FROM THE EDITOR

Dear Colleague,

I am pleased to bring you the Spring 2011 issue of the UH Neurological Institute Journal.

Through continuing collaboration with scientists at Case Western Reserve University School of Medicine, physicians at the UH Neurological Institute test and refine the latest advances in treatment for patients with disabling neurological disorders. The NI Journal highlights these advances and demonstrates our interdisciplinary strengths. As an added benefit for our readers, CME credit is readily available in each issue for the busy practitioner interested in receiving AMA PRA Category 1 Credits™.

In this issue, Jonathan Miller, MD, describes a novel technique using concomitant frame-based and frameless techniques for precise electrode placement in patients who require both surface electrodes and deep electrodes to evaluate whether they will benefit from epilepsy surgery.

Chad Zender, MD, and colleagues review how their increasing experience with endoscopic approaches of the anterior skull base has allowed them to resect tumors without compromising surgical outcomes at University Hospitals. Dararat Mingburnjerdkul, MD, and Shenandoah Robinson, MD, discuss spasticity treatment in children. The multidisciplinary team of University Hospitals Rainbow Babies & Children’s Hospital’s Spasticity Program uses individualized strategies to best tailor treatment options and help children optimize their development, comfort and independence. Read about it in this issue.

Ingrid Tuxhorn, MD, looks at epilepsy surgery for pediatric patients and explains how referring children with surgical epilepsy syndromes to a specialized pediatric epilepsy unit early can optimize seizure and psychosocial outcome.

Christopher Bailey, PhD, presents an article on sports-related concussion, a common but challenging and complex clinical phenomenon. Though the basic and clinical science of the injury is still only partially understood, the high level of recent public interest is resulting in a influx of research and leading to better management of this head injury.

The UH Neurological Institute offers an interdisciplinary approach to highly individualized therapies and offers leading-edge care, including stereotactic radiosurgery, endovascular stroke and aneurysm treatments, neurostimulation and artificial disc replacement.

Jonathan Miller, MD

Neurological Institute Physician Advice Line
216-844-1001
Appointment Request Line
216-844-2724

TABLE OF CONTENTS

2 When Close Enough Isn’t Close Enough: Dual Stereotaxy for Placement of Epilepsy Monitoring Electrodes
Jonathan Miller, MD

6 Advances in Anterior Skull Base Surgery
Chad A. Zender, MD, FACS
Rod Raaze, MD
Pierre Laverdière, MD
Warren R. Selman, MD
Nicholas C. Bambakidis, MD

11 Spasticity Treatment in Children
Dararat Mingburnjerdkul, MD, FAAP
Shenandoah Robinson, MD, FACS, FAAP

16 Expanding the Spectrum of Indications for Epilepsy Surgery in Children
Ingrid Tuxhorn, MD

21 The Neuropsychology of Sports-Related Concussion: Return-to-Play and the Management of Head Injury in Athletes
Christopher M. Bailey, PhD

University Hospitals Case Medical Center
The commitment to exceptional patient care begins with revolutionary discovery. University Hospitals Case Medical Center is the primary affiliate of Case Western Reserve University School of Medicine, a national leader in medical research and education and consistently ranked among the top research medical schools in the country by U.S. News & World Report. Through their faculty appointments at the Case Western Reserve University School of Medicine, physicians at UH Case Medical Center are advancing medical care through innovative research and discovery that bring the latest treatment options to patients.

On the cover: Endoscopic visualization of the pituitary region with conceptualized drawing of removal of intradural tumor from the frontal fossa floor (Illustration by Ravin Art & Design.)

Kim Duval, Editorial Manager
Bryan Kidish, Marketing Manager
Susan Maaja, Senior Graphic Designer

Volume 4 • Number 1 • Spring 2011

FROM THE EDITOR

University Hospitals Neurological Institute Journal
When Close Enough Isn’t Close Enough: Dual Stereotaxy for Placement of Epilepsy Monitoring Electrodes

By Jonathan Miller, MD

Epilepsy monitoring using intracranial electrodes is sometimes required to determine whether patients are candidates for further surgery. As techniques improve and indications for surgery expand, there is a need for increased precision in electrode placement. These techniques have evolved along with the specialty of neurological surgery, from early frame-based localization based on anatomic approximations to sophisticated computerized frameless systems capable of real-time identification of location of surgical instruments projected onto preoperative scans. For certain applications, frame-based stereotaxy is still required because no frameless system can rival the accuracy obtained using a rigid stereotactic frame. In this article, we outline the history of stereotaxy and describe a novel technique using concomitant frame-based and frameless techniques for precise electrode placement in patients who require both surface electrodes and deep electrodes to evaluate whether they will benefit from epilepsy surgery.

Introduction: The Clinical Problem

One in 10 Americans have had or will have a seizure at some point in their lives, and three million have some form of epilepsy. One in 10 Americans have had or will have a seizure at some point in their lives, and three million have some form of epilepsy. Almost 500 new cases of epilepsy are diagnosed every day in the United States, more than multiple sclerosis, cerebral palsy, muscular dystrophy, and Parkinson’s disease combined.1 For the United States, more than multiple sclerosis, cerebral palsy, muscular dystrophy, and Parkinson’s disease combined.1 More than one million people have some form of epilepsy. One in 10 Americans have had or will have a seizure at some point in their lives, and three million have some form of epilepsy.1

For patients who are candidates for surgical resection, prognosis can be quite good: one randomized controlled trial of surgery for temporal lobe epilepsy demonstrated a tenfold increased rate of freedom from seizure with surgery compared with the use of medications alone.2 Successful surgery for epilepsy requires precise definition of the extent and location of seizures and is usually accomplished using a combination of clinical, electrophysiological (electroencephalography), and imaging (magnetic resonance) data. However, sometimes the seizure onset zone is not readily identified using these techniques, and patients require sampling of electrical signals from the brain itself, with the use of surface electrodes in the subarachnoid space or depth electrodes passed into deep structures of the brain.3 There are limitations to both techniques, and when the seizure onset zone could be from either surface or deep tissue or when it is necessary to map the brain surface to determine the location of motor or speech areas, both electrode types must be used concurrently. To do so, it is necessary to use stereotaxy techniques, which fall into two basic categories: (1) frame-based, which utilizes a rigid frame attached to the patient’s head that is used to guide surgical instruments and (2) frameless, which uses optical techniques to triangulate the real-time position of surgical instruments relative to preoperative imaging.

Early Stereotaxy: The Stereotactic Frame

The history of stereotaxy as a tool to assist neurosurgeons in intracranial navigation largely parallels developments in neuroimaging, but the concept of a localizing apparatus attached to the head dates from far earlier. In 1899, an anatomy professor in Moscow named D. N. Zernev developed the “encephalometer,” an aluminum ring surrounding the head mounted with two arcs that could identify any point above the ring using polar coordinates.4 It was used intraoperatively on at least one occasion to define the motor cortex to drain an abscess in a patient with Jacksonian epilepsy. Shortly thereafter, Robert Clarke and Sir Victor Horsley developed another frame using a three-dimensional coordinate system based on external skull landmarks and used it for neurophysiological experiments on animals.5 Though the new term “stereotaxy” and the use of Cartesian coordinates to identify points in the head survive to the present, the Horsley-Clarke apparatus had limited clinical use.

This lack of utility changed dramatically with the evolution of imaging techniques. In the 1940s, X-ray technology could be used to define the anatomy of the cerebral ventricles, which have a defined relationship to other intracranial structures. Using this technique, Ernest Spiegel and Henry Wyck in 1947 developed the “encephalatome,” a rigidly attached frame with reference marks that could be seen on imaging and subsequently used to guide manipulation of surgical instruments.6 This technique led to a proliferation of stereotactic frames and other techniques such as stereotaxy such as electroencephalography,6 imaging for neurophysiological experiments on animals.8 Though the new term “stereotaxy” and the use of Cartesian coordinates to identify points in the head survive to the present, the Horsley-Clarke apparatus had limited clinical use.

Electromagnetic systems that could determine the position and orientation of small magnetic sensors within a low-frequency electromagnetic reference field were developed.9 Interference with metal objects led to problems in practical use. Developed in the early 1990s, optical systems consist of an array of cameras that localize the position of infrared light sources or reflecting spheres mounted on surgical instruments and compare them to a reference image. This system was highly accurate but large and cumbersome. It never entered widespread use.

In the 1980s, increased computing power coupled with improved image resolution led to the development of a number of techniques for intracranial navigation that required neither a frame nor a dedicated image on the day of surgery. The first such system was reported in 1986 and consisted of several ultrasonic sound sources and microphones that triangulated the position of surgical instruments based on the relative delay of the sound from each microphone.10 Though highly accurate under testing conditions, the system was found to be somewhat troublesome in clinical settings due to its sensitivity to air temperature, humidity, turbulence, extraneous noise, and echo.11 Another system called the “neuronavigator” consisted of a multi-pointed arm with potentiometers at each joint that determined the location of the end based on the distance and angle of each segment of the arm.12 This system was highly accurate but large and cumbersome. It never entered widespread use.

In current use are based on optical technology. These systems are user-friendly and have become ubiquitous for intraoperative navigation.

Back to Basics: Framed Stereotaxy in a Frameless Era

Though frameless techniques are considerably more efficient and cost-effective than frame-based techniques,13,14 the direct comparison of frame-based to frameless stereotaxy has repeatedly demonstrated superior accuracy using a frame. One study compared the two techniques during implantation.

