with septo-optic dysplasia – a congenital syndrome resulting in structural brain anomalies, various degrees of vision dysfunction, and pituitary hormone abnormalities. As a part of his condition, he was found to have central diabetes insipidus, hypothyroidism, and adrenal insufficiency, all of which required very close monitoring and treatment by pediatric endocrinology before he could be discharged home.

At the age of two months, a new MRI brain demonstrated increasing hydrocephalus and the infant required placement of a ventriculoperitoneal shunt as his first neurosurgical procedure. He did well with surgery, but his post-operative recovery required a team approach with the pediatric hospitalists and pediatric endocrinology team, to manage his complicated endocrine dysfunction.

He did well for several months after his shunt placement, but another follow up MRI brain done at seven months of age suggested development of an acquired Chiari malformation. An MRI spine completed at the same time also identified a tethered spinal cord. At the time he was having symptoms of increased swallowing difficulty, poor weight gain, gagging, and projectile vomiting – all of which are common symptoms of a

Figure 1. Pre-operative MRI showing hydrocephalus

Chiari malformation in an infant. Surgical treatment was recommended for both of these newly identified problems. Given his significant endocrine dysfunction and therefore increased risk with any surgical procedure, a combined surgery was performed. With close monitoring by pediatric anesthesia due to his adrenal insufficiency, a suboccipital craniectomy and expansile duraplasty was first performed to decompress the Chiari malformation. This was followed by a lumbar laminectomy for tethered cord release during the same procedure.

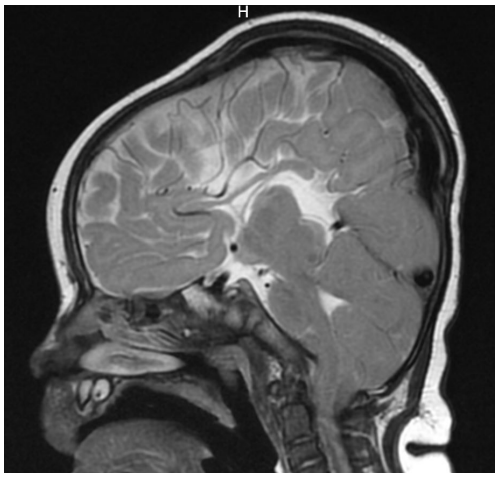


Figure 2. MRI brain showing Chiari malformation

Surgery went well, but he had a very complicated post-operative course and required a one month hospital stay before he was able to be discharged home. Pediatric critical care, endocrinology, hematology, gastroenterology, and therapy services were all involved in his recovery and continue to follow him now as an outpatient. He is now 2 years old and has not required any additional neurosurgical intervention. He continues to progress developmentally and lives in Helena with his family. While all of his surgical care has been in Kalispell, all of his pediatric subspecialty follow-up occurs closer to their home at Logan Health Specialty Care in Helena.

Prior to opening Logan Health Children's in July 2019, families with children with neurosurgical or complicated medical conditions such as this patient, were required to travel out of state to obtain care. This caused undue stress and financial strain on families already dealing with difficult medical diagnoses. The Logan Health Children's pediatric neurosurgery program along with more than 40 other pediatric specialists continue to shape pediatric healthcare for the state of Montana and allow families such as this to obtain quality care closer to home.

Case Takeaways

- Some pediatric neurosurgical conditions can be diagnosed prenatally and prenatal neurosurgical consultations with parents allow education regarding the diagnosis, prognosis, and need for intervention well before the child is born.
- Caring for children with complex medical conditions requires a multidisciplinary approach with multiple pediatric subspecialists to appropriately manage all aspects of the diagnosis.
- Logan Health Children's provides comprehensive pediatric subspecialty care to improve patient outcomes and decrease costs of care for families in Montana.

Case Study Three

Restoring Function through Neuromodulation: Deep Brain Stimulation

By Joseph Sramek, MD, and Robert Griffin, PA-C

D.D. is a 70 year old male with a four year history of right sided tremor involving his hand and to a lesser extent, his leg and head. The tremor is present with intention (drinking from a glass, writing) and is only minimally present at rest. Other than tremor, the patient did not exhibit other features of parkinsonism. The patient has no family history of tremor. The patient does not drink alcohol typically, but on rare occasion, would notice some tremor reduction after drinking wine. The patient was seen by an out-of-state movement disorder neurologist and was given the diagnosis of idiopathic Parkinson's disease (PD) was made based on a combination of clinical pictures and a positive DaTscan brain SPECT study which showed a presynaptic dopaminergic deficit.

The patient was started on carbidopa/levodopa and did not notice much benefit with respect to his tremor. As his tremor became more disabling, he was sent to us in consultation for consideration of a left subthalamic nucleus (STN) deep brain stimulator (DBS) placement. On his exam, he did not have significant tremor at rest, but his right hand tremor was substantial with spiral trace drawing and with drinking water out of a glass. He had no evidence of increase in tone or cogwheel rigidity, no masked facial features and his gait was normal with good arm swing.

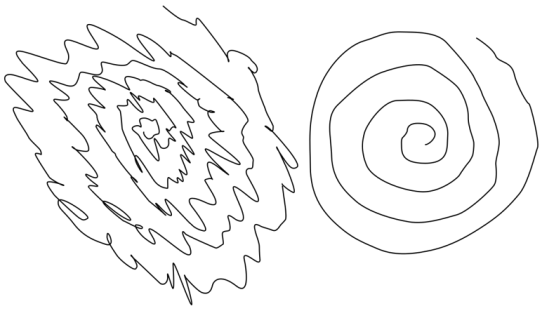


Figure 1. Spiral Trace drawing

While many of his clinical features seemed more consistent with essential tremor (ET), the decision was made to pursue placement of a left STN DBS electrode to treat his right sided tremor after a significant discussion of risks and benefits of this procedure. The surgery is performed with the use of a stereotactic head frame which is placed in the pre surgical area using local anesthetic and pin fixation to secure the frame to the skull. The patient then obtains a stereotactic localizing CT with the headframe in place and then the CT images are fused with a previously obtained MRI brain. This allows precise targeting of the STN nucleus which is a common target for DBS treatment of Parkinson's disease. The patient is then brought to the OR for the DBS electrode placement. This is done with the patient awake using local anesthetic for the scalp incision. A burr hole is created and a microelectrode is advanced over a 10 mm span to map out the STN using microelectrode recording.

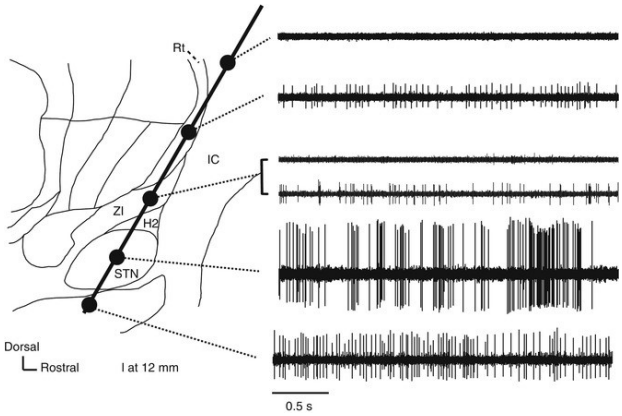


Figure 2. Images of micro electrode recording, nuclear anatomy with DBS electrode

After the STN is mapped out, a permanent electrode is placed and macro stimulation is performed to assess for tremor suppression as well as any stimulation induced side effects. In this patient, the neuronal firing pattern was not as robust as is typically encountered in a PD patient and we were unable to obtain tremor

suppression with macro stimulation. After a discussion with the patient, the decision was made to target the VIM nucleus of the thalamus, which is the typical target used to treat ET. We were able to make adjustments to the stereotactic headframe for the new target and utilize the same burr hole. At this location, we were able to get excellent tremor suppression without side effects with macro stimulation. The patient is now 6 months out from surgery with excellent tremor suppression in his right arm and leg.

DBS is a surgical treatment that is most commonly used for Parkinson's disease and ET. This treatment was FDA approved in 1997 for ET and in 2002 for treatment of advanced Parkinson's symptoms. It is also a potential treatment option for medically refractory dystonia, epilepsy and obsessive-compulsive disorder and is being studied as a potential treatment option for other disorders such as Tourette syndrome and certain chronic pain syndromes.

ET is one of the most common movement disorders with a prevalence of 1% of the population overall and 5% in adults over 60 years. It tends to occur most commonly in the hands, but can involve legs, head and voice. It is worse with action, such as writing, eating and other fine motor tasks and can have a familial component. It can be made worse with certain medications and caffeine and can improve with small amounts of alcohol (not a recommended treatment). It sometimes is confused with tremor secondary to PD. It can be treated with medications such as propranolol or primidone, however, if these are ineffective, and the tremor is debilitating, surgical treatment options such as DBS targeting the VIM nucleus can be up to 90% effective.

PD is caused by loss of dopamine producing nerve cells in the substantia nigra of the brain. It can lead to shaking, stiffness, difficulty with walking, balance and coordination and gradually progresses over time. It can be treated with a variety of medications to replace the loss of dopamine, but these medications typically become less effective over time. Indications for DBS include motor fluctuations, debilitating medication induced dyskinesias, unpredictable "off time" state and medication refractory tremor. The typical targets for DBS electrode placement include the STN and the globus pallidus interna.

DBS surgery has been available at Logan Health in Kalispell since 2013 and is one of only two places in the state of Montana where this type of treatment is offered. Risks of surgery are minimal, but include infection which could necessitate device removal. Major complications such as brain hemorrhage are rare.

Case Takeaways:

- Upper extremity tremors can be present with both ET and PD and sometimes are difficult to differentiate.
- DaTscan may be useful as an adjunct to clinical history and exam in the diagnosis of PD.
- DBS is a potential treatment option in medication refractory ET and PD, and potential treatment for multiple other disorders/syndromes.

Case Study Four

When Surgery is Not the Answer: Managing Spine Pathology Conservatively

By Justin Shobe, PA-C, MCHS

Despite spectacular medical advances, inefficiencies pervade healthcare systems across the United States. This impacts patients, providers, and clinical staff, with further reaching impacts on families and communities. In light of this, Logan Health (LH) Neuroscience and Spine: Neurosurgery, Neurology, Physical Medicine & Rehab (PM&R), and Wellness & Pain Management collectively identified several areas for improvement. By gathering feedback from providers, patients, and clinical staff, we developed a streamlined referral process for spine patients, and in 2021 we introduced The Logan Health Spine Resource Center (SRC).

The SRC is designed to improve several areas including patient expectations, clinician expectations, referral redundancy, inter-departmental communication, and time/resource management (for patients, providers, clinic staff, families, and caregivers). In doing so, we aim to positively impact our patients and fellow clinicians, thus impacting the Flathead Valley and beyond.

The SRC is an ideal option for referring providers when they feel uncertain which neuroscience specialty would be the best resource for their patient. The SRC conducts a pre-clinic screening process that directs the most appropriate route for the patient's initial scheduling. This also provides an excellent referral option when a patient requires more urgent workup, for example, when they have severe pain, but lack any "red flag" symptoms requiring emergent surgery. PM&R reserves spaces on the clinic schedule for these urgent cases. Less urgent and chronic complaints are screened and will be scheduled with an appropriate clinician within a reasonable timeframe.

