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Reflections on a 45-Year Practice of Academic Neurosurgery

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The Future of Traumatic Brain Injury: No Cure for Retrograde Amnesia
In this issue of Congress Quarterly, we focus on the great strides that have been made in the treatment of our patients in the field of neurosurgery – in a relatively short period of time. Specifically, we asked several respected members of the neurosurgical community to comment on the state of neurosurgery at the beginning of their career. This was then complemented with several articles exploring where neurosurgery is heading in the future.

We would like to commend and thank all of the authors for their great contribution and their insights and perspectives on treatment of neurosurgical disorders. Dr. Frederick Simeone reflects on his 45 years of practice and academic neurosurgery, while Dr. R. Michael Scott gives a perspective of his 40 years in neurosurgery. Dr. Edward C. Benzel discusses the growth of neurosurgical spinal surgery and Dr. William Buchheit examines the evolution of modern intracranial tumor surgery. Drs. Adam Robin, Steven Kalkanis and Mark Rosenblum complement this article with a further assessment and evaluation of the treatment of brain tumor patients. Drs. Frederick Stephens and Geoffrey Manley discuss the neurotrauma population, and Drs. Robert Spinner and David G. Kline review their experience with the advances in peripheral nerve surgery.

For the future perspectives and outlooks on treatment algorithms, Drs. Sean Nagel and Michael Steinmetz examine the future of treating pain patients; I (Dr. James Harrop) explore future algorithms of spine surgery and Drs. Robin, Kalkanis and Rosenblum, in a second article, discuss future therapies for brain tumor patients. Drs. Fagan, Markow, and Hoh provide an interesting outlook on the future of vascular neurosurgery. Drs. Yang and Hanna further analyze the future of present neurosurgical intervention in peripheral nerve surgery. Dr. Edward Smith discusses developing trends in pediatric neurosurgery. Drs. Brian Ragel and Eric Thompson provide a look at what the future of traumatic brain injury may hold.

In addition to the significant contributions above, the INSIDE THE CNS section has a focused article from Duncan McRae, Managing Editor of Neurosurgery®, the official journal of the CNS, where he discusses the journal’s progress. Lastly, Katie Orrico details the many advocacy efforts of the AANS/CNS Washington Office.

I thank you once again for your participation in our journal and as always if you, the readers, have any comments, ideas or suggestions that you wish us to review or discuss, please do not hesitate to contact us at info@1cns.org.
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CNSQ BACK PAGE

Images in Neurosurgery
Dear Congress of Neurological Surgeons members, I hope you are having a great summer. It has been an eventful quarter for the CNS.

As many of you know, the CNS suffered a tragic and unexpected loss on Monday, January 9 with the news of Dr. Christopher C. Getch’s untimely passing. Dr. Getch, the immediate Past-President of the CNS, was an inspiring leader who worked tirelessly on behalf of the CNS, its members, and the profession of Neurosurgery. He will be remembered as a great father, husband, leader, and surgeon. He was my friend and will be sorely missed.

On a much happier note, as I discussed in the last issue of the Congress Quarterly, the CNS has been conducting a search for a new Executive Director/Chief Executive Officer. This search considered over eighty highly-qualified candidates over five months, with final interviews taking place on April 27th and 28th in Chicago, Illinois. I am very happy to report that this search is now complete and that David Westman, MBA, CPA, CAE has been selected as the new Executive Director/Chief Executive Officer of the CNS. David comes to the CNS from the Association of Diabetic Educators, where he is currently Acting Executive Director. He brings with him a wealth of experience in association management, including experience as an organizational and strategic planning consultant. He has shown himself to be an outstanding communicator, resourceful problem solver, and a strong staff leader. Please join me in welcoming David to the CNS!

This issue of CNSQ is devoted to the past, present, and future of Neurosurgery. It is in my opinion that it is good to stop and consider where we, as a profession, have been, where we are, and where we would like to be. As has been detailed by a number of authors, the current state of the profession is the result of decades of innovation on the part of neurosurgeons and others. In some instances, remarkable progress has been made. In others, the profession seems on the cusp of a revolution.

