Epilepsy, or recurrent, unprovoked seizures, affects 0.5 to 1 percent of the population. It most frequently occurs during childhood, and every year approximately 25,000 to 40,000 children in the United States experience their first seizure that is not associated with a febrile illness or head trauma. Thirty to 65 percent of these children go on to have a second unprovoked seizure within the first year.
Fortunately, in most patients the seizures can be controlled with antiepileptic drugs (AED), and in some cases the epilepsy will resolve over time. However, epilepsy in roughly 30 percent of children cannot be controlled medically. In addition, even in children with well-controlled epilepsy, the morbidity associated with long-term AED use can be significant. Epilepsy surgery offers an alternative means of treating seizures and is an important weapon in the armamentarium of the epileptologist.

EARLY INTERVENTION IS KEY
Infants and children have specific vulnerabilities to even brief, recurrent seizures. If there is an ongoing “epileptic storm” in the midst of a developing brain, the brain undergoes aberrant synaptogenesis and apoptosis, as well as changes in the development of inhibitory neurocircuitry. Therefore, immature brains quickly become “programmed” to excitability with continued seizures. This leads to broad networks of epileptogenicity that can become progressively more difficult to manage. Frequent seizures result in a secondary encephalopathy with subsequent global impairment.

The consequences of uncontrolled seizures on children’s brains are severe: developmental delays, behavioral difficulties and irreversible cognitive declines are the norm. But if the seizures and ongoing epileptic encephalopathy can be stopped, whether with medication or epilepsy surgery, windows of developmental opportunity can open and lead to significant developmental gains.

Fortunately, it does not take years to determine if a patient’s epilepsy will be amenable to medical treatment. Epilepsy in 60 percent of children will be controlled with the initial AED prescribed. Of the 40 percent whose seizures persist, only 10 percent will achieve good control with a second AED. The remaining 30 percent constitute the intractable group, and subsequent medication trials are unlikely to be effective.

THE BURDEN OF EPILEPSY
The consequences of epilepsy can be severe, even in children whose seizures are well controlled. These children have a higher incidence of anxiety and depression, perform at a lower level academically, and ultimately suffer from a discrepancy in employment and income when...
compared with peers. Adults with epilepsy are less likely to marry.

Finally, side effects from AEDs can be profound. Many older AEDs can produce sedation. Phenytoin causes osteoporosis with long-term use; it is suspected but unproven that the enzyme-inducing AEDs also cause osteoporosis. Carbamazepine and felbamate can produce aplastic anemia. Valproate increases the risk of polycystic ovarian syndrome and anovulatory cycles in women. Many AEDs are teratogenic, and some animal studies have suggested that long-term AED use has oncogenic potential.

For select patients, surgery can provide relief from the burden of epilepsy.

SURGERY IS NOT A LAST RESORT
There is a tendency to view brain surgery as a high morbidity/mortality endeavor that should be reserved for the direst cases. While there are certainly risks associated with epilepsy surgery, they are often far outweighed by the risks of uncontrolled epilepsy, as well as the quality-of-life benefits associated with attaining freedom from seizures or improved seizure control. Advances in diagnostic and surgical techniques have improved success rates and decreased complication rates.

Unfortunately, patients are often unsuccessfully managed for several years before being referred to a tertiary epilepsy center for surgical evaluation. Over that time, patients often suffer irreversible cognitive losses, while the epilepsy becomes more difficult to manage/cure due to the spread of epileptogenic networks. It is likely that many incurable adult epilepsy patients would have been more easily treated surgically at an earlier age with greater preservation of cognition.

The developing brain of a child is also much more plastic than that of an adult, so it’s possible for eloquent functions such as motor control and language to re-establish in other areas of a child’s brain—a feat not possible in a mature brain. Thus, it is important that medical providers and families consider surgical options early in the course of treatment, rather than as a last resort.

DETERMINANTS OF SURGICAL CANDIDACY
The decision of whether a child is a surgical candidate is typically made by a multidisciplinary team at a tertiary epilepsy center. Evaluations require expertise from a variety of fields, including neurology, neurosurgery, neuropsychology and radiology.

Questions we consider when determining surgical candidacy:

1. **Is there a structural lesion that appears to be generating the seizures?** Seizures associated with structural lesions, such as tumors, focal cortical dysplasias, vascular malformations, hamartomas, infarcts and mesial temporal sclerosis, are more often amenable to surgical treatments. In the majority of lesional cases, we can obtain complete seizure freedom through surgery.

2. **What is the prognosis for continued nonsurgical therapy?** If a patient has failed more than two AEDs, it is likely he/she will remain medically intractable. Some epilepsy
syndromes, such as benign rolandic epilepsy, are typically self-limited and resolve over time. Other syndromes have a predictable, progressive course leading to medically intractable seizures that can only be cured with surgery. If one can identify the specific epilepsy syndrome or etiology for the epilepsy, the prognosis can typically be defined. Rasmussen’s syndrome, epilepsy associated with mesial temporal sclerosis and large cortical malformations, such as hemimegalencephaly, are almost always associated with intractable seizures and a progressive course. These epilepsy syndromes should be evaluated for epilepsy surgery quite early.

3. Is it likely that an epileptogenic zone can be identified and safely treated? Much of the preoperative assessment is geared toward determining the likelihood that a focal epileptogenic zone can be resected or disconnected without generating unacceptable neurologic deficits. If the epileptogenic zone is suspected but not certain, the patient may require intracranial EEG monitoring via implanted electrodes to better define the source of the seizures and define eloquent cortex, areas of the brain where important motor or language functions reside. Some patients have seizures without any evidence of such localization. They are typically less optimal candidates for epilepsy surgery. Others have epileptogenic foci that include eloquent areas of the brain, making surgical resection or disconnection a less palatable option.