When a patient is referred to the SRC, their referral is sent directly to the medical assistant (MA) staff member at PM&R. Our MA contacts the patient if additional screening questions need clarification (see Figure 1). After the MA screening, their case is reviewed by a PM&R provider within one business day. The PM&R provider then works with the scheduling staff to ensure the patient is being seen by the right provider at the right time (see Referral Protocol in Figure 2 below). In the absence of surgical urgency or chronic pain management needs, the patient will be scheduled for an initial evaluation at PM&R for an in-depth history, physical, and discussion of diagnosis and treatment options.

Figure 1:

SRC Screening Questions

Vertebral fracture risk:

- Recent trauma
- Age >50
- History of prolonged steroid use (eg prednisone)

Malignancy risk:

- Personal history of cancer
- Unintentional weight loss
  - How Much?
  - How Quickly?
- Constitutional symptoms
  - Fever, chills, sweating

Infection risk:

- Recent history of infection
- IV drug use
- Constitutional symptoms
  - Fever, chills, sweating

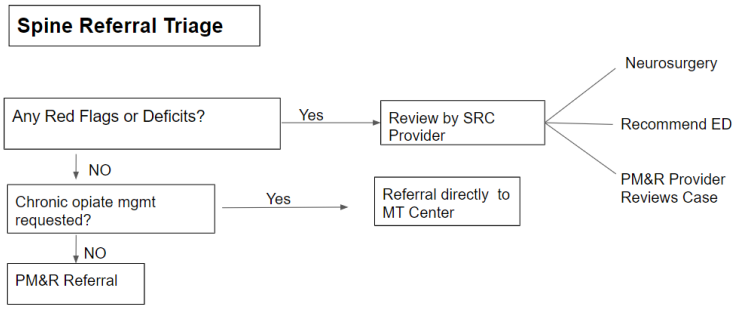
Cauda Equina risk:

- Loss of bladder control
- Loss of bowel control
- Saddle numbness

Additional Questions:

- Balance issues
- Prior Spinal Surgery
- Numbness in both hands or legs
- Worsening weakness in a limb

Figure 2:



In addition to the SRC, our physician assistants (PA) at Neurosurgery conduct a review of all incoming referrals to determine the necessity and the urgency of being evaluated by a neurosurgeon. If these patients are deemed non-surgical, or in need of further workup, these referrals are triaged and redirected to PM&R, Neurology or Wellness & Pain Management for further evaluation. The SRC's streamlined referral process optimizes the patient's and referring provider's experience.

The following case study illustrates the SRC's referral process.

"John" is a 50-year-old man with a history of new onset of low back pain with radiation into the right leg. The pain began while moving his belongings to Montana from out of state. He works as a teacher and the pain prevented him from attending work on multiple occasions. He also felt weak in the right leg. He was initially seen at Logan Health Primary Care in April 2021. After completing two Medrol dose packs with minimal relief, he was referred to the SRC.

He completed the SRC screening with PM&R MA and PA staff members. During that screening he reported worsening right leg numbness and weakness. His imaging was reviewed and he was scheduled on an urgent slot within one week. Without the SRC process, he would have likely waited several weeks until initial contact with a provider at PM&R or Neurosurgery, possibly requiring additional visits to the walk-in clinic or emergency department while he waited.

On the initial exam at PM&R he described right L4 dermatomal pain, with possible L5 involvement. He demonstrated 4/5 right quadriceps strength, decreased soft touch sensation in the right L4 dermatome, and had a positive straight leg raise (SLR), for reproduction of the radicular type pain. Reflexes remained equal in the bilateral lower extremities. Ankle clonus was absent. He described right inguinal symptoms with passive internal rotation of his right femur. The inguinal pain was different from the more distal leg pain he described with daily activity. As a result of the initial evaluation a lumbar MRI was ordered, gabapentin started at 100mg 3 times daily, and a referral was placed to physical therapy (PT) at Logan Health Physical Therapy.

The patient followed up one month later to review his MRI and progress. He reported improving right leg strength. Radicular pain was improved mildly with the gabapentin 100mg 3 times daily, so this was increased to 300mg 3 times daily. He was advised to continue PT. He denied any limitation to his activity associated with inguinal pain. The MRI demonstrated a disc protrusion at L3-4 with contact of the traversing right L4 nerve root, mild bilateral foraminal stenosis at both the L4, and L5 neural foramen.

At his follow up 1 month later, he described severe recurrent right L4 dermatomal pain. A right L4 selective nerve root block (SNRB) was ordered, which occurred 9 days later by interventional radiology.

After the SNRB his pain log was reviewed, showing excellent anesthetic and steroid phase benefit. This supported the suspicion of the L4 nerve root involvement. He reported gradual return of the right L4 symptoms, but no weakness. At the follow up exam he demonstrated 5/5 right quadriceps strength with manual resistance. Gabapentin was increased to 600mg 3 times daily and continued home exercises from PT after being discharged. He was eventually able to decrease the gabapentin to 300 mg twice daily, then stop it altogether. He was able to work and recreate without limitation at that point. He was advised to follow up as needed due to the improved manageability of his symptoms. At the initial visit his Oswestry Disability Index (ODI) score was 74%, at his final visit, 44%.

Outcomes:

We currently track patient outcomes in the SRC using the ODI, a standardized questionnaire that identifies the impact of symptoms on functional activities. The SRC strives for continuous quality improvement through

evidence-based medicine and through gathering feedback from patients and referring providers.

Additionally, specialists from PM&R, Neurosurgery and Wellness & Pain Management gather monthly to review case studies. These multidisciplinary conversations allow for continued guidance of our evidence-based practice at the SRC.

The SRC does not seek to completely replace direct referrals to Neurosurgery, PM&R, Wellness & Pain Management, and Neurology. Referring providers can still complete a normal referral process to their intended specialist, and clinicians are still encouraged to call their receiving specialist to collaborate in patient care. Additional screening may take place regarding these direct referrals in order to triage them most efficiently. If there is confusion around the end result of the referral, we encourage referring providers to reach out to our medical staff to discuss further.

The SRC is committed to improving the experience for patients and providers, reducing redundant visits, and improving timeliness of appropriate treatments. We aim to maximize the positive impact on our patients and colleagues in the Logan Health system and across our regional community.

Case Takeaways:

- Patients referred through the SRC undergo a pre-clinic screening process to determine their most appropriate starting place within LH Neuroscience & Spine.
- The SRC is an ideal option for referring providers when they feel uncertain which specialty would be the best resource.
- The SRC is also an appropriate referral option for patients requiring more urgent workup for spine complaints (in the absence of any signs/ symptoms warranting surgical emergency).
- Referring providers can still refer directly to their desired specialty within LH Neuroscience & Spine.
- Referring providers are encouraged to call their intended receiving providers to discuss questions and concerns.

Case Study Five

Emergent Treatment of Acute Ischemic Stroke: Role of the Neurohospitalist

By Kurt Lindsay, MD

Emergent treatment of acute ischemic stroke has significantly changed over the last 5-10 years, leading to improved patient care and outcomes, but also introducing challenges for rural stroke care. First, we have developed comprehensive, evidenced-based algorithms to systematically decrease the "door-to-needle" time (the time between when stroke patients present to the emergency room and when they are given "clot-busting" medication). Additionally, multiple positive clinical trials have brought forth the advent of acute endovascular treatment for stroke with large vessel occlusion utilizing mechanical clot removal at larger, comprehensive stroke centers. To meet the increasing, time-constrained demands for specialty stroke care, many centers have developed neurohospitalist programs to ensure that a stroke specialist is available and ready to help in these acute settings. At Logan Health Medical Center (LHMC) our neurohospitalist program enables close coordination with other members of the CODE STROKE team, allowing them to work acutely in parallel to decrease time to treatment, saving brain in the process. Additionally, utilizing advanced imaging techniques such as a CT angiography (CTA) and perfusion studies allow this team to predict which patients may be candidates for mechanical thrombectomy in real time, and rapidly engage transport to larger centers where this highly specialized treatment is available.

Moreover, as both our primary outpatient clinic and LHMC inpatient consultative services have dramatically grown in the Flathead Valley over the last few years, trying to continue to be in multiple clinical settings at once has grown nearly impossible. This program allows us to focus energy and expertise on each of these needed services individually.

As a neurohospitalist, we work in real-time collaboration with medical hospitalists, critical care intensivists, neurosurgeons, ER providers and our rehab team to provide timely care for patients suffering acute neurologic illness. As patients with neurologic illness transition thru the stages of their inpatient care – from the ER to the acute hospital to inpatient rehab – the neurohospitalist serves as their continuity, helping them navigate through each phase of their treatment and recovery.

The following case study demonstrates the complexities of such care and the need for rapid, specialized expertice the neurohospitalist service at LHMC is designed to provide.

The patient is a 53 y/o male without significant past medical history who is brought in as a CODE STROKE for neurologic symptoms beginning at 6:20 PM. The patient's wife was with him when he suddenly developed left-sided weakness with facial droop and dysarthria. The patient was noted by emergency medical services called to the scene to have a Las Angeles Motor Score (LAMS) of 4 - a clinical indicator score predicting large vessel occlusion (LVO) within the arterial blood supply to the brain. This was communicated to the LHMC ER en route, and the stroke team including the ER provider and the neurohospitalist were able to meet the patient in the ambulance bay. Upon arrival, a rapid neurologic examination demonstrated a National Institute of Health Stroke Score (NIHSS) of 14 – indicative of significant stroke severity. The ER provider and the neurohospitalist worked in tandem to review chart history, talk with family, monitor for any changes in exam, discuss treatment with pharmacy and facilitate appropriate imaging during the crucial first 10-20 minutes. CT head was unremarkable with exception of dense right middle cerebral artery (MCA) sign (worrisome for acute occlusive thrombus) and CT Angiography (CTA)- demonstrated right internal carotid artery and MCA occlusion (see figure 1). CT perfusion (CTP) demonstrated small core infarct and large penumbra (tissue at risk) with mismatch of 130 ml (see figure 2). He was given IV tissue Plasminogen

Activator (tPA) at 28 minutes from arrival to ER. Given the presence of a LVO, the neurohospitalist discussed the case with the neuro-interventional team at Sacred Heart Medical Center in Spokane, and they agreed with urgent transfer for mechanical thrombectomy. This procedure was performed successfully upon arrival in Spokane, with near complete removal of the occlusive clot as seen on initial CTA. The patient was discharged home on day 3 with only mild left hand incoordination and NIHSS of 1. He was seen by the neurohospitalist in an outpatient stroke clinic 2 weeks after the event, and was back working full time with a NIHSS of 0.

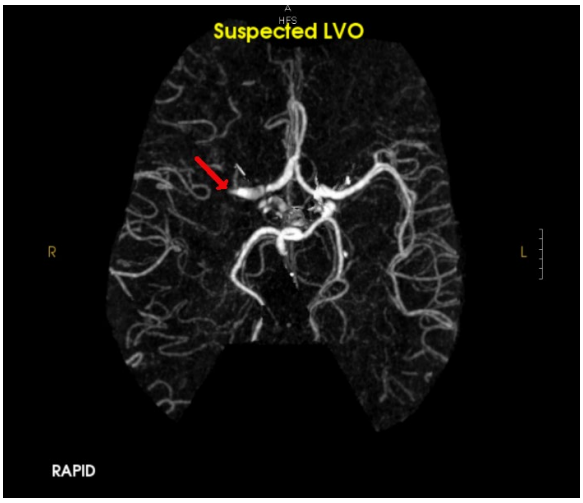


Figure 1: CT angiogram demonstrating large vessel occlusion (LVO) in right middle cerebral artery (arrow). Further review of study would also demonstrate occlusion of the right internal carotid artery (not shown).