Reference

1. More than one million people have some form of epilepsy. One in 10 Americans have had or will have a seizure at some point in their lives, and three million have some form of epilepsy.1

2. Successful surgery for epilepsy requires precise definition of the extent and location of seizures and is usually accomplished using a combination of clinical, electrophysiological (electroencephalography), and imaging (magnetic resonance) data. However, sometimes the seizure onset zone is not readily identified using these techniques, and patients require sampling of electrical signals from the brain itself, with the use of surface electrodes in the subarachnoid space or depth electrodes passed into deep structures of the brain.3 There are limitations to both techniques, and when the seizure onset zone could be from either surface or deep tissue or when it is necessary to map the brain surface to determine the location of motor or speech areas, both electrode types must be used concurrently. To do so, it is necessary to use stereotaxy techniques, which fall into two basic categories: (1) frame-based, which utilizes a rigid frame attached to the patient’s head that is used to guide surgical instruments and (2) frameless, which uses optical techniques to triangulate the real-time position of surgical instruments relative to preoperative imaging.

3. There are limitations to both techniques, and when the seizure onset zone could be from either surface or deep tissue or when it is necessary to map the brain surface to determine the location of motor or speech areas, both electrode types must be used concurrently. To do so, it is necessary to use stereotaxy techniques, which fall into two basic categories: (1) frame-based, which utilizes a rigid frame attached to the patient’s head that is used to guide surgical instruments and (2) frameless, which uses optical techniques to triangulate the real-time position of surgical instruments relative to preoperative imaging.

4. The new term “stereotaxy” and the use of Cartesian coordinates to identify points in the head survive to the present, the Horsley-Clarke apparatus had limited clinical use.

5. Stereotactic frame shown in Figure 1: Leksell stereotactic frame. (A) Front view. (B) Side view. The pins for rigid fixation onto the head are visible. (C) The indicator apparatus is attached to the frame during imaging to allow the software to determine the spatial relationship of the head to the frame. (D) The arc system is added intraoperatively to allow for precise targeting of any intracranial location using a predefined trajectory.
of deep brain stimulator electrodes, using frameless stereotaxy for one side and frame-based stereotaxy for the other, and found significantly lower rates of error in the group implanted using frame-based stereotaxy (1.2 vs. 6 mm vs. 2.5 ±/–1.4 mm, P < 0.05).3 Similar results have been reported in multiple other studies.4–11 Overall, accuracy using a frame appears to be about twice as good as frameless systems in real-world applications. As a result, frame-based stereotaxy is still used when extraordinary accuracy is required, including gamma knife radiosurgery, biopsy of deep lesions very close to vital structures, when extraordinary accuracy is required, including gamma knife applications. As a result, frame-based stereotaxy is still used when extraordinary accuracy is required, including gamma knife applications.

Dual Stereotaxy: A Novel Approach
Frame-based stereotaxy is often used to implant depth electrodes for epilepsy monitoring, especially when electrodes need to be placed in deep targets adjacent to vital structures. Sometimes a craniotomy is required to place subdural electrodes, as well as to sample surface cortical tissue to determine the evolution of seizures or to map eloquent cortex used for speech functions. Early frame-based stereotaxy has traditionally been necessary either to place the depth electrodes first using the frame and then performing the craniotomy in a separate step or to use frameless stereotaxy and accept slightly lower accuracy in electrode placement.14

To solve this problem, we postulated that it would be possible to perform a craniotomy while in the stereotactic frame, placing the depth electrodes using frameless stereotaxy and surface electrodes using frame-based stereotaxy.15 An example of the operative setup is shown in Figure 2. This combined approach works to the advantages of both techniques. Modern software makes it possible to reformat images in the standard projections so that the same preoperative images used for frame-based stereotaxy can be registered to the frameless system. Real-time X-ray can be used to verify placement of depth electrodes in the frame (Figure 3), and the frame-based instruments can be registered to the frameless system, allowing for yet another level of verification that the electrodes are in the correct place.

The trajectory for the electrodes can be precisely planned ahead of surgery by avoiding blood vessels and cerebral ventricles. Finally, electrodes can be placed either before the craniotomy from points outside the bone flap or afterwards through the cranial defect itself. One potential disadvantage of performing a craniotomy in the frame is limitation of access to the surgical field produced by the fixation posts and frame base. However, with some foresight, it is possible to carefully position the frame slightly tilted and rotated to place the center of the intended cranial flap equidistant from the fixation points, making virtually any craniotomy possible.

Detailed postoperative analysis of patients who underwent this procedure demonstrated an average error from preoperative planning of less than 1 millimeter, similar to most other studies of frame-based stereotaxy (Figures 4 and 5). Since 2008, 22 patients with epilepsy, but without lesions found with magnetic resonance imaging, have been studied at University Hospitals Case Medical Center using this technique, and all six were found to have a seizure onset zone amenable to subsequent resection. All patients undergoing resection experienced significant improvement or elimination of seizures postoperatively. Without the precision of the stereotactic frame and the versatility of the frameless system, the degree of accuracy required might not have been possible, and these patients might not have been identified as candidates for surgical resection of epileptic tissue. The combined approach is not appropriate for every case, but it is very useful when targeting sensitive structures deep in the brain is necessary. With this technique, it is possible to implant all electrodes in a single step and obtain the level of precision possible with a stereotactic frame without sacrificing subdural recordings.

Conclusions
Stereotactic techniques have changed significantly in the past 100 years, but the goal has always been the same: to allow precise navigation within the cranial cavity. Early frame-based systems have largely been supplanted by newer frameless techniques, but the accuracy possible using a frame has not been surpassed. If necessary, both techniques can be combined to expand the versatility of the approach. This combination is especially useful for epilepsy evaluation and has allowed for use of the combined systems that would otherwise not be accessible for monitoring.

Jonathan Miller, MD, reports no financial relationships with commercial interests relevant to the content of this article. 

References
 Advances in Anterior Skull Base Surgery

By Chad A. Zender, MD, FACS
Rod Rezaee, MD
Pierre Lavertu, MD
Warren R. Selman, MD
Nicholas C. Bambakidis, MD

Introduction
Anterior skull base tumors represent a rare subset of neoplasms whose treatment has evolved tremendously over the past 20 years. Traditional treatments require a craniotomy and a transfacial approach. This classic approach carries significant morbidity ranging from 15% to 40%, frequently in the form of frontal lobe injuries, pneumocephalus, meningitis, and leaking cerebrospinal fluid (CSF). Endoscopic approaches allow for excellent visualization and the potential for a less invasive approach to areas like the clivus, cavernous sinus, and petrous apex. Also, frontal lobe retraction is unnecessary. Our increasing experience with endoscopic approaches has allowed us to expand our paradigm and resect benign and select malignant tumors without compromising surgical outcomes. In this article, we discuss advantages and disadvantages of each approach, advances in stereotactic image guidance, and the endoscopic repair of the anterior skull base.1

Anterior Skull Base Neoplasms
Neoplasms of the anterior skull base have always been challenging to treat. Pioneers in treating these tumors gave hope to patients who historically had limited treatment options. Because of the rarity of these neoplasms, the complex anatomy, and the resultant communication between the bacteria ridden nasal cavity and cranial vault, complications were frequent. Over the past 30 years, techniques have been refined and methods developed to decrease perioperative morbidity and improve survival for these patients.2 Many open approaches have been described for the treatment of anterior skull base tumors; most require a transcranial approach and a transfacial approach. A two-team method that includes both a neurosurgeon and an otolaryngologist brings the expertise of both specialties to the patient and optimizes care and outcome.

Craniofacial Approach
We use a similar approach as described by Ketcham and others.3 4 The procedure begins with a bicoronal skin flap elevation and an anterior craniofacial approach with removal of the frontal bar when necessary, allowing exposure of the frontal lobes/dura, the cribriform, and entire anterior skull base back to the planum sphenoidale. Traction on the frontal lobes must be minimized and can be accomplished by removal of the frontal bar to gain sufficient inferior exposure. This “top down” approach allows the neurosurgeon to identify the superior limits of the tumor and resect tumor, dura, and involved tissues from above. A transfacial incision is then added to allow a “bottom up” approach. The otolaryngologist removes the intranasal and paranasal sinus component of the tumor. Various incisions can be utilized for exposure and access of the anterior skull base from below. A lateral rhinotomy, Weber-Ferguson, or facial degloving approach may be appropriate depending on the inferior extent of the tumor. Once adequate exposure of the tumor is achieved, the inferior component can be resected with clear margins. This approach allows for an en bloc resection, but portions of the tumor frequently must be removed separately, especially posteriorly in and around the sphenoid sinus.5 After the resection is complete, reconstruction of the floor of the anterior cranial fossa is performed, which begins by cranializing the frontal sinuses and obliterating the nasofrontal duct.6 Local tissues such as the pericranial flap based on the supraorbital vessels can be used. The pericranial flap is harvested at the beginning of the case and elevated off of the skin flap and can be separated at the end of the procedure. The pericranial flap is draped over the frontal bar and secured to the orbits laterally and the planum posteriorly. In previously treated patients, there may be a paucity of local tissues for adequate reconstruction. One of the major advances in the reconstruction of skull base defects has been the advent of microvascular free tissue transfer. Extensive tumor resection in previously treated patients requires that healthy vascularized tissue be brought in from remote sites. Coordinating these cases with a microvascular surgeon ensures that the necessary tissue is available for skull base repair.7 These open approaches revolutionized treatment of malignant lesions of the anterior skull base. Before these surgical approaches were available, patients had few options and little chance of a cure. Even with the various advances in skull base surgery, complication rates from these procedures can be as high as 30% to 40%. Meningitis, CSF leaks, intracranial hematomas, frontal lobe injuries, and tension pneumocephalus can all result from this kind of approach. Because of these complications, both otolaryngologists and neurosurgeons have been pursuing ways to remove these tumors with less morbidity to the patient.