Advancements in any field seem to occur in one of three ways. We are all accustomed to the type of advancements that occur as the result of systematic scientific research. Basic research reveals the underlying principles, while applied research defines the usefulness of these principles in clinic practice. Successful scientific research, though, requires more than dedication to the scientific method. It also requires aptitude, opportunity, and an acknowledgement on the part of society of its value. As a profession, we must continue to acknowledge this value or be prepared to accept our current inadequacies.
A second type of advancement occurs when technology outside of neurosurgery is adapted for the benefit of neurosurgical patients. This process, which is really best described as engineering, occurs at the intersection of disciplines. It happens best when resourceful, well-rounded individuals are able to look across these intersections with an open mind and see an opportunity. While collaboration with non-neurosurgeons is essential to this process, we cannot, as a profession, afford to outsource this process.

Finally, while science and engineering are essential to progress in any discipline, a third type of advancement often defines a true revolution. This type occurs when a brilliant idea occurs suddenly in the setting of a prepared mind. These advancements sweep over a discipline. They result from new ideas, not adaptations, and from answers, not questions. These advancements are few and far between, not because of their rarity, but because the underlying ideas are rarely acted upon. Thus it is essential to consider that the number of revolutionary advancements is fundamentally proportional to the number of prepared minds.

It is interesting to note that the future is not always what we would have thought. A brief review of Neurosurgery® Volume 1 reveals reports highlighting the promise of such techniques as injection of intracranial aneurysms with tissue adhesive and cerebellar stimulation for intractable seizures. How many of our current practices will be viewed similarly in another 35 years? As a spinal neurosurgeon, I am very aware of how far the field has progressed in the very short span of my career. Many of the tools and techniques that I learned about during my relatively recent training have fallen into disuse. I sometimes wonder about what I or others will think of current practices in spinal surgery twenty years from now. I hope that many practices will survive the test of time. Frankly, though, I hope that at least some will not, and that they will be replaced by ones that are newer, more effective and less morbid.

For those of you that know me, it should come as no surprise that I read Popular Mechanics. In the April 2012 issue, in an article entitled “We Need to Dream Big Again,” the author, Glenn Reynolds, opines that we need to “design bold new things for use in the physical world: space colonies instead of social media.” I hope that neurosurgeons will continue to pursue the scientific, engineering, and revolutionary advancements that have defined the profession since its inception. After all, I do hope to be afforded the privilege of old age and may need them myself! As science fiction writer Neal Stephenson is later quoted in this article as saying, “We can’t Facebook our way out of the current economic status quo.” I couldn’t agree more.
All of this may sound archaic, primitive, kind of like Cro-Magnon neurosurgery. But the time period covered is very short, so view the crudeness as an indication of progress rather than an indictment of the times.

We all had a doctor’s bag. In it was an object called ophthalmoscope. We considered this a necessary part of our armamentarium. It was a device which allowed you to look at the fundus of the eye and actually make specific diagnoses. Sometimes even brain tumors presented with papilledema as the only objective sign. On other occasions the only noninvasive way to test for high-grade carotid stenosis, was to observe retinal artery pulsations while external pressure was applied. With the advent of CT and MRI scanning it was not necessary to change the dead batteries in your ophthalmoscope, or even to carry it at all.

We had few ways to look inside the skull. Prior to computed scanning, one could perform an echogram. With this device, at the bedside, one could pass an ultrasonic pulse through the skull, and detect the echo not only from the inside of the opposite skull, but from the complex of midline structures which were usually echogenic. A shifted midline was often the best objective diagnostic criterion for a subdural hematoma in the proper clinical setting.

In the 1960s there was no easy way to diagnose a brain tumor. At first we performed a barbaric procedure, pneumoencephalography, during which air was injected into the spinal canal of a suspect patient and, while he was complaining and retching, radiographs would outline the ventricular system, and sometimes,
evidence of a mass. If the patient had papilledema it was dangerous to perform a spinal tap, so the air was inserted through burr holes usually in the parietal region. To add to this discomfort, the patient was rotated about so that the air bubble could outline the crannies of the ventricular system.

Later on we found that certain radioactive isotopes would concentrate in brain tumors and brain scans became helpful for delineating medium-size (or greater) masses.

During this era history-taking was very important. With so few objective clues to go by, carefully reconstructing symptoms was by far the most important part of the examination. We could actually look in the patient’s eyes when we took his history, and we did not have to worry about typing an electronic record and thereby breaking emotional contact (a common complaint among patients in the EMR era). In many instances the history and exam were all one had to go on and usually a diagnosis was well on its way before imaging studies were even attempted. As time went on, I found my residents would view the scans before seeing the patients, making the examination somewhat superfluous, or at least confirmatory of the radiographic prejudice they already had.