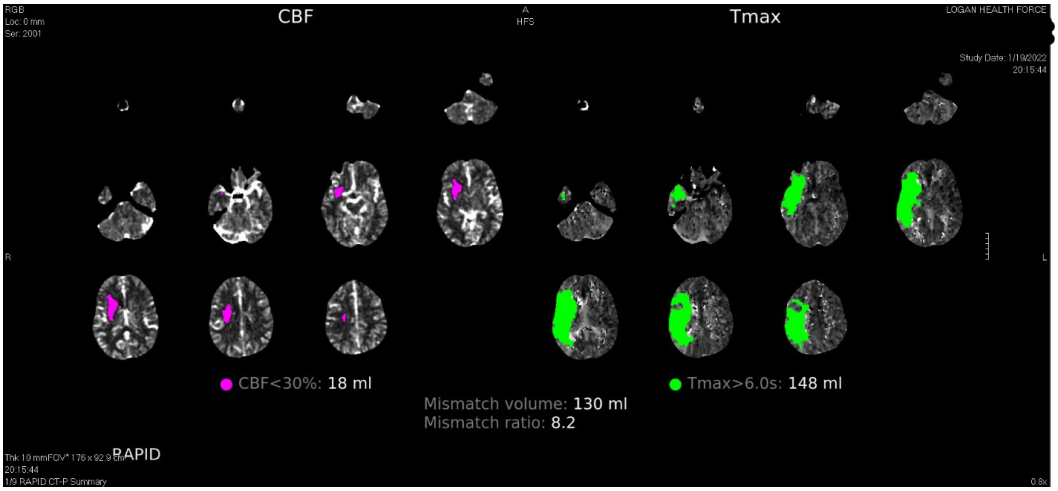


Figure 2: CT perfusion demonstrating small core infarct (red) and large penumbra (green) with a large mismatch volume of 130 ml. This mismatch volume represents viable brain tissue that can still be saved if mechanical thrombectomy is performed and successful.

Case Takeaways:

- Acute ischemic stroke care is both significantly time-sensitive and utilizes advanced imaging modalities – both facets of care requiring highly specialized evaluation in real-time.
- The development of the LHMC Neurohospitalist program allows for this rapid, in-person care locally, and allows for close collaboration with other members of the acute care team.
- The development of parallel systems-based processes to decrease the time-to-treatment with IV tPA allows for more rapid, appropriate treatment with this life-saving medication in acute ischemic stroke, while ensuring thoughtful safety guidelines. Time is still brain!
- The advent of endovascular mechanical clot removal in large vessel occlusive ischemic stroke utilizes the rapid interpretation of advanced imaging – requiring stroke specialists to be available 24/7. The LHMC Neurohospitalist program realizes this need.

Case Study Six

Neurosurgical Management of Spine Fractures

By Joshua Krass, DO, FACOS

Living in Northwest Montana poses specific challenges in regards to traumatic injuries of the spine. The mechanisms typically relate to high-speed motor vehicle accidents, ATV/UTV accidents, motorcycle accidents, collisions with wildlife, falls from height either from horseback riding, climbing, ladders, slips and falls on the ice, and secondary to an aging population with increasing identification of osteoporosis. Ultimate treatment of spine fractures is dependent on the location within the spine, any underlying pathology (i.e. metastatic cancer, osteoporosis, genetic abnormalities, etc.), and mechanism of injury. Traumatic injuries can be broken down based on specific anatomical concerns which vary depending on the location of the spine involved. These include:

1. Upper cervical spine (C1 and C2)
2. Subaxial cervical spine (C3-7)
3. Cervicothoracic junction (C7-T1)
4. Thoracic spine (T1-T12)
5. Thoracolumbar junction (T12-L1)
6. Lumbar Spine (L1-L5)
7. Sacrum and coccyx (S1-S5 and coccyx)

Treatment can also vary and includes:

Conservative

1. Bracing, typically for 3-4 months, the type of brace is dependent on the location.

a. Cervical – Miami-j or Aspen Vista; Cervicothoracic orthosis (CTO) may be necessary if stabilization of the thoracic spine is needed in addition to cervical.

b. Thoracic - TLSO

c. Lumbar - LSO

2. Bedrest – high risk for morbidity, this is avoided unless absolutely necessary and typically only when there are multiple injuries simultaneously.

3. Medication management:

a. NSAIDs – Meloxicam, Celebrex, Diclofenac, or OTC meds

b. Neuropathics – Gabapentin, Lyrica, Cymbalta, Nortriptyline, etc.

c. Narcotics

d. Muscle relaxants

e. Nasal calcitonin – typically recommended for osteoporotic compression fractures

Surgical

1. Stabilization only - typically with pedicle screws, used for fractures that do not need to decompress the spinal canal or cord and without significant ligament injury, the screws may be removed at a later date when the fracture heals.

2. Kyphoplasty/Vertebroplasty – placement of cement into isolated compression fractures or minor burst fractures without instability.

3. Stabilization with fusion – used for unstable injuries that involve the ligament and bone.

4. Corpectomy with fusion – includes removal of the entire vertebral body to either restore alignment or decompress the spinal cord or canal.

Case Six A:

17-year-old male involved in a high speed motor vehicle accident with multisystem traumatic injuries. These included bilateral pulmonary contusions, bilateral pneumothorax, intra-abdominal free fluid concerning for abdominal injury, a right zygomatic arch fracture, sternal fracture, and an unstable thoracic spine fracture as well as multiple compression fractures into the lumbar spine. He was evaluated by our emergency department, pediatric trauma surgery, pediatric intensive care, thoracic surgery, and neurosurgery. It was felt that the sternal fracture would require surgical

intervention as well as the spine fractures. Secondarily he was taken to the operating room where he had the sternal fracture plated. Given the magnitude of the bone and ligament injury as well as the multiple compression fractures and burst fractures, it was felt that he needed to have stabilization at least 3 levels above and 3 levels below the fractured sites. Secondarily we proceeded to perform a decompression of the spinal cord with T11 laminectomy and stabilization and fusion from T8-L2. In order to increase the safety of the procedure we are fortunate at Logan Health (LH) to have advanced imaging and navigation capabilities including an intraoperative CT scanner called the O-arm (Medtronic) as well as a GPS navigation system called the Stealth (Medtronic). Postoperative imaging showed excellent restoration of alignment compared to preoperatively. He wore a brace for several months after the surgery to allow adequate healing. Currently the patient is 6 months status post the procedure and has made excellent progress. He has undergone extensive outpatient therapies with physical therapy, occupational therapy, speech therapy, and our physical medicine and rehabilitation department has been involved.

Figure 1: MRI showing fracture of T10, T11, T12, and L1; angulation of the spine with compression of the spinal cord at T11

Figure 2: CT scan showing severe fracture of T11 as well as T12 with angulation of the spine

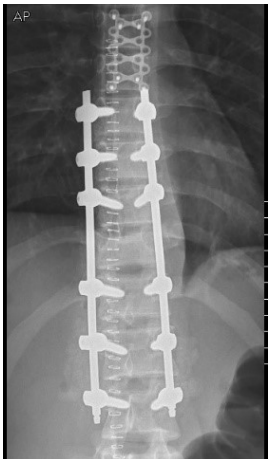


Figure 3: Post-operative x-ray showing AP view of the pedicle screws as well as sternal plating

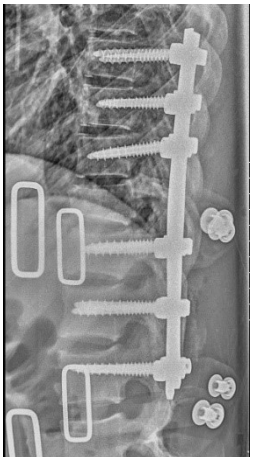


Figure 4: Post-operative x-ray showing lateral view with restored alignment and height of the fractures segments

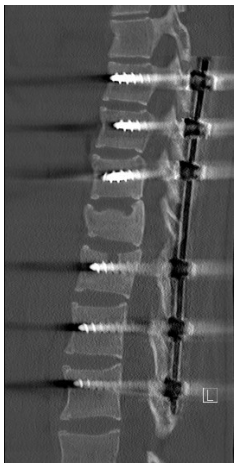


Figure 5: Post-operative CT showing healing of the fracture and stability of the pedicle screws 6 months after surgery

Figure 6: Intraoperative CT (O-arm, Medtronic)

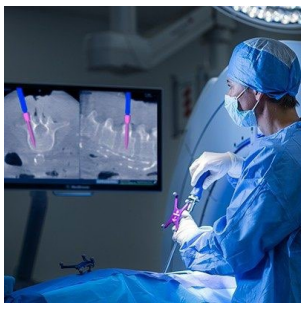


Figure 7: Use of intraoperative navigation for placement of pedicle screws with Stealth neuronavigation (Medtronic)

Case Six B:

47-year-old male involved in a motor vehicle accident with an intoxicated driver. He was initially evaluated by 2 physicians at LH who were at the scene and stabilized his neck. He was subsequently transported by EMS to the LH emergency department. Upon evaluation he was found to have numbness in the bilateral hands and weakness in the left arm. On imaging he had a very severe fracture dislocation of the cervical spine at C6-7. This caused a combination of injuries including anterior and posterior ligament tears as well as jumped and perched facets consistent with a dislocation. Secondary to the magnitude of the injuries and high risk of permanent paralysis he was taken emergently to the operating room to undergo 360 degree stabilization of the spine. His first procedure was a C6-7 reduction of fracture followed by anterior cervical discectomy and fusion with plating and interbody graft. This allowed decompression of the spinal cord as well as stabilization of the fracture initially. This was followed by a posterior approach with lateral mass screws, pedicle screws, and fusion. Utilization of advanced imaging techniques including the O-arm and intraoperative Stealth neuronavigation were imperative to allow a successful surgery and to assure that there was adequate reduction, as well as for placement of the instrumentation in a complicated situation. The patient ultimately tolerated the procedure very well. He is 9 months from surgery. The hardware is stable and he no longer has any numbness or weakness. He has weaned out of the collar and we are hopeful that he will make a full recovery.