Endoscopic Approaches
Endoscopic approaches differ significantly from their open counterparts. These approaches are endonasal and utilize a telescope with a camera and monitor (Figure 1). New units are available in high definition, and the quality of images is outstanding. The images can be magnified for the surgeon, and multiple monitors can be used. An endoscopic approach allows for surgical resection of various benign and select malignant tumors of the skull base, avoiding a craniotomy and requiring no retraction of the frontal lobes. The amount of literature showing less morbidity, without a sacrifice in surgical outcomes in appropriately selected patients, is growing.8,9 The endoscopic approach requires that the traditional Halsted principle of en bloc resection be violated. Complete tumor resection can be achieved as long as margins are sent after each area is resected. This approach requires that tumor resection be employed in a systematic fashion. First, the tumor is debulked, allowing the surgeon to remove enough of the lesion to adequately see the key landmarks that were identified on preoperative imaging. Next, in a stepwise fashion, areas of tumor involvement are cleared out and appropriate margins sent, making a very important point about endoscopic surgery. Significant tumor bulk, expansion, and destruction can distort landmarks and make it difficult to know lateral and superior limits. Preoperative magnetic resonance imaging (MRI) and computed tomography (CT) are paramount in helping the surgeon outline his or her surgical plan. An intact clivus, pterygoid plate, and cribiform plate can all help the surgeon navigate around the tumor and utilize preserved landmarks to avoid critical structures and significant morbidity.10

Figure 1: Illustration demonstrates positioning of the patient and surgical team. The anesthetist is located near the foot of the operating table so that direct access to the face can be obtained by the surgical team members. The endoscopic tower with monitor is positioned at the head of the table. Image courtesy of Ravin Art and Design.
The endoscopic approach is useful in treating primary tumors of the nasal cavity and paranasal sinuses with limited extension into the skull base and anterior cranial fossa (Figure 2). An extensive resection of the paranasal sinuses, septum, and cribiform plate is possible when indicated. Frequently, a solely endoscopic approach can be used when tumors are appropriately selected. Even when tumors extend into the orbital contents or have significant extension into the tumors are appropriately selected. Even when tumors extend into the orbital contents or have significant extension into the brain parenchyma, a combination of endoscopic and open approaches can be utilized.1 An endoscopic approach in conjunction with a traditional craniofacial approach allows for a safe and oncologic resection of larger and more advanced tumors. Combining the two approaches allows for complete tumor resection and avoids incisions on the face, providing better cosmesis.

Central lesions like pituitary adenomas and craniopharyngiomas can also be treated via an endoscopic approach (Figures 3 and 4). Cooperation between the neurosurgeon and the head and neck surgeon is paramount. The endoscopic approach requires the otolaryngologist to perform limited endoscopic sinus surgery. Blateral sphenoidotomies, a posterior septectomy with removal of the sphenoid rostrum and keel, are performed. Surgical resection of the middle turbinate does not need to be done routinely.15 Once a common sphenoid sinus is created, it is usually necessary to take down the entire intersinus septum. The carotid arteries laterally and the optic nerves superiorly and laterally are identified while remembering that the intersinus septum will direct the surgeon to one of the carotid arteries posteriorly. Care must be taken in the sinus not to fracture this lesion coming into view with the dural margins. A transnasal endoscopic approach. (B, right) After the cyst is drained, the posterior wall of the sphenoid. (D) A view of the sella after removal of the intersinus septum of the nasal cavity. (B) Image after bilateral sphenoidotomies just prior to removal of the posterior wall of the sphenoid. (C) A view of the sella after removal of the intersinus septum and the posterior wall of the sphenoid. (D) A view of the sella during tumor removal.

Central lesions like pituitary adenomas and craniopharyngiomas can also be treated via an endoscopic approach (Figures 3 and 4). Cooperation between the neurosurgeon and the head and neck surgeon is paramount. The endoscopic approach requires the otolaryngologist to perform limited endoscopic sinus surgery. Blateral sphenoidotomies, a posterior septectomy with removal of the sphenoid rostrum and keel, are performed. Surgical resection of the middle turbinate does not need to be done routinely.15 Once a common sphenoid sinus is created, it is usually necessary to take down the entire intersinus septum. The carotid arteries laterally and the optic nerves superiorly and laterally are identified while remembering that the intersinus septum will direct the surgeon to one of the carotid arteries posteriorly. Care must be taken in the sinus not to fracture this lesion coming into view with the dural margins. A transnasal endoscopic approach. (B, right) After the cyst is drained, the posterior wall of the sphenoid. (D) A view of the sella after removal of the intersinus septum of the nasal cavity. (B) Image after bilateral sphenoidotomies just prior to removal of the posterior wall of the sphenoid. (C) A view of the sella after removal of the intersinus septum and the posterior wall of the sphenoid. (D) A view of the sella during tumor removal.

Endoscopic harvesting of this flap has been described, but the vascularized septal flap is easier to harvest and very versatile. Prior to the development of a reliable vascularized flap, endoscopic skull base resections had a high rate of CSF leaks, ranging from 10% to 20%. The Hadad-Basagasteguy flap has helped revolutionize endoscopic skull base repair.66 This vascularized flap is based on the posterior septal artery as it runs below the sphenoid ostium. When tumor resection doesn’t require resection of the septal mucosa, this flap can be harvested at the beginning of the case. Once the sphenoid ostium is identified, the mucosa above the ostia is cut and is carried onto the septum high in the nasal vault. The incision is brought anteriorly and then inferiorly and is pedicled on the mucosa running laterally. Care must be taken in the sinus not to fracture this lesion coming into view with the dural margins. A transnasal endoscopic approach. (B, right) After the cyst is drained, the posterior wall of the sphenoid. (D) A view of the sella after removal of the intersinus septum of the nasal cavity. (B) Image after bilateral sphenoidotomies just prior to removal of the posterior wall of the sphenoid. (C) A view of the sella after removal of the intersinus septum and the posterior wall of the sphenoid. (D) A view of the sella during tumor removal.

Central lesions like pituitary adenomas and craniopharyngiomas can also be treated via an endoscopic approach (Figures 3 and 4). Cooperation between the neurosurgeon and the head and neck surgeon is paramount. The endoscopic approach requires the otolaryngologist to perform limited endoscopic sinus surgery. Blateral sphenoidotomies, a posterior septectomy with removal of the sphenoid rostrum and keel, are performed. Surgical resection of the middle turbinate does not need to be done routinely.15 Once a common sphenoid sinus is created, it is usually necessary to take down the entire intersinus septum. The carotid arteries laterally and the optic nerves superiorly and laterally are identified while remembering that the intersinus septum will direct the surgeon to one of the carotid arteries posteriorly. Care must be taken in the sinus not to fracture this lesion coming into view with the dural margins. A transnasal endoscopic approach. (B, right) After the cyst is drained, the posterior wall of the sphenoid. (D) A view of the sella after removal of the intersinus septum of the nasal cavity. (B) Image after bilateral sphenoidotomies just prior to removal of the posterior wall of the sphenoid. (C) A view of the sella after removal of the intersinus septum and the posterior wall of the sphenoid. (D) A view of the sella during tumor removal.

Conclusion
As our experience with an endoscopic approach has increased, its utility in treating both benign and malignant tumors of the anterior skull base has expanded. It can be used as an adjunct with open approaches, avoiding incisions on the face, or used alone, allowing the otolaryngologist and neurosurgeon to work endoscopically to resect tumors. Stereotactic image guidance has expanded our ability to navigate across the skull base, even when normal structures are distorted or destroyed by neoplasms. New endoscopic techniques in skull base reconstruction have allowed us to perform more extensive resections and decrease morbidity to the patient.

Nicholas C. Bambakkids, MD, is a consultant for Medtronic Seiforx Danek, and Warren R. Selman, MD, is a consultant for Styker and Anspach, though these relationships have not affected the content of this article. The other authors report no financial relationships with commercial interests relevant to the content of this article.

References
Spasticity Treatment in Children

By Dararat Mingbunjerdsuk, MD, FAAP
Shenandoah Robinson, MD, FACS, FAAP

Spasticity is a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex. Progress in understanding the molecular basis of spasticity is underway, and novel therapeutic strategies to minimize the injury that leads to spasticity are in the pipeline. Currently, the diagnosis of motor disorders in children is often associated with angst in families, particularly the term “cerebral palsy.” A thorough assessment by an experienced multispecialty team can offer parents and caregivers definitive information that can relieve unfounded concerns and provide hope and empowerment. For many children, spasticity is just one component of an array of neurological impairments. Thus, the impact of spasticity on a child’s development can vary tremendously. The impact of spasticity can also change over time as the child ages. Teenagers and young adults are much more likely to experience significant discomfort from untreated muscle spasms.

Injury at one or several sites along the pathway from the primary motor and premotor cortex to spinal circuitry can result in spasticity. In children, spasticity can be seen commonly in neurological disorders such as cerebral palsy, spinal cord injury, and stroke as well as in a subset of childhood-onset neurodegenerative diseases with central white matter destruction, such as X-link adrenal leukodystrophy, metachromatic leukodystrophy, and Pelizaeus-Merzbacher disease. The pattern of muscle involvement typically affects certain muscle groups more than others. For example, flexors, adductors, and other internal rotators are affected more than extensors, and extensor groups are affected more than flexors. Spasticity is often evident by 1 year of age and may improve or resolve during early childhood. In addition to recognizing the presence of spasticity, it is important to identify other types of motor disorders. For example, dystonia is commonly present in combination with spasticity in patients with cerebral palsy. The decision to treat spasticity is based on the severity of tone abnormality and the impact it has on the child’s comfort, function, cosmesis, and ease of care. Chronic spasticity may have negative effects on a child’s growth and development. Prolonged involuntary muscle contraction results in permanent shortening in the muscle and tendon, restricting the range of motion in the affected joints, which may cause progressive dislocation of hip joints, bone and joint deformities, and discomfort. Generally, spasticity is treated if it interferes with mobility such as crawling, standing, and walking or with activities of daily living such as feeding, dressing, bathing, and toileting. If these activities are not affected, no treatment is necessary. On the other hand, a certain degree of spasticity can aid the child’s function. For example, some children use lower extremity spasticity to compensate for muscle weakness during ambulation or transfers. In such a situation, reduction of useful strength during ambulation or transfers may actually negatively impact a child’s development.