By the time I started, angiography was already on its way. We viewed the angiograms intensely. We knew the names of all the arteries and we were excited if we could diagnose a tentorial meningioma because of an enlarged meningeal vessel. But performing the angiogram was sometimes traumatic. Prior to catheter-trained neuroradiologists, we could access any major cerebral artery in the neck, usually by the torture of direct carotid puncture, or even worse, attempting to hit the vertebral artery deep in the neck before it entered the spine. Rarely a sub-minimal injection had devastating results. With the advent of automatic injection, retrograde brachial arteriography humanized the process of visualizing the posterior circulation. When neuroradiology came along, most busy neurosurgeons were glad to give up arteriography and myelography.

It all changed in the mid-1970s with the advent of CT scanning. The first scans, called EMIs (named after the British company which produced them while simultaneously making records for the likes of the Beatles and others) were heavily pixilated, crude, blurred, images, but a godsend because they visualized the intracranium painlessly. In the late 1970s I was on the committee which decided that four such machines would be necessary in Philadelphia, and patients could be transported from whatever institution to the nearest scanner. Some died in transit and a lot of handwringing preceded the important decision as to whether to send your patient for one of these precious scans. Could we predict that a few decades later multiple fixed and portable CT scanners would be found in every large hospital? Magnetic resonance scanning revolutionized neurosurgery in the 1980s. We now had a detailed sagittal view of the brain which made both diagnosis and surgical planning more accurate. This led to the discovery of previously unrecognized conditions, such as the Chiari malformation which was rarely anticipated unless the air from a pneumoencephalogram outlined descended cerebellar tonsils. Now armed with accurate intracranial/extracranial metrics, the field of image-guidance blossomed, although we were usually able to find a tumor with a relatively small incision based on external measurements, experience, and a lot more attention to detail.

Neuroimaging also led to accurate diagnosis of spinal conditions. The CT scan eliminated the need for myelography in many cases, such as cervical spinal cord compression, disc herniation, etc. The MRI scan became the study of choice for spinal cord tumors some of which, particularly intramedullary, could not be diagnosed easily in any other manner. Again, because of the sagittal view, magnetic resonance imaging became singularly indispensable in the diagnosis of surgical and nonsurgical spinal disorders. For both intracranial and spinal disorders, MRI scanning led to more accurate surgical planning, minimally invasive techniques and the development of surgical instruments, including the Pandora’s Box of spinal instrumentation.

It is undisputed that neuroimaging has revolutionized neurosurgery in the past half century. Less incrementally, advances in perioperative care, drug therapy, and surgical instrumentation have improved our performance. Superb results are expected, not praised as technical feats, and the providers who do them are no longer the heroes as they were in the past.

But we don’t need heroes... do we?
W
de I began my neurosurgical resi-
dency training in 1969, there was
no such thing as “pediatric neurosur-
gery,” only the rare pediatric hospital or train-
ing program where more pediatric neurosurgery
might be practiced, and where the rare giants in
this very young field – Matson, Raimondi, and
Hendrick, to name just a few – practiced and
educated. It was rare that anyone specialized
in any particular aspect of neurosurgery, and as
one might expect there were many differences
from our practice today.

The training was certainly different. There
was no residency match in the late sixties, I ob-
tained my position in the Massachusetts Gen-
eral Hospital training program by calling the
office of the Chairman every two weeks after
submitting my application two years earlier,
until I finally wore them down and they were
convinced that I was now finally no longer draft
fodder for the Vietnam War.

Resident salaries were at the poverty line.
As interns at Boston City Hospital, we had
been paid $2,500 per year, from which $500
was deducted for health insurance. We took
solace in getting free laundry for our white uni-
forms, and a free late-night meal. We went on
strike for better pay – in the spirit of the times,
the strike was called a “heal-in”. Every patient
coming to the emergency ward was admitted,
filling the hospital corridors to overflowing. The
hospital capitulated, with salaries immediately
rising to the princely sum of $6,000 per year.
To be fair, our small home in Newton, Mass,
purchased in 1969 cost $28,000, and a Ford
Falcon in 1966 went for $2,060.