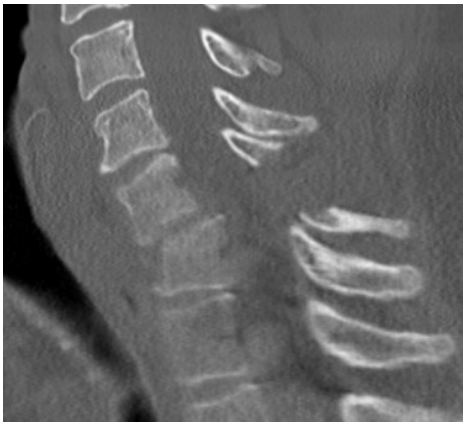


Figure 1: Lateral CT showing fracture dislocation anteriorly at C6-7 as well as severe widening posteriorly

Figure 2: Lateral CT showing "jumped facets"

Figure 3: Lateral CT showing "perched facets"

Figure 4: Post-operative lateral x-ray showing anterior and posterior hardware as well as alignment of the spine

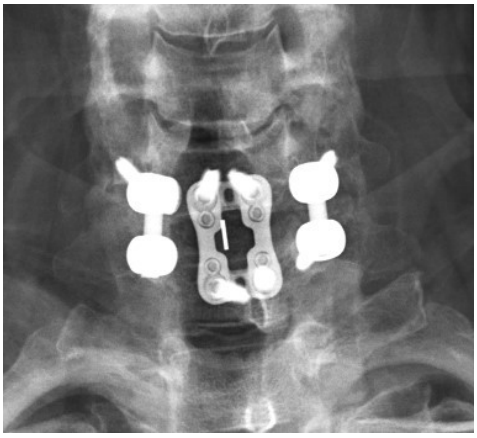
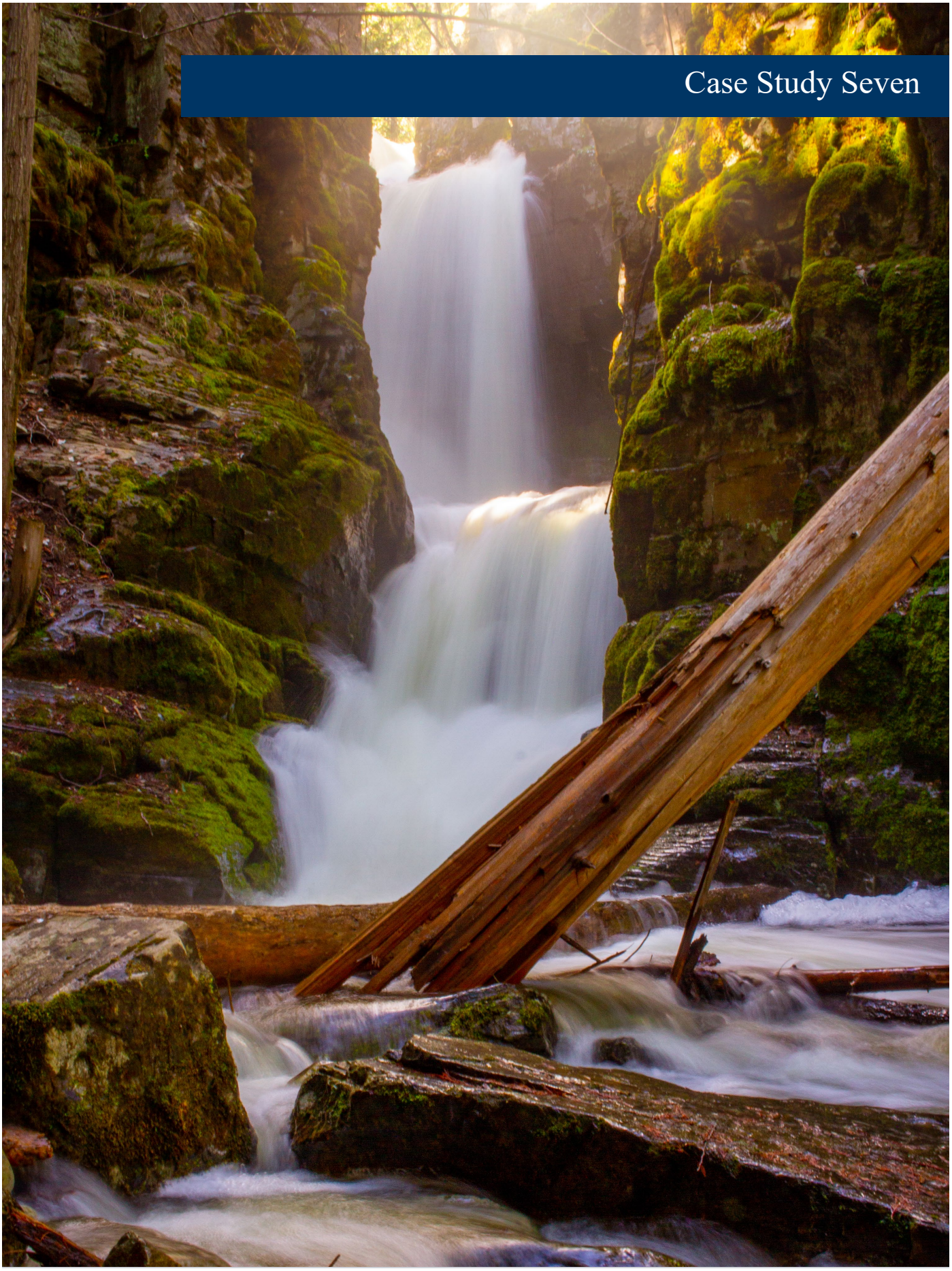


Figure 5: Post-operative AP x-ray showing anterior plating and posterior hardware

Case Takeaways:

- Given the complexity of spine fractures and their management it is best to have a high index of suspicion after traumatic events and evaluate with imaging such as x-ray or CT and have a low threshold for referral to the emergency department for a formal evaluation, this is especially true for those with malignancy or osteoporosis.
- Frequent evaluation for osteoporosis and aggressive management in our aging population is invaluable to decrease the risk of fractures. This also improves bone quality to decrease the severity of fractures and complexity of treatment when they occur.
- Avoidance of NSAIDs, steroids, and nicotine aid in healing of fusion when instituted.
- Communication between primary care and neurosurgery is essential to insure a comprehensive approach and improved healing for patients with spine fractures with or without surgical intervention.

Case Study Seven



Concussion Management: A Multidisciplinary Approach

By Rachel Zieder, MD and Tanner Ferderer, MD

Concussions are common injuries in our country, and my 12-year-old daughter fell prey to the icy sidewalks of Montana this year. She slipped forward, struck her forehead, and her heavy backpack fell forward to push her head harder into the ground. Her recovery gave me an inside look into the daily care of a concussed middle schooler rather than just a weekly visit in the office. I definitely gained some insights that have been very helpful in patient care and it gave me a more practical education, especially on returning a student to learning after a concussion.

The concussion occurred on Tuesday, January 11, and she had a mild headache before bed that evening. The next morning she awoke with a mild-moderate headache, and she was kept home from school to rest in her room without screen time or reading. She had no other symptoms of concussion beyond headache and it was unclear whether she had a concussion or just a sinus headache as a cold was going through our family at the time. On the following day, her headache felt quite a bit better and we were hoping it was just a sinus headache. Her athletic director, coach, and athletic trainer were contacted regarding possible concussion and the need to avoid practice/games, as we wanted to be cautious, treating it as a concussion. After 30 minutes of screen time in her first class, her headache had worsened to the point that she had to leave school. Screening tests for concussion, including Vestibular Ocular Motor Screening for vision abnormalities, were slightly impaired and concussion was diagnosed.

Initial treatment for concussion is rest followed by symptom limited activity, which was our approach. She stayed home again on Friday and had a long weekend due to a holiday. By Tuesday, the 18th she was feeling quite a bit better and tolerated reading, some screen time, and light aerobic activity without worsening symptoms. She returned to school with some recommended academic accommodations which were turned in at the front office. She had minimal increase in symptoms, though she continued to have a mild-moderate headache throughout the day and did not tolerate loud noises during class transitions. She stayed after school to watch her basketball team play in a game and developed nausea after the game. We were concerned that her symptoms had worsened from the loudness of her basketball game and mental strain from school. It turns out her nausea was from gastroenteritis that was going through the school, and the next couple of days were spent recovering from that illness. It was difficult to determine which symptoms were from concussion and which were from gastroenteritis; however, after the normal course, her GI symptoms resolved. She reported struggling with her teachers not following recommended accommodations on that first day back at school, especially as the end of semester was approaching. On Wednesday, the 19th, I was copied on an email from the principal who had sent out the list of the academic accommodations to her teachers. This clarified why the accommodations were not followed on her initial day back at school as the teachers were unaware of them. She returned to school that Friday, the 21st, starting the day with no headache, but ended it with a mild one. Because of the communication from the principal, her teachers allowed her to participate in make-up work during classes and rescheduled tests for the following week.

She felt even better over the weekend and was able to work on homework, though she still required multiple explanations for some new material and constant cueing to stay on task. She also tolerated a little more physical activity on the indoor rower for a short period of time. We encouraged this symptom limited activity as light aerobic exercise has been shown to shorten recovery from concussion. By Wednesday, the 26th, she had no further concussion symptoms after a full day of school including multiple tests. Repeat screening tests had normalized. The athletic trainer was contacted and advanced her through the return-to-play (RTP) protocol as indicated over the following weeks.

Based on this experience, I am very grateful for the work that Save the Brain is doing to provide advocacy, education, and communication within the school systems of the Flathead Valley. There has been a lot of research into returning concussed athletes to sports and physical activity which has led to fairly specific guidelines that are widely accepted and used when a student is in that portion of his or her recovery.

However, up until recently, there has been much less research done surrounding the process of returning to learning and school after concussion. Based on this new research it is clear that concussed students are underserved in schools and the effects of concussion on returning to the learning process are under-recognized at all levels within the school system. These effects extend to the teacher in addition to the students themselves. Teachers often feel ill-equipped to implement "return-to- learn" guidelines without more specific instruction, then on top if it, still need to teach the remainder of the class.

Some students, parents, and providers get so frustrated with the process that they request formal educational programs such as a 504 plan; however, studies show that these slow access to available academic support and can cause tension between the school system and parents. Another area of concern is the lack of ability to communicate between the school system and healthcare providers. Student-centered care plans have been shown to effectively fill these voids when they include input from pre-established guidelines, the school system, and medical experts. Plans should include educational materials, symptom checklists, and guidelines for classroom adjustments based on symptoms.

Save the Brain has responded to this significant need by implementing the Concussion Advocacy Program (CAP) within school systems throughout the Flathead Valley. A Concussion Advocate (CA) is a representative chosen by a school to help support students in their process of returning to school and learning. They serve as an advocate for the student, provide education to teachers and parents, and serve as a point person for communication between the medical team and the school. Each advocate attends a 3-4 hour training session given by the Save the Brain leadership team which equips them to provide this level of support.

The CA meets with concussed students weekly at a minimum. They look at symptom checklists and discuss any challenges the student is facing, whether it be a specific class, teacher, or activity. They advocate for the student by providing educational material and clarifying recommendations to teaching staff. They also serve as a line of communication between the healthcare provider and school, as parents are given the option to release information regarding concussion to the CA at their child's school. This allows the CA to contact the healthcare provider with concerns or questions about the student.