Multidisciplinary Team Provides Individualized Approach

The treatment team for spasticity management consists of the child and caregivers, primary care physicians, physical and occupational therapists, nurses, neurologists, physiatrists, neurosurgeons, orthopaedic surgeons, orthotists, social workers, and psychologists. The goal of spasticity management is not to cure but to increase...
**Physical Therapy and Occupational Therapy**

Physical therapy and occupational therapy remain the mainstay intervention for spasticity. A stretching and strengthening exercise program may prevent or delay the spatial complications and enhance potential benefits of other treatment modalities. Management is best coordinated in multi-disciplinary programs combined with daily stretching exercises performed by caregivers. Caregivers are essential to the success of any of the more invasive treatment options discussed below.

**Oral Medications**

The advantage of oral medications is the ease of use. However, the systemic side effects are often problematic. Oral medications are most appropriate for children who need mild tone reduction or who have diffuse involvement in most extremities. Similar to other areas of pediatric medicine, most anti-spasticity medication trials have been conducted in adults and relatively few trials have been carried out in children. Therefore, the choice of agent is often based on personal experience and trial and error rather than rigorous, evidence-based medicine.

**Botulinum Toxin**

Botulinum toxin (BTX) is a tetanus toxin produced by the anaerobic bacterium *Clostridium botulinum*. It is a potent neurotoxin with a relative specificity for the autonomic nervous system. It acts at the neuromuscular junction and results in flaccid muscle paralysis by binding to presynaptic nerve endings and suppressing the release of acetylcholine. There are seven naturally occurring serotypes of the toxin, A–G, all of which are used to reduce spasticity in children with cerebral palsy.12,13 It can be delivered via injection, which can be either intramuscular or intrathecal, dependent on individual patient needs. The duration of action is determined by the site of injection, the size of the dose, the age of the patient, and the serotype of BTX used. Adverse effects of BTX injection are usually mild and transient and consist of pain at the injection site, a flaccid syndrome, and excessive weakness.14,15 The botulinum toxin complex is immunogenic, and repeated exposure can lead to immuno-resistance and decreased efficacy with repeated injections. These injections are contraindicated in children who experience worsening of their spasticity during a growth spurt but are less effective as a primary long-term solution for children with severe spasticity.

**Selective Dorsal Rhizotomy**

Although the nonsurgical treatments described above are effective for many children, other children continue to have pain with walking or difficulty to spasticity. These children, especially those with spastic diplegia secondary to preterm birth, may benefit from selective dorsal rhizotomy. The term dorsal rhizotomy refers to the cutting of the posterior sensory nerve roots after they exit the spinal cord. Selective refers to the use of electrophysiological monitoring during the procedure to identify and cut only those nerve roots that are most abnormal.

The goal of selective dorsal rhizotomy is to help normalize the feedback loop that causes increased muscle tone. Normally, motor commands that modulate spinal cord function and suppress muscle tone. Children who have cerebral palsy from preterm birth have limited descending inhibitory input from the brain and thus experience excessive muscle tone in the extremities. In addition, children with cerebral palsy, who have experienced isolated muscle movements and experience increased spread of muscle tone to adjacent muscle groups and limited isotonic contractions. The procedure normalizes the spinal cord feedback loop by cutting a portion of the sensory roots at each spinal level in the lumbar and upper sacral segments. This procedure selectively reduces abnormal muscle tone without affecting sensation.

The multidisciplinary Spasticity Team at University Hospitals Rainbow Babies & Children's Hospital is the only children's hospital in the multi-state region to offer this surgery using a minimally invasive approach. After the dura is opened under the operating microscope, the spinal dorsal roots are identified and divided into rootlets (Figure 1). A specially trained electrophysiology team monitors the response of each nerve rootlet as it is tested. The surgeon evaluates the rootlets with electrophysiology and selects the rootlets to cut. The location and percentage of rootlets that are cut are individualized for each child. The wound is irrigated, and the child is awakened from anesthesia. The first night after surgery, the child is typically monitored in the Pediatric Intensive Care Unit while receiving continuous intravenous pain medicine. The day after surgery, the child moves to a room on a regular floor and begins oral pain medicine and physical therapy. Children lie flat in bed for three days post-operatively to minimize the risk of cerebrospinal fluid leak. An intensive physical therapy (four to five sessions a week) is continued for at least six weeks after the surgery. This intensive therapy will greatly help the child's improvement after surgery. The only restrictions on the child's

**Botulinum Toxin**

Botulinum toxin (BTX) is a tetanus toxin produced by *Clostridium botulinum*. It is a potent neurotoxin with a relative specificity for the autonomic nervous system. It acts at the neuromuscular junction and results in flaccid muscle paralysis by binding to presynaptic nerve endings and suppressing the release of acetylcholine. There are seven naturally occurring serotypes of the toxin, A–G, all of which are used to reduce spasticity in children with cerebral palsy.12,13 It can be delivered via injection, which can be either intramuscular or intrathecal, dependent on individual patient needs. The duration of action is determined by the site of injection, the size of the dose, the age of the patient, and the serotype of BTX used. Adverse effects of BTX injection are usually mild and transient and consist of pain at the injection site, a flaccid syndrome, and excessive weakness.14,15 The botulinum toxin complex is immunogenic, and repeated exposure can lead to immuno-resistance and decreased efficacy with repeated injections. These injections are contraindicated in children who experience worsening of their spasticity during a growth spurt but are less effective as a primary long-term solution for children with severe spasticity.

**Selective Dorsal Rhizotomy**

Although the nonsurgical treatments described above are effective for many children, other children continue to have pain with walking or difficulty to spasticity. These children, especially those with spastic diplegia secondary to preterm birth, may benefit from selective dorsal rhizotomy. The term dorsal rhizotomy refers to the cutting of the posterior sensory nerve roots after they exit the spinal cord. Selective refers to the use of electrophysiological monitoring during the procedure to identify and cut only those nerve roots that are most abnormal.

The goal of selective dorsal rhizotomy is to help normalize the feedback loop that causes increased muscle tone. Normally, motor commands that modulate spinal cord function and suppress muscle tone. Children who have cerebral palsy from preterm birth have limited descending inhibitory input from the brain and thus experience excessive muscle tone in the extremities. In addition, children with cerebral palsy, who have experienced isolated muscle movements and experience increased spread of muscle tone to adjacent muscle groups and limited isotonic contractions. The procedure normalizes the spinal cord feedback loop by cutting a portion of the sensory roots at each spinal level in the lumbar and upper sacral segments. This procedure selectively reduces abnormal muscle tone without affecting sensation.

The multidisciplinary Spasticity Team at University Hospitals Rainbow Babies & Children's Hospital is the only children's hospital in the multi-state region to offer this surgery using a minimally invasive approach. After the dura is opened under the operating microscope, the spinal dorsal roots are identified and divided into rootlets (Figure 1). A specially trained electrophysiology team monitors the response of each nerve rootlet as it is tested. The surgeon evaluates the rootlets with electrophysiology and selects the rootlets to cut. The location and percentage of rootlets that are cut are individualized for each child. The wound is irrigated, and the child is awakened from anesthesia. The first night after surgery, the child is typically monitored in the Pediatric Intensive Care Unit while receiving continuous intravenous pain medicine. The day after surgery, the child moves to a room on a regular floor and begins oral pain medicine and physical therapy. Children lie flat in bed for three days post-operatively to minimize the risk of cerebrospinal fluid leak. An intensive physical therapy (four to five sessions a week) is continued for at least six weeks after the surgery. This intensive therapy will greatly help the child's improvement after surgery. The only restrictions on the child's
activity are sponge baths for one week after surgery and no swimming for two weeks to help prevent wound infection. Overall, selective dorsal rhizotomy has a very low complication rate.

Benefits of Selective Dorsal Rhizotomy

Children who undergo a selective dorsal rhizotomy experience life-long benefits after a single procedure. They usually can expect to decrease their dependence on devices to assist ambulation. It is an effective procedure that has been shown to produce long-term improvement in muscle tone in research studies with 20 years of follow-up.20,21 Many children who have had selective dorsal rhizotomy often have a decreased need for other surgical procedures for spasticity, such as orthopedic procedures.22 Many children also note improved use of their arms and improved school performance. These added benefits are related to reducing the spasticity and have been found with other treatments that reduce spasticity, such as intrathecal baclofen medication pumps.

Intrathecal Baclofen Pump

Although nonsurgical treatments are effective for selected children with spasticity, others still suffer from immobility and discomfort. Many children with spasticity or other motor disorders have limited potential to ambulate. They also suffer muscle spasm, have difficulty maintaining adequate nutrition, and are difficult to position for personal hygiene. These children, who typically are not ideal candidates for selective dorsal rhizotomy, may benefit from an intrathecal baclofen pump. The pump is surgically inserted in the abdominal wall, and it pumps baclofen into the spinal fluid through a small catheter (Figure 2). By delivering baclofen directly to the cerebrospinal fluid, many of the unwanted central effects of oral therapy are eliminated. Intrathecal baclofen is 1000-fold more potent than oral baclofen.

With increased flexibility and comfort from intrathecal baclofen, children can experience a significant improvement in their quality of life. The Spasticity Team at UH Rainbow Babies & Children’s Hospital evaluates all children who are potential candidates for an intrathecal baclofen pump on an individualized basis. Children with severe spasticity from almost any cause, such as meningitis, stroke, trauma, or prematurity, can benefit from a pump. Ideally, the child can cooperate with the physical therapist to make the most of the improvement in muscle tone after surgery, but cooperation is not imperative as it is for a selective dorsal rhizotomy.