The MGH residency was directed by Dr.
William Sweet, an expert on pain, which he
inherited from his prior chief, Dr. J.C. White.
There was no special training in the care of
children. Dr. Sweet was a gifted surgeon in
many areas – I remember him taking out a cra-
niopharyngioma with great skill in that era of
no microscope, with loupes for magnification
and a large mirrored headlamp for illumina-
tion. It was the hey-day of the boron-neutron
capture era. Dr. Sweet’s lab would constantly
be on the look-out for a boron-containing com-
pound that might concentrate in a glioblas-
toma for subsequent proton bombardment in
the MIT cyclotron. When such a compound was
discovered, it would be hurled into the front
lines; the resident would be asked to infuse
the newly-designed compound into the patient
preoperatively by performing a direct carotid
puncture at the bedside, and then sitting there
for the next three hours while the compound
was infused via a Harvard pump.

In those days, pre-steroids, the glioma pa-
tients often did not do well with the extra bolus
of fluid they were receiving – let alone the un-
known effects of the compound itself – and
many a trip to the operating room was made
for emergency decompression of the swell-
ing tumor. There was no IRB at MGH, and to
the best of my knowledge, no permit was ever
signed – but then again no permit was ever
signed before surgery.

The residents worked hard, every other
or every third night – with certainly no duty
hours restrictions. I remember feeling abused
only on the Sunday mornings when Dr. Sweet
would call me in on my day off to perform a

Figure 1. A pneumoencephalogram in a
6-year-old with a visual field cut.
The figure is centered on the sella, and demonstrates
a nodule of calcification in the sella and the
craniopharyngioma extending out of the sella (arrows).
Air fills the lateral and third ventricles.

Figure 2. Aneurysm surgery at the
Boston City Hospital in the early 70’s.
Robert Heros holds a retractor on the frontal lobe, and
RMS holds a Mayfield aneurysm clip. Note the headlight
illumination and loupes magnification (no ‘scope!).

Figure 3. External ventricular drainage in the 50s
through the 70s, with a Scott Cannula. Journal of
Neurosurgery, 10 (1953): 438. Used with permission of
the AANS.
graded pin and weighted-hair sensory exam on a patient on whom he planned to carry out insertion of a dorsal column stimulator. These exams took hours and when one spouse complained volubly, Dr. Sweet prescribed a course of psychotherapy for the couple involved.

As residents, we carried out surgery for the same problems we deal with now, with the major exception of pain. Surgery for the patient with pain was in its ascendancy. Because of the keen interest of White and Sweet in the neuroanatomical pathways of pain, we were always doing neurosurgical procedures to treat it – from subarachnoid phenol blocks, to open cordotomy, to medullary and mesencephalic tractotomy, and in the case of Thomas Ballantine, cingulotomy. I never saw a frontal leucotomy or lobotomy during my residency, and rival trigeminal neuralgia surgeon Peter Janetta’s name was never mentioned. We did carry out extensive decompression for trauma – the bifrontal craniotomy as described by Kjellberg (Figure 4). The residents hated this operation, since it left the patients in a vegetative state for weeks with their frontal regions bulging, like a caricature of Martians from outer space.

I should emphasize again that there was no microscope in use at all except for a rare open pituitary tumor operation. I have a treasured photograph of Roberto Heros (then my first year resident) and me clipping an anterior communicating artery aneurysm at the Boston City Hospital, Roberto with a hand-held retractor on the frontal lobe, and me holding the clip using loupes and a headlight (Figure 2).

I think that all of our subspecialties came into their own with the advent of modern imaging. The diagnoses throughout my residency, until the last three months, were all made by direct-stick carotid arteriograms, pneumoencephalograms, air or pantopaque ventriculograms, or myelograms. We estimated lesion location by noting shifts of normal structures on these studies, armed with a good knowledge of neurology after a careful examination of the patient, and learned how to palpate and probe the brain when it was exposed to find the tumor. A trauma case went straight from the emergency room – possibly after a one-shot single-a-p injection carotid arteriogram – to the operating room where multiple bilateral burr holes were placed, looking for a treatable epidural or subdural clot.