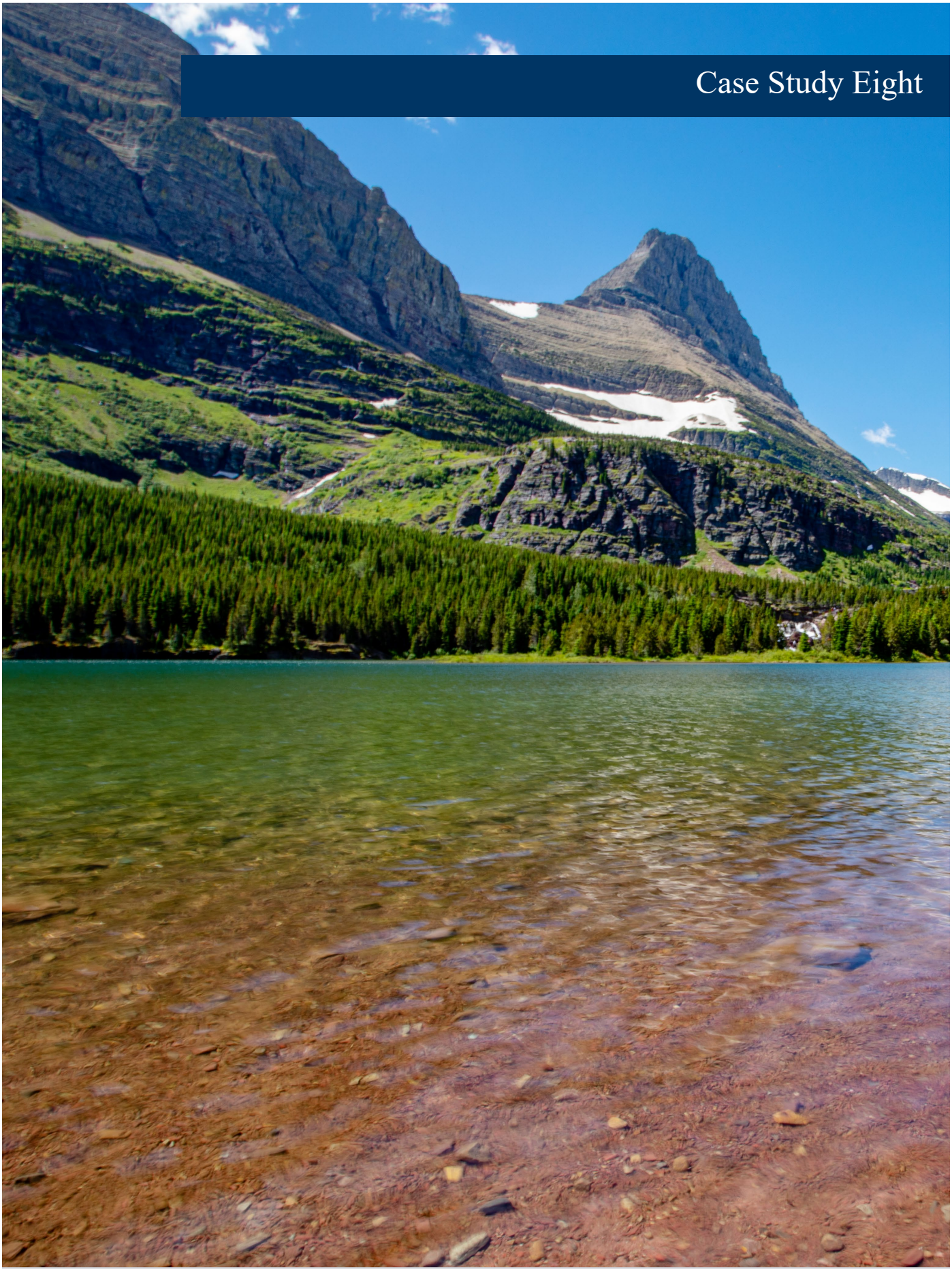
While my daughter's school has begun the process of developing a CAP, it has not yet been formalized and ongoing education will need to take place in order for it to function as intended. This experience has made it clear to me that our CAP is a worthwhile endeavor that will help support our students, educate our school systems, and provide the needed communication between the healthcare team and our schools to provide the best concussion care available.

Going through this process personally helped me identify some challenges that could be significant stumbling blocks for a concussed student whose parent is not the co-medical director of the local concussion management program.

Case Takeaways:

- It took a couple of days for me to determine that my daughter truly had a concussion. To an untrained person, this would be extremely difficult.
- Once it was diagnosed, I knew the protocols for rest and gradual return to cognitive activity, making it a fairly smooth transition; however, this would be challenging without access to that education.
- I had access and expertise to determine appropriate academic accommodations once she was able to tolerate returning to school and was contacted by the principal once the accommodations were communicated to the teachers. I was able to advise my daughter about when to talk to her teachers and what type of testing schedule was appropriate for her. Depending on scheduling of appointments, this information may be difficult to access for the general public.
- Timely communication of academic accommodations makes a big difference in the students experience at school. Protocols for reporting these recommendations are not always clear to the student or parent.
- Once the concussion has healed and the student is ready for the RTP process, timely communication is essential to allow the student to return to sport/activity as soon as possible. Detailed communication between the athletic trainer and healthcare provider is essential.
- Rest is crucial, and concussion symptoms can last weeks. Encourage patience while the brain heals.

Case Study Eight



Enhancing Recovery and Outcome

By Mark Weber, MD

This is the case of a 69-year-old, previously very active man, with a past medical history of hypertension, paroxysmal atrial fibrillation, and thymectomy, who presented to an outside hospital ED with a 2 day history of chest pain. Imaging studies showed evidence of an aortic dissection. The patient was intubated and transferred to Logan Health Medical Center (LHMC) for further evaluation and management. He was evaluated by cardiothoracic surgery and surgical intervention was recommended. The patient underwent replacement and repair of his ascending aorta and resuspension of his aortic valve, with an operating room time of 7 hours and a bypass time of 214 minutes.

Postoperative CT angiography (CTA) of the neck showed an occluded right common carotid artery. His initial CTA of the head showed decreased vascular marking in the distal right middle cerebral artery (MCA) distribution. The patient had evidence of dense left sided hemiparesis following surgery. A follow up CTA of the head showed extensive right MCA distribution ischemia, with evidence of cerebral edema and 3-4 mm of midline shift. The patient was diagnosed with a large right MCA territory stroke in the context of acute aortic dissection with extension into bilateral common carotid arteries.

He was started on full anticoagulation with a heparin drip. He developed severe thrombocytopenia that required discontinuation of heparin and multiple platelet transfusions. Heparin-induced thrombocytopenia testing ultimately was negative. Hematology was consulted and recommended starting steroids for autoimmune thrombocytopenia.

The patient was extubated on post-operative day (POD) #5. He required placement of a nasogastric tube on POD #5 due to oropharyngeal dysphagia.

He developed postoperative atrial fibrillation (AFib) with rapid ventricular response (RVR) and underwent successful cardioversion following loading with amiodarone.

On POD #9 the patient was successfully transferred out of the ICU to the intermediate care unit.

On POD #9 the nasogastric tube was discontinued and he was cautiously started on a puree textured diet with honey-thick liquids.

The patient developed a right upper extremity deep vein thrombosis and was started on therapeutic dosed Lovenox. His platelets remained stable.

He developed recurrent AFib with RVR and underwent repeat loading with amiodarone and repeat cardioversion with return to normal sinus rhythm.

On POD #18 the patient developed a symptomatic left pleural effusion that required an interventional radiology thoracentesis.

Lovenox was successfully converted to warfarin on POD #20. On POD #20 the patient was admitted to the comprehensive acute inpatient rehabilitation unit (IRF) at LHMC for intensive rehabilitation treatment. At the time of admission to IRF, the patient was dependent for all functional mobility, including bed mobility, transfers, ambulation, and wheelchair mobility. He was maximal assistance to dependent for all functional transfers and activities of daily living. He had evidence of severe oropharyngeal dysphagia that required a puree diet with honey-thick liquids, aspiration precautions, and full supervision with all meals. He also had evidence of moderate cognitive dysfunction on formal cognitive testing.

During IRF treatment, the patient developed further decline in his platelet levels, despite the very slow weaning of steroids. Hematology continued to follow the patient during his IRF admission and ordered treatment with IVIG for 2 days and continued treatment with high-dose steroids, which resulted in stabilization of his platelets. He then resumed slow weaning of his steroids.

He required a 31 day IRF admission, during which time the patient participated in an intensive treatment program consisting of PT, OT and SLP in conjunction with 24-hour-per-day skilled rehabilitation nursing care. He required close medical management throughout his rehabilitation admission and was able to maintain medical stability and avoid additional medical complications.

At the time of discharge from IRF the patient had achieved significant functional and cognitive improvements. He was minimal assistance with bed mobility, minimal assistance for transfers, minimal assistance to ambulate 30 feet with a front-wheeled walker, minimal assistance with wheelchair mobility and management for 150 feet, and minimal assistance to descend 4 stairs using a handrail. He was independent for eating and oral hygiene, supervision for toileting, supervision for toilet transfers, supervision for dressing, moderate assistance for footwear, and moderate assistance for showering and bathing. He had continued evidence of left sided hemi-neglect and a left visual field cut, but was better able to attend to his left side and was able to visually cross midline to compensate for his left visual field cut.

He was able to safely swallow a mechanical soft diet with thin liquids without signs or symptoms of aspiration. He had continued evidence of dysphonia but significantly improved voice quality when compared with admission voice quality. Additional follow up with ENT was scheduled to further evaluate his vocal cord function.

He had continued evidence of mild cognitive dysfunction in the areas of immediate and delayed recall, and problem solving.

During the IRF admission, the patient's wife received considerable training with all therapy disciplines and was able to demonstrate the ability to safely and confidently assist her husband in the home setting.

After 31 days of admission to IRF, the patient was discharged to home with his wife along with home health, PT, OT, and SLP provided by Logan Health Home Care.

The patient continued to progress with home health therapy treatments and was able to transition to outpatient therapy at Logan Health Rehabilitation.

He continues to require some assistance from his wife in the home setting but his independence has continued to increase. Outpatient therapy treatment is anticipated for another 4 months and additional gains in independence are anticipated.

He continues to follow up with primary care, physical medicine and rehabilitation, neurology, cardiology, hematology, ENT and cardiac surgery.

Case Takeaways:

- Patients with complex medical and rehabilitation needs are often best treated in the IRF setting, where intensive rehabilitation treatment is provided in conjunction with close medical management and skilled nursing care.
- The American Heart Association guidelines for stroke rehabilitation and recovery clearly recommend inpatient rehabilitation for patients with stroke who meet criteria for admission. Multiple research studies have documented that long term outcomes, mortality, and hospital readmission rates for patients with stroke are better with intensive rehabilitation programs than with skilled nursing facilities (Belagaje SR, et al. J NeuroIntervent Sur 2015;7:322-325; Bettger JP, et al. Stroke 2015;46:A146; Chan, L et al. Arch Phys Med Rehabil 2013;94(4);622-629).

- Rehabilitation in the IRF setting, uses an interdisciplinary team approach that results in improved functional outcomes for patients and improved readiness of caregivers for community discharge.
- Patients admitted to IRF often require continued follow up from specialists.
- Functional recovery in the IRF setting is focused on achieving a functional level that allows the patient to safely return to community living.
- Home health services are frequently utilized following discharge from IRF to assist patients in their transition to community living and facilitate continued functional recovery in the home setting.
- Outpatient therapy services are frequently utilized after home health treatment, especially when the patient's mobility has improved enough to reduce the burden of community transportation. Expertise in outpatient stroke treatment is not available in most outpatient rehabilitation treatment locations. Generally, hospital-based outpatient rehabilitation centers are well equipped to treat stroke patients.
- Recovery from a severe stroke can be a long process, with some patients requiring 6 months or more of coordinated therapy treatments. The most rapid recovery from stroke typically occurs during the 12 weeks following the stroke but continued functional recovery is anticipated for up to 2 years.