At UH Rainbow Babies & Children’s Hospital, children who are potential candidates for the pump undergo a test dose of intrathecal baclofen via a lumbar puncture under sedation. The test dose provides a glimpse of the impact of decreased muscle tone, most families feel the benefits far outweigh the adverse reaction. A physical therapist evaluates the child before the test dose and then multiple times during the several hours after the dose to quantify the impact of the pump. In general, children who have pump have fewer complications related to immobility.22 Added potential benefits for children include improved use of their arms and improved school performance. Many patients report that the children with intrathecal baclofen therapy are much more comfortable and can better maintain their weight than without the pump.

While the pumps themselves rarely malfunction, there can be complications related to the catheter breaking, occluding, or migrating that typically require surgery to correct the problem. The pump and catheter can be a nidus for infection. At UH Rainbow Babies & Children’s Hospital, the infection rate for baclofen pumps during the past three years has been 2.04% per procedure. Infections can require removal of the pump and typically require extended treatment with intravenous antibiotics. If the baclofen dose is increased too quickly, the child may experience an overdose, typically requiring supportive care in the hospital. Despite these potential complications, most families feel the benefits far outweigh the risks. The team at UH Rainbow Babies & Children’s Hospital is used to caring for children with cerebral palsy who have other complex medical conditions, such as pulmonary problems, epilepsy, and impaired cognitive development. UH Rainbow Babies & Children’s Hospital is known for its family-centered care.

Conclusion

Spasticity and related motor problems can limit a child’s mobility and cause discomfort. Current therapy regimens and treatments offer a spectrum of effective options for children. The multidisciplinary team of UH Rainbow Babies & Children’s Hospital’s Spasticity Program uses individualized strategies to best tailor treatment options to the child’s background, goals, and preferences. Children optimize their development, comfort, and independence.

References


Authors

Daratarn Mingbunjerdsuk, MD, FAAP
Medical Director, Rainbow Spasticity Program
UH Neurological Institute
University Hospitals Rainbow Babies & Children's Hospital
Assistant Professor, Division of Pediatrics
Case Western Reserve University School of Medicine
216-844-3891
Daratarn.Mingbunjerdsuk@UHhospitals.org

Shenandoah Robinson, MD, FACS, FAAP
Surgical Director, Rainbow Spasticity and Epilepsy Programs
UH Neurological Institute
University Hospitals Rainbow Babies & Children's Hospital
Medical Director, Rainbow Spasticity and Epilepsy Programs
Case Western Reserve University School of Medicine
216-844-4341
Shenandoah.Robinson@UHhospitals.org

14 | UNIVERSITY HOSPITALS • Neurological Institute Journal • Spring 2011

Spring 2011 • Neurological Institute Journal • 216-844-2724 • UHhospitals.org/neuro • 15
Expanding the Spectrum of Indications for Epilepsy Surgery in Children

By Ingrid Tuxhorn, MD

Introduction
The incidence of epilepsy peaks in children and the elderly, and a number of well-defined syndromes may be amenable to surgical management, resulting in a cure with complete seizure control or palliation with significantly improved seizure control. Surgery for epilepsy is no longer a treatment of last resort. Early onset of seizure, a high frequency of seizure, and intractability are significant risk factors for overall poor developmental and social outcome in children. Therefore, children with surgical epilepsy syndromes should be referred to a specialized pediatric epilepsy unit early and selected early for operation to optimize seizure and psychosocial outcome. Indeed, early epilepsy surgery may be considered a disease-modifying approach to management of refractory seizures.

Unique Aspects of Epilepsy Surgery in Children
Unique neurobiological aspects of epilepsy in children, especially young children, have been recently recognized and require specific pediatric epilepsy expertise in a multidisciplinary tertiary care center with high-level services in pediatric epilepsy, imaging, surgery, cognition, mental health, and behavioral medicine. A uniquely pediatric approach is required for referral, diagnosis, and management. The recent recommendations of the subcommittee for pediatric epilepsy surgery have highlighted the following aspects.

Neurobiological aspects: Brain maturation in infancy and childhood affects the clinical manifestation of seizure semiology, the electroencephalography (EEG) signature, and neuroimaging findings. Generalized seizure syndrome, including spasms as well as myoclonic and tonic seizures, is noted frequently in young children with focal epilepsies arising from the temporal lobe and extratemporal neocortex. In addition, the interictal and ictal EEG may be less localizing and show generalized features.

Comorbidities are common in pediatric patients of epilepsy surgery and include epileptic encephalopathy, mental retardation, and behavioral and psychiatric disturbances. Increasing evidence from a number of studies suggests that early surgical intervention is critical in infants with catastrophic epilepsy to prevent meningitis and deleterious secondary brain damage leading to developmental arrest and regression. There is compelling evidence that adequate timing of surgery leads to the restart of development and may result in a higher long-term cognitive level of functioning. As there is little evidence at this point for postoperative catch-up or normalization of deficits, there may be a narrow time window to allow best recovery in infantile catastrophic surgical syndromes.

Psychosocial aspects: Chronic epilepsy poses a significant burden on patients and their families, and an earlier reduction of this burden will improve quality of life. Therefore, every attempt should be made to make surgery available early to children that are good surgical candidates to confer psychosocial benefits on these patients.

Surgical Epilepsy Syndromes
Compared with adult patients, the etiologies of surgical epilepsies in children generally more extensively involve the brain and cerebral cortex and are more diverse; however, there are few studies documenting the exact incidence of these conditions. In addition to well-defined etiologies that are well-recognized as surgical epilepsy substrates by pediatric epilepsy experts, the spectrum of surgical epilepsies is expanding based on reports from a number of pediatric centers around the world. The following etiologies and syndromes are commonly recognized.

Hemispheric syndromes: Children with refractory epilepsy due to a unilateral epileptogenic zone that lateralizes with a unilateral brain pathology (e.g., stroke, Rasmussen encephalitis, hemimegalecephaly) and pre-existing hemiplegia may be good candidates for a hemispheric disconnection procedure to treat hemispheric epilepsy. The seizure outcome is excellent, particularly in children with an epileptic encephalopathy. Functional hemispherectomy or hemispherotomy is the procedure of choice in acquired atrophic lesions, and a more anatomic procedure with removal of cortex is the procedure of choice with dysplastic lesions, which result in highly epileptogenic hemispheric tissue mantles so that hemispherotomy procedures may not result in as good seizure control (Figure 1).

Cortical dysplasia: Abnormalities of corticogenesis are the most frequent cause of refractory focal epilepsy in children amenable to surgical treatment. The pathology is varied and may be exquisitely focal and difficult to appreciate on magnetic resonance imaging (MRI) or extensive affecting multiple lobes. The epilepsy syndromes are equally varied and include early onset infantile epileptic encephalopathies, including West syndrome with hypsarrythmia, Ohtahara syndrome with EEG in a burst suppression state, Lennox-Gastaut syndrome as a multifocal epileptic encephalopathy, and a well localized focal symptomatic epilepsy. A number of studies have shown that the seizure outcome depends on complete resection of the epileptogenic substrate. These cases may be complex to evaluate and may require invasive EEG evaluation with intracranial electrodes placed subdurally or intracerebrally.

Sturge-Weber syndrome: Children with Sturge-Weber syndrome (SWS) are commonly recognized.

Tuberous sclerosis complex (TSC): TSC is typically characterized by multiple cortical tubers of variable epileptogenicity. Children with single epileptogenic tuber complexes may be good surgical candidates with good long-term seizure control after tuberectomy. Recognition of these cases may be facilitated by a large size, the presence of calcifications of the tuber, and information from newer imaging modalities that might include alpha-methyl-L-tryptophan positron emission tomography (PET), diffusion tensor imaging in conjunction with EEG data, and magnetoencephalography as well as other source localization techniques. Patients with TSC may be candidates for multistaged procedures (Figure 2).

Hypothalamic hamartoma: Gelastic epilepsy due to hypothalamic hamartoma is frequently therapy-resistant and carries a high risk for dementia and neuropsychiatric dysfunction. Ablation of the hamartoma, which is probably intrinsically epileptogenic without abnormalities of corticogenesis, results in near complete seizure control. Prior to surgery, the child required frequent hospitalization and emergency care for prolonged seizures.

Figure 1: Left hemispheric multicystic encephalomalacia in a child with frequent medically refractory seizures that responded well to hemispherectomy. The presurgical evaluation with video-EEG monitoring from surface electrodes confirmed unilateral left-sided seizure onset. The patient, whose spastic hemiparesis did not worsen after surgery, became seizure free.

Figure 2: A 3-year-old with tuberous sclerosis had multiple tubers in both hemispheres and subependymal nodules. The hamartomatic left hemisphere was responsible for generating all seizures in this child, and a left hemispherectomy resulted in near complete seizure control. Prior to surgery, the child required frequent hospitalization and emergency care for prolonged seizures.

Figure 3: Left hemispheric multicystic encephalomalacia in a child with frequent medically refractory seizures that responded well to hemispherectomy. The presurgical evaluation with video-EEG monitoring from surface electrodes confirmed unilateral left-sided seizure onset. The patient, whose spastic hemiparesis did not worsen after surgery, became seizure free.
damage of the hypothalamic proper, is a challenge in these cases and poses a complex risk-benefit scenario. Stereotactic, endoscopic, and disconnective techniques have been applied as well as various other techniques such as radiosurgery and seed implantation. These patients need referral to a highly skilled and experienced center (Figure 3).

**Temporal lobe epilepsy**

Temporal lobe epilepsy is typically diagnosed in adulthood, however, a high proportion of adult patients have onset of mesial temporal lobe epilepsy due to hippocampal sclerosis in their early teens. Hippocampal sclerosis frequently follows a complicated febrile convulsion in early childhood with subsequent medically refractory seizures arising from the damaged mesial temporal structures. Seizure outcome is excellent after localized resection of the limbic structures with open but minimally invasive surgical resections. In addition, a number of developmental tumors (e.g., ganglioglioma, dysembryoplastic neuroepithelial tumor) may cause early drug-resistant focal epilepsy that is amenable to surgical resection. As there is a high association with neuropsychiatric disorders, including autism spectrum and cognitive dysfunction, the epilepsy should be treated early with surgical options.