When the CT scan came along, we began to see things that had never been seen before. I never operated on a cavernous malformation of the brain until the fateful day that the CT was installed at the MGH in late 1973. A young patient with a field cut and negative arteriogram underwent a CT scan demonstrating a parietal-occipital clot, persuading us to take him to the operating room to find not the AVM we expected but a cavernous malformation. This led to a career-long interest in CT and later MRI imaging in the diagnosis and treatment of congenital disorders of the brain and spinal cord as well as in vascular pathology in the developing brain.

We repaired myelomeningoceles in those days guided by diagrams in the standard texts, whose tissue layers and planes never really made sense to me as a resident. The CT scans, and the later CT myelograms and spinal MRIs finally helped us to make sense of the lesions we were dealing with and how to repair them. The evolution of subspecialties, and the marked improvement in CNS imaging, has led to improvements in the care of pediatric patients that we couldn’t begin to dream of in the 70s.
In the late 70s, I was in the midst of my neurosurgical training at the Medical College of Wisconsin. Complex spine surgery was in its infancy and routine neurosurgical spine surgery consisted of the relatively uncommon anterior cervical discectomies with autograft fusion (without plating), and the standard variety of dorsal decompression procedures, along with opening and performing the decompression component of complex spine operations for Orthopedic surgeons.

Complex spine surgery, which was infrequently performed by neurosurgeons, consisted of ventral thoracic and lumbar decompression (previously introduced for the management of complex pathologies such as Pott’s disease) and fusion procedures without instrumentation. Harrington rods, cervical dorsal wire fixation, and other less common techniques (such as Knodt rods, the Dunn device, etc.) were being increasingly employed for degenerative pathologies and trauma by neurosurgeons.

During this era, neurosurgeons rarely entered the emerging complex spine surgery arena; thus, they performed predominantly decompression procedures and pathology specific procedures (such as tumor resections via laminectomy and trauma). This was in keeping with the neurosurgeon of this era being generalists. Although spine surgery composed by far the greatest portion of neurosurgical procedures, neurosurgeons rarely specialized. Neurosurgeons performed simple ‘bread and butter’ spine operations (eg, discectomies and laminectomies) in high volumes – but rarely performed more complex operations. In this era, there were few neurosurgery subspecialists in any domain – particularly spine. The circumstances and politics of the late 70s and early 80s, however, set the stage for change.

Neurosurgery spine surgery pioneers of this era, led by my mentor Sanford Larson, began employing Harrington rods (that were originally developed for scoliosis applications) for spine trauma and tumors, laminar fixation techniques (such as Knodt rods) for degenerative disease, and pioneered new approaches to ventral spine decompression such as the lateral extracavitary decompression for ventral thoracic and lumbar pathologies. It should be clearly understood that orthopedic surgeons aggressively dominated the complex spine surgery domain in the 70s. It was with significant courage that Larson, his contemporaries and their protégés (my generation) entered this arena. We were challenged at ‘every turn’ by our then, orthopedic surgeon antagonists. We literally fought to learn new techniques. Our opponents in this ‘fight’, organized orthopedic surgery and individual orthopedic surgeons, were tenacious and persistent. They, in many ways, attempted to block neurosurgeons from educational opportunities and clinical access. Neurosurgeons struggled to overcome the obstacles placed by orthopedic surgery, while at the same time attempting to strengthen our image as spine surgeons. Many stories exist depicting both small and large ‘battles’ in small and large hospital venues, as well as at the national political plane.

Nevertheless, that was then and this is now. It is emphasized that times have changed and bygones have indeed become bygones.

What was it like to be training and practicing neurosurgery in this era? For me, it was a wonderfully enriching experience. I (along with my resident contemporaries at the Medical College of Wisconsin) was both a witness and a contributor to the process by which neurosurgery and neurosurgeons emerged as complex spine surgeons.

What was it like to be a spine surgeon in the late 70s and early 80s? It was difficult, challenging, and yet rewarding – just as it is today. What do I mean by this? Well, it was difficult to operate without pedicle screws, anterior cervical plates, lateral mass fixation techniques, and on, and on, and on. We performed the vast majority of our decompression operations via a dorsal approach. We had wires for cerclage dorsal cervical and occasional thoracic and lumbar fixation and we began employing Harrington rods and Harrington rod variant techniques (including Luque and combination techniques) for thoracic and lumbar stabilization. At the time, all were perceived by us to provide a less than desirable offering to our patients. We struggled with postoperative deformity (e.g., flat backs), spinal instability and suboptimal clinical results. At that time, we did not know what we were missing. Then came anterior cervical plates, pedicle screws, ventral fixation techniques for the thoracic and lumbar spine, and on, and on, and on. After using and improving these new technologies, we then ‘saw’ what we had been missing in the 70s.