Case Study Nine

Considerations on the Management of Back Pain: Multimodal Spine Evaluation

By Anna Coles, MD

Logan Health (LH) houses several clinics under the Neuroscience and Spine service line, with each clinic evaluating patients with back pain but through the lens of varied skill sets. The cooperation between our clinics allows for patients with complicated findings and symptoms to be seen quickly by these complementary specialists to develop a plan of care.

In one such example a healthy patient in his 30s was referred to the LH Wellness & Pain Management clinic for evaluation of 1.5 years of back pain. Pain started suddenly while weight lifting and involved primarily the right low back and hip, with intermittent radiation down his right leg to the calf. Exam was notable for pain of the right low back and groin with provocative hip maneuvers, straight leg raise with replication of pain radiating into the right lateral thigh and calf, and symmetric 3+ reflexes at the Achilles and patella. However, the most notable finding was marked leftward listing of his torso while in standing, with prominent thrust of the right hip laterally and visible atrophy of the muscles of his right low back. He could stand up straight with effort but at rest found himself leaning towards the left. Patient denied ever being told he had scoliosis while growing up, he felt that this sensation of curving or leaning of his spine started about 1 year ago.

MRI and right hip x-ray were ordered for evaluation. Hip x-ray was unremarkable while MRI showed broad based disc bulges at L3-4, L4-5, L5-S1 with rightward bulge at L4-5 causing effacement of the right lateral recess. Patient was referred for electromyography (EMG) to LH Physical Medicine & Rehab (PM&R) for assistance in clarifying the cause of the patient's scoliosis and lumbar muscle atrophy, with concern for possible neuromuscular disease.

EMG conducted by PM&R demonstrated evidence of acute axonal loss isolated to the right lower lumbar paraspinals, without evidence of axonal loss in the leg. There were no findings of myopathic changes.

Physicians in the pain management department and PM&R were able to discuss this case over the phone, using imaging, EMG, and physical exam to understand this patient's presentation. Ultimately it was identified that disc bulge at L4-5 was primarily compressing the L5 dorsal ganglion, resulting in axonal injury and lumbar paraspinal atrophy, with more mild, demyelinating involvement of the ventral rami contributing to his radicular syndrome.

Findings and options for management were discussed with the patient, including L5 selective nerve root block or discussion with neurosurgery. Patient noted ongoing improvement in his pain with PT and so chose to continue with conservative care, although additional options will be considered if he has a pain exacerbation or develops additional muscle atrophy.

Case Takeaways:

- This case was an example of a patient with a confusing and concerning initial presentation who was able to be seen quickly in 2 of our LH clinics to come to a clear diagnosis. The availability of interdisciplinary evaluation and care benefits patients seen in our hospital system, allowing plans of care to be developed that fit the patient and their specific needs.

Case Study Ten

The Aging Population: Cervical Spondylosis and Myelopathy Diagnosis and Treatment

By TC Origitano, MD, PhD

Cervical spondylosis is defined as spinal canal and neural foramina narrowing in the cervical spine secondary to multifactorial degenerative changes. It is one of the most common degenerative disorders of the spine affecting 95% of patients by the age of 65. The vast majority of these patients are asymptomatic. Three types of symptoms predominate either alone or in combination: neck pain, cervical radiculopathy, and/or myelopathy. This case study will focus on myelopathy which by definition implies duress to the spinal cord. The symptoms can be subtle and often develop insidiously. What brings patients in for evaluation is often increasing neck pain and stiffness. A careful history must be taken looking for subtle changes in those aspects of life requiring fine motor skills and coordination: hand writing deterioration, difficulty with buttons, making change, balance and trouble walking. Patients should be questioned about whether they are having an increase in tripping especially when transferring between surfaces (wood to rug) or going upstairs. They may often comment that dancing has become harder, and have scuff marks on the toe of their shoes where they continue to stub their toe. A diminished step height is part of the myelopathy picture. Patients may complain of arm numbness and tingling which is generally bilateral and associated with activity versus unilateral and upon awakening associated with carpal tunnel. There can be a subtle increase in tone throughout the body and exaggerated reflexes. Actual motor and sensory testing at rest can be quite normal.

In some cases symptoms are brought on by range of motion of the cervical spine, especially in extreme flexion or extension. A classical finding which is actually rare is the sensation of electricity going down the spine or out into the arms known as the Lhermitte's sign. This can also occur with axial loading of the cervical spine. Fine motor control of the hand necessary for writing, or rapid alternating movements are diminished. Classically, reflexes are exaggerated both in the arms and legs (if only legs think thoracic cord). Reflexes can be normal or blunted due to associated cervical and lumbar radiculopathies. When signs and symptoms point to cervical radiculopathy, workup generally consists of a cervical MRI and flexion extension cervical spine films. Often times electromyography and nerve conduction (EMG/NCS) studies are obtained to differentiate concomitant carpal tunnel or possible peripheral neuropathy. Select patients will undergo a CT of the cervical spine to evaluate boney anatomy and look for calcification of the anterior ligaments (which may influence surgical approach). It is key to get dynamic cervical spine films because spinal stenosis can increase with range of motion exacerbating the spinal cord compression (remember that most MRI's and CT's of the spine are with the patient in the supine position).

The patient is a 58-year-old female presenting to medical services with a complaint of diffuse weakness. Her gross motor and sensory examination were normal. Her reflexes in both her upper and lower extremities were 3/4 throughout with a couple beats of clonus at the ankles bilaterally. Her gait was wide based and unsteady. She had a positive Rhomberg sign. Range of motion of her neck brought on numbness and tingling in her extremities bilaterally. It is important to look for fasciculation's which may lead one to consider other motor neuron diseases. Looking at the tongue for fasciculation's can often be helpful for it is a large muscle covered with a thin mucosa and is often affected in motor neuron diseases.

Imaging studies demonstrated significant degenerative changes throughout the cervical spine without abnormal movement. A MRI demonstrated a high grade stenosis at C3/4 with abnormal signal change in the cord. The patient was treated with an anterior decompression of the cord with fusion. Decision making regarding surgical approach is predicated on extent of compression, level(s) of compression, deformity and normality of motion. It should be noted that reversal of symptoms is not guaranteed. Operative interventions

primary end point is to stop the progression of the myelopathy and to decrease the risk of spinal cord injury should fall or trauma occur. Experience has demonstrated that the earlier the diagnosis is made, the more likely there will be a reversal of symptoms: No guarantees.

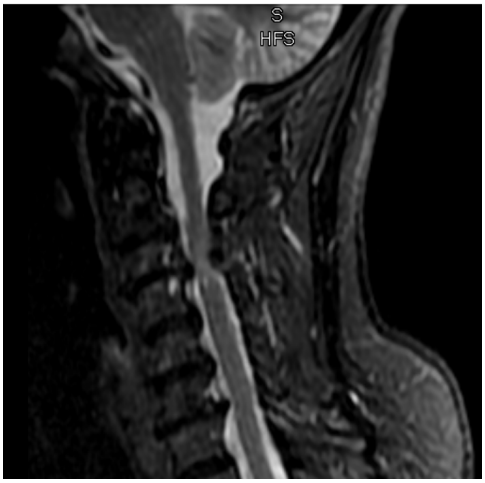


Figure 1. Preoperative MRI demonstrating cervical cord compression with signal change in the cord.

Figure 2. Postoperative MRI after anterior decompression and fusion utilizing autologous bone, peek interbody and osteosynthetic plate stabilization. Cord signal changes have resolved.

This patient had post-operative improvement in her symptoms. Resolution of symptoms can be ongoing for up to two years. The cord signal change can be permanent predisposing the patient to ongoing neurological symptoms.

Case Takeaways:

- Signs of cervical myelopathy can be subtle. Examination at rest can appear normal. Reflex testing, gait observation and fine motor testing is essential to help with diagnosis. Increased reflexes in the setting of gait disturbance and fine motor loss should prompt referral or imaging.
- The differential diagnosis for cervical myelopathy is significant including, parkinsonism, ALS, peripheral neuropathy, and lumbar neurogenic claudication.
- Work up consists of dynamic cervical spine films, a MRI of the cervical spine (or if only lower extremities hyperreflexia cervical and thoracic MRI).
- Decompression of the cord whether anteriorly or posteriorly will have the best opportunity to stop the progression of the myelopathy and avoid potential catastrophic injury to the cord. Patients with myelopathy have decreased step height leading to more falls. Falls with hyperextension of flexion can lead to injury of the already tenuous central cord leading to central cord syndromes or worse.
- Questions to ask: Are you having trouble with your handwriting; can you still tie your shoes or button your buttons; are you tripping more especially when transitioning surfaces; do your arms and legs feel heavier with use; can you induce numbness tingling or electrical jolts with neck motion?

Case Study Eleven

Educational Mission: Increasing the Clinical Neuroscience Acumen across the Region

By TC Origitano, MD, PhD

While increasing in clinical prevalence, the clinical neurosciences remain steeped in mystery and lack of experience. This is often the result of an educational system which sparingly exposes healthcare providers to the clinical neurosciences. Shortages exist for primary neuroscience providers (neurologist and neurological surgeons). These shortages are in part due to a long and arduous training period and have exacerbated their misdistribution to more urbanized areas. In Montana, this distribution problem is enhanced by the vast expanses of distance and limited large population areas.

To provide advanced and comprehensive clinical neuroscience care in Montana, a two prong solution is necessary: 1) regionalization for higher acuity patients 2) regional education for referring centers increasing their comfort level with managing appropriate patients with neurological disorders.

From its inception, one of the primary goals of Logan Health Neuroscience & Spine was to provide comprehensive educational venues to elevate the clinical neurosciences. Each encounter with a provider is an opportunity to educate. To accomplish this goal, venues must cross the spectrum of health care providers: ER physicians, hospitalists, primary care providers, nursing, and advanced practice providers.

COVID has certainly brought challenges to education. Traditionally, Neuroscience & Spine services had the following educational venues:

1) Weekly case conference: discussion of unique and challenging cases would be discussed across neurological surgery, pain management and physical medicine and rehabilitation.

2) Monthly imaging conference: reviewing up to date imaging on a spectrum of neurologic disease processes.

3) Monthly trauma conference: neurological surgery supports and plays a key role in the care and management of neuro-trauma cases both pediatric and adult.

4) Weekly tumor board/cancer conference: contributing both cranial and spinal neuro-oncology cases and input.

5) Emergency Neurological Life Support (ENLS) courses: biannual courses in ENLS are offered to both nursing and physician staff which covers diagnosis and management of the most common neurological emergencies.

6) Annual Neurological Surgery Boot Camp for Advanced Practice Providers: held annually has attracted participation from across the continental United States and Alaska. It provides didactic, interactive, and practical hands on procedural practice for advanced practice providers.

7) Annual Neuroscience & Spine Synergies Report: this annual report not only provides statistics on the capabilities and capacities of the service line (can be found online) but also harbors original articles related to the management of a wide variety of common neurological illnesses and injuries.

8) Save the Brain program: provides educational venues and materials for the training of healthcare providers, coaches, trainers and parents on concussion diagnosis, management and recovery.