In school-age children and teens with lesions involving neocortical structures of the dominant lobe, a detailed presurgical evaluation should be considered as a multistep approach to assure that the individually available resources for presurgical evaluation with surface interictal and ictal EEG, vascular, ischemic, or inflammatory pathologies) carries the best seizure outcome prognosis. Referral to an experienced and well versed epilepsy center, where a standardized presurgical evaluation with surface interictal and ictal EEG, structural and functional imaging, language, memory and cognitive testing is performed, should be considered early in such cases.2

Even intractable epilepsies due to multicentric or extensive bilateral disease, such as tuberous sclerosis, SWS, or remote lesions due to strokes, may be surgically remedial with either cure or palliation.10 Infants and children with epileptic encephalopathies due to well-defined epileptic lesions are excellent candidates for surgical treatment. The presurgical evaluation in these cases may require invasive video EEG monitoring with intracranial electrodes and functional interictal and ictal imaging with single photon emission computed tomography, PET, and functional MRI (fMRI) to localize the epileptogenic zone and delineate it from eloquent cortex that may not be sacrificed without resulting in permanent neurologic deficit. Though congruence of diagnostic findings is the gold standard for presurgical selection, it has become apparent that generalized epileptiform discharges in the constellation of other localizing features (e.g., pathologic substrate, seizure semiology) may not be a contraindication to surgery. This suggestion may particularly apply to the static structural epileptic encephalopathies in infants and early childhood, which may be particularly challenging to demarcate from progressive metabolic disorders. These cases require the expertise of experienced and knowledgeable level IV pediatric epilepsy centers.2

**Outcomes**

In children, as in adults, the primary aim of epilepsy surgery is freedom from seizures with minimal if any functional deterioration. However, the chances of seizure freedom will depend in part on the type of procedure, the degree of completeness of disconnection, and the type and extent of the pathology. After temporal lobectomy for hippocampal sclerosis, seizure outcome rates in children are similar to rates in adults and may be higher, approaching 75% to 85% in some series.10 However, such rates may be lower in children with comorbidities, such as learning difficulty or pervasive developmental disorders.9 These comorbidities should not lead to denying surgery to such children. With regard to extratemporal resection, the likelihood of seizure freedom will range between 40% and 70%, depending on the extent of resection possible of the epileptogenic and anatomic substrate causing the epilepsy.10,11 In children undergoing extensive procedures, such as hemisnectomies in the form of either anatomic hemispherectomy or variants of functional hemispherectomies, seizure outcome appears related to the type of pathology. The lowest rates of seizure freedom for developmental malformations are reported for hemimegalencephaly, which may reflect the extreme epileptogenicity of this type of malformation, the technical challenge of disconnecting the highly abnormally configured hemisphere, and in some cases the risk of seizures originating from the normal appearing hemisphere. Though in some cases, there is the suggestion that seizure may also arise from the contralateral hemisphere, the completeness of disconnection will be highly relevant for seizure outcome, and anatomical hemispherectomy may lead to greater chance of seizure-free outcome. Anatomical hemispherectomy is the preferred procedure in a number of centers specialized in the surgical management of catastrophic epilepsy due to this malformation.

The point in time that the outcome is measured will be relevant in determining the degree of seizure freedom, particularly in children with cortical malformations. Series that monitor outcome up to 10 years following surgery have found that individuals undergoing resection for cortical malformations were less likely to be seizure free at 10 years compared to other pathologies.10,11 It is more difficult to determine whether medication can be stopped. However, data suggest that reduction or withdrawal of antiepileptic drugs cannot be guaranteed and may be achieved in 50% to 70% depending on the series.10

The risk of deficits following focal resection will depend on the area of brain to be removed and the likelihood that this area retains function despite causing seizures. With regard to hemi-disconnection procedures, children with pre-existing hemispligia have little risk for additional motor deficits. In some patients, reorganization and persistent ipsilateral tracts may protect the child from loss of adequate motor function. Presurgical evaluation with motor fMRI, transcranial magnetic stimulation, and tractography will optimize risk assessment in these cases.

In infants and young children with catastrophic epilepsy, surgery in the dominant left hemisphere is possible, a number of case series show a strong potential for language acquisition due to interhemispheric shift of language in early onset severe epilepsy. In older children who have acquired normal language, the language dominance needs to be assessed with a Wada test and language fMRI studies. With left dominance, the risk of language deterioration or loss will be high in children undergoing left hemispherectomy for Rasmussen encephalitis. As there is a high risk for additional functional deficit in these cases, the gains to be achieved with regard to cognitive preservation by attaining seizure remission need to be weighed carefully against the likelihood of functional deficits, particularly with regard to language when the dominant hemisphere is affected. A hemianopia, if not already present, will be inevitable.

There is substantial data emerging on developmental, cognitive, and behavioral outcomes after epilepsy surgery in children. Early onset seizures are a high risk for poor developmental outcome. Similarly, early cessation of seizures is likely to lead to improved cognitive outcome. Early onset epilepsy under the age of 2 is associated with a lower IQ in the long term, presumably related to the early onset of seizures.12

Many studies show that IQ is maintained postoperatively and not impacted negatively as feared by parents or physicians unfamiliar with the outcomes of these patients. There is some evidence that development may stabilize or in some cases catch up to the norm rather than falling off in static encephalopathies. The clinical variables predicting risk for loss and chance for gain are not well understood and need to be studied in greater detail in further term multicenter outcome studies.4

Behavior outcome is unpredictable and is often the most burdensome issue in children with ongoing seizures and global developmental impairment. However, there is encouraging evidence for improved attention and behavior following hemispherectomy for epileptic encephalopathies.13 The rate of psychiatric symptoms in children requiring temporal lobe resection for epilepsy is very high,14 and behavior problems are notable in children presenting for hemispherectomy.11 The latter procedure was first reported for treatment of behavior disorders in children with epilepsy and congenital hemihypoplasia, but improvements in behavior cannot be guaranteed. In some children, a psychiatric disorder may evolve postoperatively. It is important to counsel parents about the variability of these outcomes and explain that dramatic improvements in behavior or behavior may be realistic. Rehabilitative programs and support should be offered to children and families with significant preoperative comorbidities because of these issues.

Ingrid Tuxhorn, MD, reports no financial relationships with commercial interests relevant to the content of this article.
Epilepsy Center at UH Rainbow Babies & Children's Hospital

A key component of the Division of Pediatric Epilepsy, the Epilepsy Center at UH Rainbow Babies & Children's Hospital provides comprehensive, integrated and state-of-the-art diagnosis and treatment including surgery – to children with epilepsy across all age groups. The division is heavily involved in research that directly benefits patient care and translates into improving the lives of children with epilepsy and their families. Closely integrated with UH Rainbow Babies & Children's Hospital's Division of Pediatric Neurosurgery, the Epilepsy Center at UH Rainbow Babies & Children's Hospital has access to a vast number of specialists and surgeons, including renowned pediatric neurosurgeons Alan Cohen, MD, FACS, FAAP, Chief of Pediatric Neurological Surgery, and Shenandoah Robinson, MD, Surgical Director, Rainbow Spasticity and Epilepsy Programs. Its alignment with the Division of Pediatric Neurosurgery and access to the Pediatric Epilepsy Monitoring Unit and Pediatric Intensive Care Unit allows the center to offer the most advanced approaches to diagnosing, managing and treating epilepsy in infants and children.

The Neuropsychology of Sports-Related Concussion: Return-to-Play and the Management of Head Injury in Athletes

By Christopher M. Bailey, PhD

Introduction

Concussion or mild traumatic brain injury (MTBI) is a particularly complex clinical phenomenon. Since the 1980s, the sports arena has provided a natural laboratory for examining the nature and consequences of concussion and, in the process, revealed a variety of circumstances and characteristics that are unique to the management of concussion in athletics. This article will describe the pathophysiology of concussion, its epidemiology, risk factors for poor outcome, and the current methods for evaluation and clinical management of the injury.

What is Concussion?

The most recent consensus statement on concussion in sports defines concussion as “a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.” Though most definitions reference concepts such as trauma-induced injury and altered mental status, a clear and widely accepted definition of mild head injury has been a topic of much controversy for decades. As a result, a variety of labels have been proposed to describe a concussion and symptoms associated with relatively uncomplicated mild head injury, cerebral concussion, and simple or complex mild head trauma, including minor head injury, mild traumatic brain injury, and post-concussion syndrome. The most recent consensus statement on concussion in sports defines concussion as “a functional brain injury caused by biomechanical forces sufficient to cause transient axonal shearing and/or rotational brain injury.”

The pathophysiologic mechanisms of concussion are generally thought to center around acceleration/deceleration forces that act on the brain and result in a complex metabolic cascade. Animal model research suggests that the force from concussive blows leads to stretching and shearing of neurons, irregular shifting of ions across cell membranes, and changes in cerebral blood flow, all of which leave neurons temporarily dysfunctional but not destroyed.

Author

Ingrid Tuxhorn, MD
Chief, Division of Pediatric Epilepsy
UH Neurological Institute
University Hospitals Case Medical Center
Professor, Pediatric Epilepsy Division
UH Rainbow Babies & Children's Hospital
Case Western Reserve University
School of Medicine
216-266-6644
Ingrid.Tuxhorn@UHhospitals.org

References

6. Ingrid Tuxhorn, MD, FACS, FAAP, Chief of Pediatric Neurological Surgery, the Epilepsy Center at UH Rainbow Babies & Children's Hospital

MTBI represents 75% of all hospital visits associated with traumatic brain injury (TBI), with MTBI costing the nation approximately $17 billion per year in medical care, lost productivity, and litigation. The true prevalence of the injury is unknown given that an estimated 30-50% of all concussions never receive medical attention. MTBI poses a need for appropriate diagnosis and management is clear, particularly for athletic populations that participate in sports and may place themselves at greater risk for repeated head injury. This need is complicated by difficulties in identifying concussion through traditional imaging techniques, which is likely due to the mechanism of the injury that results in changes on a cellular and/or metabolic level.