From our experiences, what can I and my contemporaries teach the spine surgeons of today? Well, we learned to operate with little supportive technology – like operating with a ‘broken bottle and a stone’ (the notion of conceptually operating with the most minimal of technological advances is characterized here by operating with a ‘broken bottle and stone’ and was borrowed from Tim Cohen). The case presented in Figure 1 exemplifies this con-
cept. A 21-year-old male incurred C45 bilateral locked facets and quadriplegia (complete myelopathy) following an altercation in the early 1980s (Figure 1 left). MRI was not yet conceived; nor was modern spine stabilization techniques. In this era, the vast majority of spine surgical procedures were performed via dorsal surgical approaches. Hence, 22 gauge twisted cerclage stainless steel wires were used to secure fixation and bone graft position following intraoperative deformity reduction. The end result is depicted by an intraoperative X-ray (Figure 1 right). The patient did not improve neurologically.

Surgeons of this era were afforded the opportunity to develop both the confidence and the ability to deal with very difficult and underresourced clinical scenarios, such as was the case with this young man and his devastating injury. In a very real sense, this was like operating with a ‘broken bottle and a stone’. The creativity fostered by the need to compensate for limited resources strengthens decision-making and technical skill sets. Indeed, the spine surgeons of the 70s and 80s era were very creative. Their creativity resulted in the substantial innovations we and our patients enjoy today. These innovations make surgery easier, faster and safer. There is a down side to the ease of surgery provided by technological advances, however. The collective ‘we’ have lost some of our insight into how to operate with a ‘broken bottle and a stone’. I see in the trainees of today, on a routine basis, a substantial reliance on technology – at the expense of what I perceive to be a more appropriate reliance on intrinsic knowledge, common sense, and the fundamentals of spine surgery. Some sort of re-orientation may be in order. I feel privileged to have had the exposure I had. I am better because of it. I can only hope that I and my contemporaries can craft a way to provide this ‘privilege’ for the next generation, the trainees of today.

Is the scenario of the 70s all that different from what we are currently experiencing? Today, things are much better. Yet, we still struggle with postoperative deformity, spinal instability and suboptimal clinical results. This is in spite of the introduction of a myriad of techniques not available to us in the past. It is likely that spine surgeons in 2040 will be reminiscing and reflecting about the incredible challenges they faced in the early years of this millennium (e.g. today). Like in the 70s, neurosurgeons of today cannot foresee what is to come. They could not possibly appreciate how innovations would affect patient care and the surgeons’ ability to advance the field of spine surgery.

It is good to reminisce and reflect. We can learn from prior experiences – both our own, and those of others. History does have a propensity to repeat itself. Hence, an understanding and appreciation of history can most certainly be of benefit as we look to advance our field and pass our advances to the next generation.

> SURGEONS OF THIS ERA WERE AFFORDED THE OPPORTUNITY TO DEVELOP BOTH THE CONFIDENCE AND THE ABILITY TO DEAL WITH VERY DIFFICULT AND UNDERRESOURCED CLINICAL SCENARIOS... IN A VERY REAL SENSE, THIS WAS LIKE OPERATING WITH A ‘BROKEN BOTTLE AND A STONE’. <

Figure 1. Left: A 21-year-old male incurred C45 bilateral locked facets and quadriplegia (complete myelopathy) following an altercation in the early 1980s. Right: The end result is depicted by an intraoperative X-ray.
Comparing brain tumor surgery today with brain tumor surgery in 1962, when I entered my neurosurgical career, two things have not changed: the tumor and the patient. From beginning to end, it’s a completely different world.

All patients being prepared for a craniotomy had their head completely razor shaved—without exceptions. This policy was not without unintended consequences. For example, a new overzealous resident “scrubbing” on their first neurosurgical case once shaved bald a lady about to have a cervical laminectomy.

With no skeletal or cranial fixation, it was impossible to secure the head firmly. For supratentorial craniotomies, the head was simply laid on a rubber donut and held secure, by hand, while the bone flap was being cut. For posterior fossa craniotomies, the patients were placed in the sitting position with the head attached with surgical tape to a tubular contraption which was part of the operating table.