9) Peter M. Sorini, MD Educational Endowment: this endowment funds a summer internship for college students interested in pursuing careers in the neurosciences. It provides an opportunity to experience the clinical neurosciences first hand and contribute to a clinical research project.

10) Logan Health Medical Center grand rounds: a variety of clinical neuroscience topics are presented throughout the year.

11) UPDATE IN THE CLINCAL NEUROSCIENCES: this program is scheduled for September 14-16, 2022. It will provide both didactic lectures, case studies, and hands on practical experience (i.e. lumbar puncture, ER simulation, etc.) in the clinical neurosciences. The following topics will be reviewed:

    a) The neurological exam

    b) Status epilepticus

    c) Stroke diagnosis and management

    d) Traumatic brain injury

    e) ICP management

    f) Pediatric neurosurgical evaluation and management

    g) Seizure management in children

    h) Concussion management

    i) Headache management

    j) Functional neurosurgery

    k) Diagnosis and treatment of spinal disorders

12) Logan Health Stroke and TeleStroke Programs: ongoing education for ten Montana critical access hospitals biannually, structured as a combination of web-based interactive lectures, case studies and in-person provider and RN training with emphasis on evidence-based acute stroke care and telestroke utilization/protocols.

As healthcare providers we are committed to be ongoing learners. To stand still on your education is to fall behind. Education is a vital component of advancing the quality and complexity of neuroscience health care. With every interaction between providers there is an opportunity to learn, to grow, and to mature our knowledge with the ultimate reward of enhancing our patient's outcomes.

Logan Health Neuroscience & Spine encourages providers to take advantage of these educational opportunities and participate in the growth and development of the neuroscience healthcare community.

Case Takeaways:

- Neuroscience educational increases over all clinical acumen, expediting recognition of patients who need higher acuity care and permitting lower acuity patients to remain local.
- When in doubt, call. Every experience is an opportunity for education. The combination of sharing imaging and direct person to person discussion can lead to timely, advanced care for the patient and comfort for the provider.

Case Study Twelve

The Aging Population and Neurogenic Claudication: The Costco Sign

By TC Origitano, MD, PhD

Lumbar spondylosis is common and increases with age. As our population ages and remains active with the aid of hip and knee replacements, the stressors on the lumbar spine continue to increase. The lumbar spine is subject to higher forces as it bears the weight of the entire upper body. Most significant degeneration occurs at the transitional areas from L3-S1 (highest at L4/5 and L5/S1). Unlike the cervical and thoracic regions, the lumbar spinal canal harbors the cauda equine with the spinal cord ending at L1.

When diagnosing neurogenic claudication, the history again plays a significant role. Patients will complain of a gradual decrease in their ability to ambulate distances. Significant others or partners may complain of "having to leave them behind." Neurogenic claudication can be confused with vascular claudication. Examination of the pulses in the distal extremities and or obtaining a formal vascular study (Ankle-Brachial Index) can help with differentiating between vascular and neurogenic etiologies. With neurogenic claudication, symptoms can often be relieved by bending forward (thereby slightly increasing the diameter of the lumbar canal). The mechanism of symptom generation is believed to be ischemia to the active roots at the site of compression. Stopping of activity and bending forward relieves the ischemia, restoring function and resolving symptoms. The patient will often tell you as they walk their legs become heavier. They may develop numbness and in some occasions back pain. They will make subtle changes in their life styles. To observe this phenomenon one only has to visit their local Costco. Costco has long aisles. If one stands and watches you can see individuals pushing their carts at the beginning of the aisle and as they progress down, they slow down and continue to bend forward over the cart until they ultimately stop, and "get left behind" (The Costco Sign).

The patient is a 73-year-old very active female. She loves to hike in the park and chops wood to heat her home. Over the course of the last 6 months she has noted progressive loss of the ability to walk distances, having to stop and sit down, bending forward to relieve the heaviness and numbness to her legs. She notes that she drives around the parking lot of the grocery store to try to find a place close to the store as it is difficult for her to walk distances. On examination she has a normal motor and sensory examination of the lower extremities. Her reflexes at the knees and ankles are diminished (not an uncommon finding at her age).

Remember that most patients are examined at rest. To elicit her symptoms she is sent into the hallway to walk. After two- three minutes she begins to be symptomatic. The work up includes MRI of the lumbar spine (figure one). Severe stenosis is seen at L4/5. Dynamic lumbar spine films are also obtained. These films should be done as weight bearing in order to observe any abnormal movement or slippage of the spine with movement and during weight bearing. Oblique films are not required and add little to the workup. If a slip is noted, that would change the operative approach requiring stabilization along with decompression. If a slip exists as part of the stenotic region it will depend if it is a dynamic slip (moves therefore requires fusion) or stable (does not move and may not require fusion). The vast majority of patients are well served by a posterior decompression (laminectomy) without fusion.

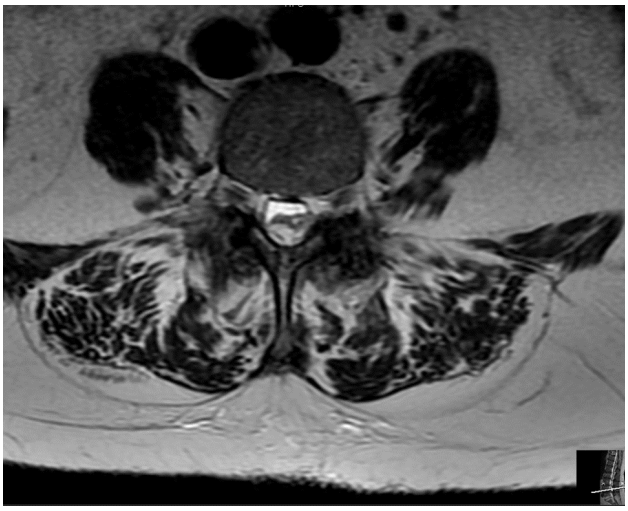


Figure 1: Normal canal level above stenosis

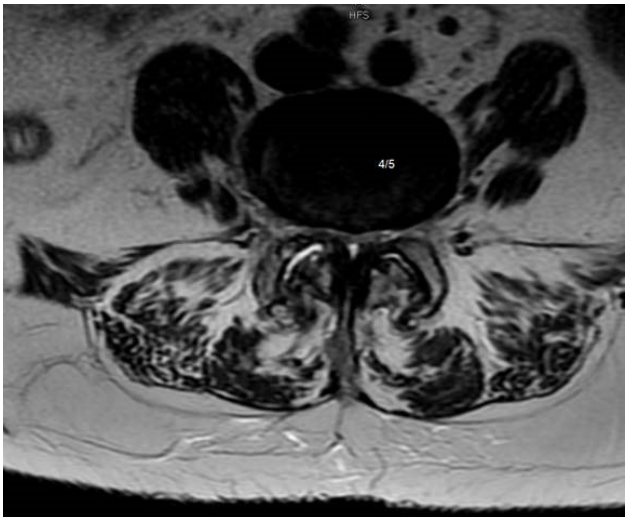


Figure 2: L4/5 level of severe lumbar stenosis

Case Takeaways:

- Patients with neurogenic claudication from lumbar spinal stenosis may have a normal neurological examination. Symptoms and signs can be brought on by ambulation.
- The history will reveal subtle changes in life style with progressive decrease in activities. Ask about how they do in places which require ambulation (Costco) and if their significant other or partner feels like they are “leaving them behind.”
- Work up includes a MRI of the lumbar spine and upright dynamic lumbar spine films. This will reveal the levels and degree of compression as well as assess changes in the spine with axial loading.
- Treatment is generally posterior decompression. Findings of slippage or dynamic movement might necessitate fusion.
- Functional recovery is generally very good with restoration of ability to ambulate without symptoms.

Case Study Thirteen

Labral Tear with Nerve Entrapment

By Austin Johnston, DO

Logan Health Neuroscience & Spine is a synergistic cadre of medical specialties working together to provide quality care within Logan Health (LH). LH Physical Medicine & Rehab (PM&R) seamlessly integrates within neuroscience and spine providing both diagnostic and therapeutic services. PM&R performs nerve conduction studies and electromyography (NCS/EMG) to assist with the diagnosis of suspected peripheral nerve entrapments, radiculopathy, polyneuropathy, and myopathy. The judicious use of NCS/EMG testing as an extension of the physical exam can assist with diagnosing nerve or muscle injury in a timely and cost efficient manner. The following is a case in which NCS/EMG helped to identify a shoulder labral tear and cyst with suprascapular nerve entrapment in a medically complex patient with chronic pain.

A young woman in her 20s with a history of chronic musculoskeletal pain initially presented to PM&R in 2018 with complaints of transient arm paresthesia. On physical exam she was noted to have hypermobility and an anterior rib subluxation. Peripheral nerve entrapment in the upper extremities and axonal cervical radiculopathy were ruled out with NCS/EMG. LH Wellness and Pain assisted with management of her rib pain with osteopathic manual manipulation (OMM). PM&R referred her to a genetic counselor due to her hypermobility and she received a clinical diagnosis of the hypermobility type of Ehlers Danlos Syndrome (EDS).

She was followed routinely by PM&R for several years to assist with therapies, bracing/splinting, and injections for recurrent pain associated with her joint hypermobility. She remained physically active with dance during this time, but returned to clinic with complaints of right shoulder pain, and a physical exam that was suspicious for rotator cuff tendinopathy. Physical therapy was initiated and she continued to receive OMM without relief. At follow up mild atrophy was noted involving the infraspinatus muscle, and the electrodiagnostic study was repeated with evidence of a right acute suprascapular nerve entrapment. A shoulder MRI was ordered and revealed a posterior superior labral tear with a large paralabral cyst extending into the suprascapular notch. She was referred to orthopedics for further evaluation and received arthroscopic labral repair and cyst decompression. She was diligent with her rehabilitation following her surgery, but at approximately 10 months post op she continued to complain of arm pain, paresthesia, and weakness. A repeat diagnostic study was performed with evidence of excellent suprascapular nerve reinnervation (healing) and no ongoing or acute nerve injury. A repeat MRI with contrast demonstrated interval postsurgical changes of superior and posterior superior labral repair, no evidence of paralabral cyst, and resolution of edema within the infraspinatus. Findings were suggestive of postoperative changes vs recurrent tearing. With no evidence of recurrent nerve injury, ongoing conservative management strategies were pursued.

This case highlights how NCS/EMG was able to efficiently diagnose acute nerve injury in a patient with a challenging chronic pain syndrome and hypermobility. The testing also confirmed nerve recovery and healing following cyst removal.

Case Takeaways:

- PM&R performs NCS/EMG as an extension of the physical exam assisting with the diagnosis of axonal radiculopathy, peripheral nerve entrapment, polyneuropathy, and myopathy.
- This study may be performed as a timely and cost efficient screening tool in complicated patients with frequent pain complaints and a clinical exam suggestive of peripheral nerve injury.
- NCS/EMG is useful in confirming healing or progression of nerve injury following a procedure and may assist with prognosis for recovery.