No matter how it is defined, concussion represents a public health problem. Approximately 1.5 million concussions per year lead to emergency department visits. The true prevalence of the injury is unknown given that an estimated 30-50% of all concussions never receive medical attention. MTBI represents 75% of all hospital visits associated with traumatic brain injury (TBI), with MTBI costing the nation approximately $17 billion per year in medical care, lost productivity, and litigation. MTBI is particularly common in community. The Centers for Disease Control and Prevention reported that 200,000 sports-related head injuries are treated in emergency departments annually within the United States and sports-related concussion accounts for approximately 20% of all TBI per year. Given the public health problem that concussion poses, a need for appropriate diagnosis and management is clear, particularly for athletic populations that participate in sports and may place themselves at greater risk for repeated head injury. This need is complicated by difficulties in identifying concussion through traditional imaging techniques, which is likely due to the mechanism of the injury that results in changes on a cellular and/or metabolic level.

The pathophysiologic mechanisms of concussion are generally thought to center around acceleration/deceleration forces that act on the brain and result in a complex metabolic cascade. Animal model research suggests that the force from concussive blows leads to stretching and shearing of neurons, irregular shifting of ions across cell membranes, and changes in cerebral blood flow, all of which leave neurons temporarily dysfunctional but not destroyed.
The metabolic cascade following a concussion is thought to occur in three phases: an initial period of hyperglycemia, followed by a metabolic depression, followed by a period of recovery. Neuroimaging with computerized tomography or magnetic resonance imaging (MRI) is often normal following sports concussion either because structural injury is absent or current techniques are not sensitive to the cellular and/or metabolic effects that occur in concussion. D'Errico and Giza describe promising neuroimaging techniques that may be sensitive to concussion (including diffusion tensor imaging, functional MRI, magnetic resonance spectroscopy, and positron emission tomography), though these techniques are impractical or not appropriately validated for current clinical use with concussion.

Though concussion is a relatively mild injury by nature, it can be associated with complications and possibly enduring symptoms if not appropriately managed. Clinicians should be aware of a variety of risk factors that could predispose athletes to poorer outcomes. Athletes who have previously sustained a concussion are more than two times more likely to sustain a second concussion and may be more likely to experience greater post-concussive symptoms. Recent evidence suggests that high school and college athletes who sustain concussion may be at greatest vulnerability for repeated concussion within seven to 10 days following the injury, with evidence that approximately 80% of repeated concussion occurs during that period. Multiple concussions over a career of professional athletics has been shown to lead to an increased likelihood of late life cognitive impairments/memory problems, motor neuron disease, and depression. Women may be at greater risk for cognitive symptoms following concussion, and children may require longer recovery periods than college athletes. Studies also suggest that individuals with learning disorders may have greater cognitive difficulties following TBI. Rare but catastrophic outcomes related to cerebral edema have also been postulated as occurring from repeated concussion, particularly if a second injury is sustained before symptomatic resolution from a first injury. Some authors postulate that the cases of so-called Second Impact Syndrome may be the result of undiagnosed subdural hemorrhage, though much remains to be understood about this phenomenon. Given these risk factors, current management guidelines are made according to the individual's presentation by tracking cognitive and physical symptoms post-injury while considering the above risk factors.

Evaluation of Sports Concussion and Neuropsychology

Since the seminal work of Barth, Alves, Ryan, and colleagues, neuropsychological testing has been utilized as one of the primary methods for tracking and managing sports-related concussion. The comparative model developed by Barth and colleagues is recognized as the best practice. Neurological Institute Journal  2011  Spring  216-844-2724  UHhospitals.org/neuro

Since the seminal work of Barth, Alves, Ryan, and colleagues, neuropsychological testing has been utilized as one of the primary methods for tracking and managing sports-related concussion. The comparative model developed by Barth and colleagues is recognized as the best practice. The individual's presentation by tracking cognitive and physical symptoms post-injury while considering the above risk factors.

The metabolic cascade following a concussion is thought to occur in three phases: an initial period of hyperglycemia, followed by a metabolic depression, followed by a period of recovery. Neuroimaging with computerized tomography or magnetic resonance imaging (MRI) is often normal following sports concussion either because structural injury is absent or current techniques are not sensitive to the cellular and/or metabolic effects that occur in concussion. D'Errico and Giza describe promising neuroimaging techniques that may be sensitive to concussion (including diffusion tensor imaging, functional MRI, magnetic resonance spectroscopy, and positron emission tomography), though these techniques are impractical or not appropriately validated for current clinical use with concussion.

Though concussion is a relatively mild injury by nature, it can be associated with complications and possibly enduring symptoms if not appropriately managed. Clinicians should be aware of a variety of risk factors that could predispose athletes to poorer outcomes. Athletes who have previously sustained a concussion are more than two times more likely to sustain a second concussion and may be more likely to experience greater post-concussive symptoms. Recent evidence suggests that high school and college athletes who sustain concussion may be at greatest vulnerability for repeated concussion within seven to 10 days following the injury, with evidence that approximately 80% of repeated concussion occurs during that period. Multiple concussions over a career of professional athletics has been shown to lead to an increased likelihood of late life cognitive impairments/memory problems, motor neuron disease, and depression. Women may be at greater risk for cognitive symptoms following concussion, and children may require longer recovery periods than college athletes. Studies also suggest that individuals with learning disorders may have greater cognitive difficulties following TBI. Rare but catastrophic outcomes related to cerebral edema have also been postulated as occurring from repeated concussion, particularly if a second injury is sustained before symptomatic resolution from a first injury. Some authors postulate that the cases of so-called Second Impact Syndrome may be the result of undiagnosed subdural hemorrhage, though much remains to be understood about this phenomenon. Given these risk factors, current management guidelines are made according to the individual's presentation by tracking cognitive and physical symptoms post-injury while considering the above risk factors.

Evaluation of Sports Concussion and Neuropsychology

Since the seminal work of Barth, Alves, Ryan, and colleagues, neuropsychological testing has been utilized as one of the primary methods for tracking and managing sports-related concussion. The comparative model developed by Barth and colleagues is recognized as the best practice. The individual's presentation by tracking cognitive and physical symptoms post-injury while considering the above risk factors.

The metabolic cascade following a concussion is thought to occur in three phases: an initial period of hyperglycemia, followed by a metabolic depression, followed by a period of recovery. Neuroimaging with computerized tomography or magnetic resonance imaging (MRI) is often normal following sports concussion either because structural injury is absent or current techniques are not sensitive to the cellular and/or metabolic effects that occur in concussion. D'Errico and Giza describe promising neuroimaging techniques that may be sensitive to concussion (including diffusion tensor imaging, functional MRI, magnetic resonance spectroscopy, and positron emission tomography), though these techniques are impractical or not appropriately validated for current clinical use with concussion.

Though concussion is a relatively mild injury by nature, it can be associated with complications and possibly enduring symptoms if not appropriately managed. Clinicians should be aware of a variety of risk factors that could predispose athletes to poorer outcomes. Athletes who have previously sustained a concussion are more than two times more likely to sustain a second concussion and may be more likely to experience greater post-concussive symptoms. Recent evidence suggests that high school and college athletes who sustain concussion may be at greatest vulnerability for repeated concussion within seven to 10 days following the injury, with evidence that approximately 80% of repeated concussion occurs during that period. Multiple concussions over a career of professional athletics has been shown to lead to an increased likelihood of late life cognitive impairments/memory problems, motor neuron disease, and depression. Women may be at greater risk for cognitive symptoms following concussion, and children may require longer recovery periods than college athletes. Studies also suggest that individuals with learning disorders may have greater cognitive difficulties following TBI. Rare but catastrophic outcomes related to cerebral edema have also been postulated as occurring from repeated concussion, particularly if a second injury is sustained before symptomatic resolution from a first injury. Some authors postulate that the cases of so-called Second Impact Syndrome may be the result of undiagnosed subdural hemorrhage, though much remains to be understood about this phenomenon. Given these risk factors, current management guidelines are made according to the individual's presentation by tracking cognitive and physical symptoms post-injury while considering the above risk factors.

Evaluation of Sports Concussion and Neuropsychology

Since the seminal work of Barth, Alves, Ryan, and colleagues, neuropsychological testing has been utilized as one of the primary methods for tracking and managing sports-related concussion. The comparative model developed by Barth and colleagues is recognized as the best practice. The individual's presentation by tracking cognitive and physical symptoms post-injury while considering the above risk factors.
Return-to-Play and Treatment Following Concussion

Possibly the best initial treatment for anyone who has sustained an MTBI is rest and education about the nature, symptoms, and high likelihood of recovery from the injury. In non-sports samples, authors have shown that early intervention with educational materials, affected symptoms, and the natural recovery course of concussion has been associated with both a reduced mean symptom duration following concussion as well as reduced distress and reduced number of symptoms.\(^2\) A similar approach with athletes is important, particularly for those individuals whose symptoms may endure longer than expected.

In addition to education, a stepwise increase in activity is the most recent consensus statement on concussion in sports lists six steps to return-to-play, with presumed recovery from the concussion at that time. The statement suggests that an athlete should proceed from one step to the next if asymptomatic at the current level for approximately 24 hours, which would lead to approximately one week for full rehabilitation, if the athlete remains asymptomatic throughout. If any post-concussion symptoms occur while in the stepwise program, then the athlete should return to the previous asymptomatic step and attempt to progress again after a further 24-hour period of rest has passed. The return-to-play protocol is tabled in Section 1.