4. Is there a role for palliative surgery? Some children have incurable epilepsy but still can benefit from surgery to decrease the frequency or severity of their seizures. For example, some patients with intractable generalized epilepsy gain substantial benefit from sectioning of the corpus callosum to eliminate drop attacks (tonic/atonic seizures), though they will continue to have other types of less-severe seizures. Other patients may have bihemispheric/multifocal epileptogenic zones. If one area is producing the predominant intractable seizures, resection of this area

**FIGURE 1.** 3-D imaging demonstrating stereoelectroencephalography (SEEG), the placement of electrodes inside the brain, placed in a minimally-invasive manner.
may provide a substantial reduction in seizure frequency and result in a significant improvement in quality of life.

Surgical Techniques
A variety of surgical techniques are used to treat pediatric epilepsy. The appropriate surgery is determined by the extensive presurgical evaluation. The initial phase of surgery is often diagnostic — electrodes are temporarily implanted intracranially to better localize the epileptogenic zone and to map areas of eloquent brain to be preserved.

Recently, we have adopted a minimally invasive technique of monitoring intracranially called stereoelectroencephalography (SEEG) (Figure 1). This involves placing electrodes via tiny individual incisions and holes in the skull via robot-assisted stereotactic guidance. (See “The Newest Member of the Neurosurgery Team: A Robot” on page 8.) By avoiding a large incision and craniotomy, there is decreased risk of infection and less postoperative discomfort. Once the area of seizure onset and eloquent brain are localized, attention is turned to therapeutic techniques to eliminate the seizures.

There are three broad categories of therapeutic surgical techniques:

1. Resection. Surgical resection of epileptogenic tissue is the mainstay of epilepsy surgery. Resections can be limited, as in the case of small lesions (lesionectomies) or areas of epileptogenic brain (topectomies). They can also include complete or partial resections of lobes of the brain (lobectomies). At the extreme end of the spectrum, the entire cerebral hemisphere can be removed (anatomic hemispherectomy) or disconnected (functional hemispherectomy) in the case of broad areas of pathology, such as Rasmussen’s syndrome, Sturge-Weber syndrome or perinatal infarctions.

2. Disconnection. If an epileptogenic zone is disconnected from the rest of the brain, the

Specialty Spotlight
Neurosciences Center
Children’s Hospital of Wisconsin’s Neurosciences Center is the largest and most comprehensive pediatric neurosciences center in the state. The center combines excellent clinical care for children with innovative research, while advancing the development of pediatric neurological and neurosurgical treatment options. This depth and breadth of complex knowledge and experience makes our program one of the nation’s best for neurology and neurosurgery, according to U.S. News & World Report.

We offer the most advanced diagnosis and treatment options for various neurological and neurosurgical conditions, including highly sophisticated imaging capabilities and minimally invasive surgical options. Our specialists treat the full range of neurological conditions from birth through childhood, and we have nationally recognized expertise in epilepsy.

The Epilepsy Center at Children’s is designated a Level 4 epilepsy center by the National Association of Epilepsy Centers. This is the only Level 4 pediatric epilepsy center in the state of Wisconsin. This designation means we provide the highest level of complex and specialized care for children living with epilepsy.

Learn more about the Neurosciences Center at Children’s and find hospital and clinic locations at chw.org/neurosciences.
seizures can be cured (if the only connection is cut) or made significantly more manageable by slowing conduction (by eliminating the main conduit of transmission). A functional hemispherectomy involves both resection and disconnection as a means of eliminating the transmission of epileptogenic discharges to normal brain. Disconnections are often performed to minimize the morbidity associated with a more extensive resection. Sectioning of the corpus callosum (corpus callosotomy) will often slow conduction of seizures in the case of bilateral onset, thereby reducing the severity of seizures and often eliminating drop attacks.

3. Stimulation. There is a trend in functional neurosurgery toward nondestructive techniques involving electrical stimulation of the nervous system to modulate activity. Currently, vagal nerve stimulation is the only mainstream stimulation technique used in pediatric epilepsy. It is typically a palliative procedure with minimal risk and side effects. Deep brain stimulation and cortical stimulation are techniques that show promise in adult human trials for managing some forms of epilepsy. Pediatric trials are forthcoming.

4. Ablation. A newer epilepsy surgery technique is stereotactic laser ablation (SLA). This minimally invasive technology involves placing a very small laser applicator into the targeted brain tissue or tumor. The laser is then activated with the patient in an MRI scanner to monitor the energy delivery to the targeted tissue. This allows for precise destruction of deep targets in the brain without the morbidity associated with open brain surgery (Figure 2). Only smaller targets can be treated with this technology, so it is not appropriate for most patients. Those patients who are candidates typically enjoy shortened recovery times. Most patients go home the day after the procedure with minimal postoperative discomfort. Children’s Hospital of Wisconsin is one of the few hospitals in the world where SLA is performed.

SUMMARY
• The immature, developing brain is particularly susceptible to the ravages of poorly controlled seizures, leading to permanent developmental/cognitive losses and the development of broader epileptogenic networks.
• It is imperative that children with epilepsy achieve maximal control in a timely fashion to prevent these long-term sequelae.
• A significant subset of children with epilepsy can benefit from epilepsy surgery as a curative measure or for palliation.
• The earlier these patients are identified and treated, the better the neurological/developmental outcome.
• The decision-making process for determining surgical candidacy and the appropriate surgical approach is complex and requires a multidisciplinary team at a comprehensive epilepsy program.