In the early 1960s finding the tumor was more an art form than a science. With only the neurological exam, angiograms and air studies (pneumocephlograms) to go by, it was not unheard of to operate and never find the tumor. As a consequence, to optimize the chance of success, all craniotomies were very large.

For frontal lesions, the scalp flap usually began at the Gabbella, followed the sagittal suture to the vertex, and curved down in front of the ear to the zygoma. Another choice was a coronal incision from zygoma to zygoma. For posterior supratentorial lesions, it was the reverse, starting at the zygoma in front of the ear and up to the sagittal suture, then posterior to the external occipital protuberance. Posterior fossa craniotomies were begun with either a bow shaped incision from mastoid tip to mastoid tip, or one from the external occipital protuberance down to the mid-cervical spine.

The craniotomy itself was all done by hand—beginning by drilling multiple burr holes—as many as 6 or 8—with a “Hudson Burr”. Then, going through the burr holes, a thin narrow steel guide was passed between the bone and dura. Using this guide, a wire with sharp teeth—called a Gigli saw—was pulled through and with a back and forth sawing motion, the bone plate was cut free.

The posterior fossa always had a complete mastoid to mastoid craniectomy with rongeurs including the foramen magnum.

Both above and below the tentorium, the dura was always opened along the bone edge for maximum exposure. If we couldn’t see the tumor on the surface, we continued searching by palpating the cortex, feeling for a firm area. If we felt something, the next move was to probe deeper into the brain with a “brain cannula”—a blunt 16 gauge needle. When we located resistance—hopefully caused by the tumor—we made a transcortical incision following the cannula tract. The walls of this tract were then held open during the rest of the procedure by the resident using a handheld malleable aluminum blade bent to fit—no self-retaining retractors.

Gliomas, etc. were removed with suction and solid tumors with finger enucleation, both of which were reasonably bloody, especially the latter. The one surgeon who used his finger the most described the bleeding as a “total situation” and he was right. To get things under control, the cavity was packed with big wet cotton balls called “fluffies”—which tamponaded the bleeding. These cotton balls worked astonishingly well in slowing the bleeding and made the situation manageable. Ultimately, we would slowly remove the cotton, uncovering individual bleeders. As the bleeders were exposed, the surgeon would then grasp them with the tip of a steel forcep and the resident on command would activate the Bove and touch the free end—a slow but effective method, it was used to coagulate specific points. Blood loss was always a problem, and intraoperative transfusions common.

Post-op the patient spent a short time in the Anesthesia Recovery Room and then went directly into a regular hospital room, where they were managed by skilled nurses and busy residents. There were no neuro ICUs, no electronic monitoring, and no intensivists.

Compared to today it may sound like the Wild West, but things seemed to work out and the patients survived.

What a remarkable difference 50 years has made—it has been a privilege to be part of it.
Surgery for brain tumors has changed significantly since Sir Rickman Godlee performed one of the first glioma resections in 1884. There have been advancements in the techniques of surgery, anesthesia and post-operative care which have reduced peri-operative complications related to blood loss, infection and elevated intracranial pressure, which were major operative hurdles in the late 19th and early 20th centuries. Nobel-prize winning discoveries have been made in physics, chemistry and medicine which have contributed greatly to the advent of various imaging modalities, our understanding of ionizing radiation and its applications to cancer treatment, and our comprehension of the molecular machinery underlying cancer cell physiology. This article will highlight many of the advancements made over the last 40 years in surgery, imaging, radiation, basic science, and medical therapy and the manner in which these advancements have changed the way neurosurgeons treat patients with brain tumors.

Surgical innovations credited to Harvey Cushing including the use of operative anesthesia, suction and electrosurgery helped to lay a foundation for modern neurosurgical technique that was expanded upon by Gazi Yasargil through the use of the operating microscope during the middle-to-late 20th century. Surgical advancements including high output lighting, portable ultrasonography, the operating microscope, endoscope and associated micro-instrumentation, the development of power drills, bipolar coagulation, ultrasonic surgical aspirators and stereotactic and intra-operative image-guidance helped to replace more antiquated technologies largely in use prior to the 1970s such as the trephine, Hudson Brace and Gigli saw. These innovations have resulted in more precise surgery and less operative mortality.