In my own practice, once athletes have returned to the baseline level of performance, they undergo post-concussion computerized neuropsychological evaluation and begin the progressive increase in exertion outlined in Table 1. If computerized testing reveals any levels, the athletes are seen for a face-to-face neuropsychological exam, where additional neuropsychological measures of attention, memory, and information processing speed are confirmed to complete that the athlete’s cognitive functioning does not reflect a need for further recovery from the injury. This follow-up examination also allows for reassessment and education about several variables that could prolong concussion recovery (e.g., a history of psychological distress, learning disorder, or previous head injury) and provides an opportunity to educate athletes and families about the injury and the impact that future injuries might have on continued participation in the athlete’s sport.

Regarding the management of concussion, the American Athletic Trainers’ Association (NATA) provides guidelines for when to disqualify athletes from participation in sports for differing durations.\(^3\) The NATA suggests that any athlete who suffers any period of loss of consciousness or persistent concussion symptoms such as headache, confusion, dizziness, or amnesia (no matter how mild or transient) should be disqualified from play or practice for the remainder of the day. A recent meeting of the National Collegiate Athletic Association (NCAA) Concussion Committee has recommended more stringent guidelines that require immediate removal from the competition or practice upon diagnosis of concussion, even if symptoms disappear within minutes. Disqualifying an athlete for a season has generally been accepted as appropriate after the athlete’s third concussion, though a variety of complications such as the severity of the injuries and duration between injuries can make this decision difficult. When to end an athlete’s career in a given sport is a much more difficult question to answer and is often done on an individual basis and according to the number of previous concussions sustained, the apparent vulnerability of the athlete to concussion, and the duration of symptoms that the individual has experienced post-MTB1. The 2009 International Censorship Meeting recognized that one size does not fit all when it comes to concussion and that individual vulnerability must be taken into account when addressing this important issue.

Although pharmacotherapy is not considered a first-line treatment for concussion symptoms, it may be useful in the treatment of persistent symptoms. This statement is particularly true if an athlete experiences comorbid conditions that may be exacerbating the initial symptoms experienced post-concussion.

Table 1: Return-to-Play Protocol

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Objective</th>
<th>Functional Exercise at Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No activity</td>
<td>Complete physical and mental rest</td>
<td>Recovery</td>
</tr>
<tr>
<td>2. Light aerobic exercise</td>
<td>Walking, swimming, or stationary cycling keeping intensity, 70% maximum</td>
<td>Increase heart rate</td>
</tr>
<tr>
<td>3. Sport-specific exercise</td>
<td>Skating drills in ice hockey, running drills in soccer</td>
<td>Add movement</td>
</tr>
<tr>
<td>4. Noncontact training drills</td>
<td>Progression to more complex training drills, e.g., passing drills in football and ice hockey, plyometric progression resistance training</td>
<td>Exercise, coordination and cognitive load</td>
</tr>
<tr>
<td>5. Full contact practice</td>
<td>Following medical clearance, participate in normal training activities</td>
<td>Restore confidence and assess skills by coaching staff</td>
</tr>
<tr>
<td>6. Return to play</td>
<td>Normal game play</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion

Sports concussion is one of the most common but challenging and complex clinical phenomena that sports medicine clinicians are asked to manage. Part of the complexity of this injury is associated with the fact that both the basic and clinical science of the injury is still only partially understood. Cantu notes that there have been more publications on the topic of sports-related concussion since the year 2000 than all other publications on the topic of concussion for the entire period between 1969 and 2000, at the highest level of recent public influence and this peak of interest, great strides in the management of sports concussion and head injury in general have been made. No doubt, future research will assist clinicians in making even more-broadly-based diagnoses and treatment recommendations to minimize the risk of poor outcome in both amateur and professional athletes who sustain a concussion.

Christopher Bailey, PhD, reports no financial relationships with commercial interests relevant to the content of this article.

References


Author: Christopher Bailey, PhD

Mild Concussion Center

Interdisciplinary and longitudinal approach, treatment processes at the Memory & Cognition Center help maintain cognitive, physical and emotional fitness. Programs for community and caregiver education, quality of caregiving, and risk factors for memory loss have been a center priority.

Conditions treated:

- Alzheimer’s disease
- Mild cognitive impairment
- Parkinson’s disease dementia
- Frontotemporal dementia
- Adult Attention Deficit-Hyperactivity Disorder
- Trisomy 21 (Down syndrome)
- Normal pressure hydrocephalus
Credits awarded on a per article basis. The School of Medicine also requires that faculty make disclosures to the activity participants all relevant financial relationships with commercial interests. Where disclosures have been made, conflicts of interest, real or apparent, must be resolved. The policy of the Case Western Reserve University School of Medicine CME Program requires that the Activity Director, planning committee members and all activity faculty (that is, anyone in a position to control the content of the education activity) disclose to the activity participants all relevant financial relationships with commercial interests. Where disclosures have been made, conflicts of interest, real or apparent, must be resolved. Disclosure will be made to activity participants prior to the commencement of the activity. The School of Medicine also requires that faculty make disclosure statements. The School of Medicine also requires that faculty identify any discussion of “off-label” or investigational use of pharmaceutical products or medical devices.

To Obtain AMA PRA Category 1 Credits™
- Read the article.
- Reflect on the content.
- Successfully complete the post-test located at UHhospitals.org/nijspring2011
- A grade of 100% is required for passage.
- Complete the evaluation.
- Print the certificate of credit for your records.

Your credits will be recorded by the Case Western Reserve University School of Medicine CME Program and made a part of your transcript. For more information, contact the CME program at medcme@case.edu.

Fee
There is no fee for this program.

Medical Disclaimer
Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required. The authors have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication.

Although every effort is made to ensure that this material is accurate and up-to-date, it is provided for the convenience of the user and should not be considered definitive. Neither the authors nor Case Western Reserve University School of Medicine nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they are not responsible for any errors or omissions or for the results obtained from the use of such information.

Learners are encouraged to confirm the information contained herein with other sources. This information should not be construed as personal medical advice and is not intended to replace medical advice offered by physicians. Case Western Reserve University School of Medicine will not be liable for any direct, indirect, consequential, special, exemplary, or other damages arising here from.

Target Audience
This continuing medical education (CME) program is provided by Case Western Reserve University School of Medicine and is intended for all physicians, particularly neurologists and neurological surgeons, family practice and internal medicine physicians, interested in the latest advances in the management of neurological disorders.

Educational Objectives
Upon completion of this educational activity, the participant should be able to:
- Explain the indications for using frame-based systems and frameless techniques when placing electrodes for monitoring epilepsy.
- Evaluate the various surgical approaches to anterior skull base tumors.
- Identify and justify the available treatment options for spasticity in children.
- Summarize the unique aspects of epilepsy surgery in pediatric patients.
- Describe the current methods of evaluation and clinical management of sports-related concussion.

Accreditation Statement
Case Western Reserve University School of Medicine is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

Case Western Reserve University School of Medicine designates this Journal-based CME activity for 1.0 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

CME Information
The policy of the Case Western Reserve University School of Medicine CME Program requires that the Activity Director, planning committee members and all activity faculty (that is, anyone in a position to control the content of the education activity) disclose to the activity participants all relevant financial relationships with commercial interests. Where disclosures have been made, conflicts of interest, real or apparent, must be resolved. Disclosure will be made to activity participants prior to the commencement of the activity. The School of Medicine also requires that faculty make disclosure statements.

To Obtain AMA PRA Category 1 Credits™
- Read the article.
- Reflect on the content.
- Successfully complete the post-test located at UHhospitals.org/nijspring2011
- A grade of 100% is required for passage.
- Complete the evaluation.
- Print the certificate of credit for your records.

Your credits will be recorded by the Case Western Reserve University School of Medicine CME Program and made a part of your transcript. For more information, contact the CME program at medcme@case.edu.

Fee
There is no fee for this program.

Medical Disclaimer
Medicine is an ever-changing science. As new research and clinical experience broaden our knowledge, changes in treatment and drug therapy are required. The authors have checked with sources believed to be reliable in their efforts to provide information that is complete and generally in accord with the standards accepted at the time of publication.

Although every effort is made to ensure that this material is accurate and up-to-date, it is provided for the convenience of the user and should not be considered definitive. Neither the authors nor Case Western Reserve University School of Medicine nor any other party who has been involved in the preparation or publication of this work warrants that the information contained herein is in every respect accurate or complete, and they are not responsible for any errors or omissions or for the results obtained from the use of such information.

Learners are encouraged to confirm the information contained herein with other sources. This information should not be construed as personal medical advice and is not intended to replace medical advice offered by physicians. Case Western Reserve University School of Medicine will not be liable for any direct, indirect, consequential, special, exemplary, or other damages arising here from.

University Hospitals
With 150 locations throughout Northeast Ohio, University Hospitals serves the needs of patients through an integrated network of hospitals, outpatient centers and primary care physicians. At the core of our health system is University Hospitals Case Medical Center. The primary affiliate of Case Western Reserve University School of Medicine, University Hospitals Case Medical Center is home to some of the most prestigious clinical and research centers of excellence in the nation and the world, including cancer, pediatrics, women’s health, orthopaedics and spine, radiology and radiation oncology, neurosurgery and neuroscience, cardiology and cardiovascular surgery, organ transplantation and human genetics. Its main campus includes the internationally celebrated UH Rainbow Babies & Children’s Hospital, ranked among the top hospitals in the nation; UH MacDonald Women’s Hospital, Ohio’s only hospital for women; and UH Seidman Cancer Center (formerly UH Ireland Cancer Center), a part of the Case Comprehensive Cancer Center, which holds the nation’s highest designation by the National Cancer Institute of Comprehensive Cancer Center.