Case Study Fourteen

Normal Pressure Hydrocephalus

By TC Origitano, MD, PhD, and Justin Shobe, PA-C, MCHS

Cerebrospinal fluid (CSF) circulates about the brain and spinal cord. Normal pressure hydrocephalus (NPH) develops due to a chronic increase in CSF volume, causing disruption in neurologic function.[1] Crossover exists between the signs and symptoms of NPH and several other neurologic pathologies. This often results in delayed diagnoses, worsened debility and the potential for additional injuries. Logan Health Physical Medicine & Rehab (PM&R) has teamed with the Logan Health Rehabilitation and the rest of Neuroscience & Spine to develop a comprehensive diagnostic criteria for patients with suspected NPH. This evaluation involves a high volume lumbar puncture (HVLP) with a standardized physical exam before and after the procedure. While no gold standard exam or imaging study exists, this collaborative testing regimen helps solidify the diagnosis, leading to the most appropriate therapeutic interventions. This article outlines the relevant anatomy, pathophysiology, clinical findings and the HVLP exam in the setting of suspected NPH.

Anatomy:

Three protective layers, known as meninges, overlie the developed brain. These include the dura (outer), arachnoid (middle) and pia (inner) mater. In the healthy brain, the cerebrospinal fluid (CSF) assumes the space between the arachnoid and pia mater (the subarachnoid space). CSF helps make the brain buoyant, and provides a cushion against the forces of nature that we encounter every day. Four CSF containers (ventricles) occupy the cerebrum. The choroid plexus, present all four cerebral ventricles, acts as a diffusion barrier that pulls fluid and critical products from the blood into the CSF circulation. Raised granulations within the arachnoid surface provide a return route for CSF to enter the venous system. Veins surrounding the spinal nerve roots also resorb CSF distally.

Pathophysiology:

The subarachnoid space has a fluid capacity of approximately 120 mL of CSF. The ventricular system has a capacity of 30 mL CSF. The body circulates and replaces this volume up to four times per day, producing about 500 mL of CSF daily.[2] Major obstruction to this fluid flow becomes problematic rather quickly. However, NPH patients slowly increase their circulating volume at a rate that correlates with the gradual onset of neurological deficits and symptoms. Their brain and other neurologic structures maximally accommodate the extra fluid.[1] Due to the expected decrease in brain mass as we age, older patients generally tolerate the change more readily.

Normal pressure hydrocephalus can follow trauma, infection and subarachnoid hemorrhage (SAH), but about one third of cases have no inciting event or discernible cause.[1] Due to the slow rise in CSF volume and insidious onset of symptoms, neurologic changes may be missed by patients, families and practitioners. Patients can develop these changes in the rehabilitation environment, and diligent neurologic exams are critical in avoiding the missed diagnosis of NPH.

Signs and Symptoms:

Precipitous rises in intracranial pressure may cause headache and papilledema, but these are less typical in NPH. Classic NPH symptoms include the triad of mental impairment, apraxic gait, and incontinence.[1] An apraxic gait is similar to the gait pattern seen in Parkinsonism, where the patient's feet seem stuck to the floor. Patients need not exhibit all three disturbances to warrant a detailed exam, advanced imaging (CT, MRI, etc.) and HVLP. Imaging studies cannot always detect NPH. A confident diagnosis of NPH relies on patient history, physical exam, diagnostic imaging and HVLP.

The HVLP involves catheter insertion into the subarachnoid space and withdrawal of 30-50 mL of

CSF. This procedure can be painful and poses inherent risk of infection, spinal fluid leak and hemorrhage, so the index of suspicion must be sufficiently high when ordering it. In the setting of trauma and acute increases in intracranial pressure (ICP), the CSF pressure measured at the initial access to the subarachnoid space is elevated. NPH often demonstrates a hallmark 'normal' opening pressure when lumbar puncture is performed. NPH patients can still experience increased ICP, particularly at night, causing worsened symptoms.[1] As mentioned above, these deficits can result from other pathologies. One of the most common misdiagnoses is Parkinson's disease and Parkinsonism. Further confounding diagnostic efforts, the pathologies of NPH, stroke and Parkinsonism may coexist. Prior to definitive diagnosis of stroke, Parkinson's disease or Parkinsonism, NPH should be ruled out.

Exam:

As noted, several physical exam signs should increase suspicion of NPH. Efforts have been made worldwide to create an inclusive exam protocol that provides optimal sensitivity and specificity. One of the most common forms of testing includes HVLP with pre- and post-procedure physical evaluations. Logan Health Rehabilitation and PM&R designed a protocol at Logan Health Medical Center that includes HVLP and measures several functional areas of the brain.

This regimen tests the patient before and after a HVLP. If the patient truly has NPH, improvement should be measurable in cognition, coordination, stamina and balance. When comparing pre-HVLP and post-HVLP exam scores, patients who demonstrate marked improvement may be candidates for shunt placement. The shunt typically creates a conduit between the cranial ventricle and the abdomen (ventriculoperitoneal shunt), allowing regulated flow of CSF from the brain. This pressure relief provides increased gait safety, decreased neurologic symptoms and improved independence. A 2016 literature review by Mihaj et al.[3] found an average of 75% specificity with the HVLP method of testing. While this test is excellent at confirming suspected NPH patients, current literature has shown that a negative test does not preclude a patient from having NPH, and, thus potentially benefiting from shunt placement. Interestingly, higher volumes of lumbar taps (up to three HVLP procedures, totaling 100-120mL) has correlated with increased sensitivity.[3,4] Unfortunately, increasing the number of procedures also increases the risk to the patient.

On the day of the procedure, the patient undergoes two identical evaluations. The first half of the exam takes place in the morning at LH Rehabilitation under observation of a physical therapist and PM&R practitioner. After testing, the patient reports directly to Interventional Radiology for the HVLP, extracting 30-50 mL of CSF. After the procedure and a brief monitoring period, the patient returns directly to LH Rehabilitation for the post-procedure evaluation. The exam components are described below.

Pre and Post Lumbar Puncture Exams:

The entire exam takes between 30-40 minutes to administer. The providers and therapists evaluate cranial nerves, upper and lower extremity strength, sensation, and reflexes. Coordination, balance, gait and coordination are measured according to validated exam protocols. The Berg Balance Assessment Tool provides balance evaluation in five different positions and functional tasks. A six-minute walk test observes gait changes, base of support, foot clearance, stride length and gait efficiency. This test also measures the total distance covered in six minutes. The timed up and go (TUG) test is a measurement commonly used in evaluation of Parkinson's disease. This chiefly evaluates for bradykinesia (difficulty with initiating motion). This abnormality can be found in the setting of both Parkinsonism and NPH, among other pathologies. With the patient's permission, portions of these tests may be filmed in order to glean subtle changes in pre-and post-HVLP exams.

Finally, the patients undergo a standard Mini Mental Status Exam which is designed to objectively measure cognitive deficiencies. Scores between 26 and 30 are considered normal in the general population. Patients with scores between 10 and 20 usually cannot safely live independently. Scores between 0 and 9 indicate severe impairment and most patients in this range will have difficulty eating and walking.[5] Response rate and accuracy tend to improve after HVLP in NPH patients.

Summary:

NPH can present an elusive diagnosis. The HVLP protocol provides a highly specific approach to help build the case for the appropriate treatments. While the lumbar puncture procedure poses risks to the patient, the diagnostic benefit can lead to appropriate and life-changing interventions. Consistent coordination amongst providers and physical therapists will continue to expedite correct diagnoses and optimize patient outcomes in the setting of NPH. Further research can help improve the validity, sensitivity and specificity of these testing measures. Ultimately, providers will continue to consider the entire clinical picture of a patient when deciding the most appropriate treatment strategies.

Case Study:

The patient is a 59-year-old female who has a ten year history of progressive hearing loss and ringing in her left ear. A MRI of the brain was ordered which demonstrated a small left acoustic neuroma. Over the past several months she began to complain of progressive gait and balance difficulty, and intermittent urinary incontinence. Her examination on presentation was one of a wide based gait, and increased upper and lower extremity reflexes. These findings were more consistent with a myleopathy and could not be explained by the presence of a small acoustic neuroma. MRIs of the cervical and thoracic spine were obtained. These studies demonstrated a clean thoracic spine and mild-moderate cervical stenosis. The findings on the cervical and thoracic MRIs did not explain the symptom complex. Over the course of her work up her ataxia increased and she began to develop increasing urinary incontinence. Re-evaluation of her brain MRI led to a suggestion that her ventricular system appeared mildly distended with preservation of the subarachnoid space.

The combination of gait disturbance, increasing urinary incontinence, slightly enlarged ventricles with preserved subarachnoid space led to a presumptive diagnosis of Normal Pressure Hydrocephalus.

The patient was sent to Physical Medicine & Rehab for pre-lumbar puncture protocol performance evaluation. This evaluation quantitates balance, gait and mental status serving as baseline to measure improvement after cerebral spinal fluid drainage. The patient then underwent a lumbar puncture. Opening pressure was normal. A large volume tap was performed removing 30-50 cc of cerebral spinal fluid. Repeat performance testing on the day of lumbar puncture demonstrated statistical improvement across the spectrum of evaluations. The results of this evaluation suggested a high probability for durable improvement with cerebral spinal fluid diversion.

Primary cerebral spinal fluid diversion for normal pressure is actualized utilizing a ventriculoperitoneal shunting. This process places a small plastic catheter through a dime size hole in the skull into the cerebral spinal fluid space in the center of the brain. The catheter is interfaced with a valve system which drains through a second catheter into the abdominal cavity where the spinal fluid is absorbed. The catheter and valve system run under the skin and are generally not visible. The placement of these shunting systems have become more minimally invasive, accurate, and functional with the application of new technologies:

1) The ventricular catheter can be stereotactically guided to its final destination utilizing a computer assisted surgical navigation system decreasing the risk of catheter misplacement and need for revision.

2) The valve system is adjustable and can be reprogrammed through the skin which allows multiple adjustments to optimize results eliminating the need for reoperation to change valve settings.

3) The abdominal cavity is accessed endoscopically which requires only 2-3 small puncture sites, and assures accurate drainage catheter placement.

4) The catheter systems are now antibiotic impregnated lowering the potential risk of infection.

Patients are admitted to the hospital on the day of operation. The operative intervention takes approximately 1-1.5 hours. Patients are discharged the next day. Serial examinations during the ensuing weeks can lead to optimization of performance through reprograming of the valve by utilizing a magnetic adjustment tool.

Postoperatively the patent in this case study had sustained improvement in gait and balance.

Case Takeaways:

- Normal pressure hydrocephalus is an elusive diagnosis.
- The syndrome clinically consists of gait disturbances, urinary incontinence and progressive dementia.
- Critical review of MRI and High Volume tap with pre-tap and post-tap performance testing can aid in determining diagnosis and whether shunting would be helpful.
- Technological components in operative intervention (intraoperative navigation/ endoscopic abdominal surgery) and adjustable shunts have improved the safety of treatment.

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Contacts

Logan Health Neuroscience & Spine
Department of Neurological Surgery
200 Commons Way, Suite B
Kalispell, MT 59901
p: (406) 752-5170

Logan Health Neuroscience & Spine
Department of Neurology
200 Commons Way, Suite C
Kalispell, MT 59901
p: (406) 752-5095

Logan Health Physical Medicine & Rehab
205 Sunnyview Lane
Kalispell, MT 59901
p: (406) 758-7035

Logan Health Wellness & Pain Management
245 Windward Way, Suite 101
Kalispell, MT 59901
p: (406) 756-8488

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