Brain imaging has likewise undergone significant evolution from its relatively humble early 20th century beginnings. First there was Dandy’s method of air ventriculography and more recently the imaging “revolution” of the 1970s and 1980s beginning with Godfrey Hounsfield’s 1971 EMI CT scanner and continuing through Paul Lauterbur and Raymond Damadian’s MR imager made commercially available in 1980. The practical use of CT and MRI technology ensued throughout the late 1980s and early 1990s with the development of enhanced MRI scans, alternative MRI sequences including diffusion tensor imaging, functional MRI, PET scanning and MR spectroscopy, which led to a virtual revolution in diagnosis, localization and operative planning thanks to the technology’s broad applicability to the pre-, post- and intra-operative theaters.

Advancements in the field of radiation therapy have greatly enhanced the armamentarium neurosurgeons utilize in treating brain tumors. Radiation therapy was rather limited prior to the middle of the 20th century, initially relegated to the use of whole brain therapy with Polonium and Radium. In the 1970s, the ability to deliver cobalt and cesium-based therapies in a regional fashion, radiation sensitizers and stereotactically focused radiation dosing created a non-invasive adjunct to surgery for many patients with brain tumors. LINAC, high LET and Boron Neutron Capture are all advances of the 1980s which gave way to altered fractionation and conformal radiation field shaping capabilities in the 1990s. More recent advancements including stereotactic radiosurgery with fractionation and regional radiation therapy with IMRT have given patients additional less invasive treatment options.

Basic science achievements in brain tumor biology include the establishment of in-vitro and in-vivo models of glioma since 1970. Clonogenic assays were developed to facilitate in vitro testing of animal and human gliomas and to optimize the dosing, sequencing and timing of chemotherapy and ionizing radiation treatment paradigms. Working hypotheses based on these models included the clonal hypothesis of tumor formation, studies of cellular kinetics and early stem cell concepts of...
malignancy. The 1980s heralded the development of molecular biology and with it growth factors, transmembrane receptors and intracellular signal transduction. Tumor cell biology, specifically the way in which cancer cells relate to their environment and molecular mechanisms by which they proliferate, migrate and invade surrounding tissue, was elucidated and implicated angiogenesis as a major factor in tumor viability and invasion. Since then major discoveries related to control of basic cellular mechanisms by which they proliferate, migrate and invade their environment and molecular mechanisms by which they relate to their environment and molecular mechanisms by which they proceed to these splendid research endeavors.

The National Cancer Institute's (NCI) Brain Tumor Consortium (BTC) instituted in 1994 accelerated brain tumor research for therapy into the 21st century. In 2005, the NCI in conjunction with the National Human Genome Research Project began The Cancer Genome Atlas (TCGA), with Henry Ford Hospital and MD Anderson as the leading contributors, with the hope of coordinating research, compiling tissue and consolidating data to help identify genes that drive certain types of cancer. More recently Rembrandt, an online repository for molecular brain neoplasia data has been instituted giving researchers online access to molecular data for over 500 specimens. Brain tumor research today is rapidly progressing owing in large part to these splendid research endeavors, but these well-functioning paradigms of collaboration, education and research did not always exist. They are largely predicated upon an evolution in thought which first occurred in the late 1970s with the advent of the first brain tumor tissue bank at the University of California, San Francisco, which served as a model for tumor banking at Henry Ford Hospital, MD Anderson and elsewhere. The Brain Tumor Study Group, Radiation Therapy Oncology Group and regional cancer groups promoted efforts in brain clinical trials beginning in the late 1960s. In the 1980s, multisite, neurosurgical interaction focused on brain tumor treatment that fostered the development of the AANS/CNS Section on Tumors in 1984. As outlined in the History of the AANS/CNS Section on Brain Tumors, the original section was a collaborative work initiated by Edward Laws and Mark Rosenblum, who served as the first Section Chair. The Section has the privilege of being the first organization designed to study and treat brain tumors and has worked to publish guidelines for brain tumor treatment, establish surgical-oncologic fellowships, grants, research opportunities, and contributed to reducing in hospital post craniotomy mortality significantly during its tenure. Multispecialty interactions have been further enhanced with the formation of the Society of Neuro-Oncology, founded by Dr. Victor Levin at MD Anderson in 1996, which continues to serve a valuable role today.

Medical treatments have been evolving as our understanding of brain tumor biology improves. The Brain Tumor Study Group trials of the 1970s demonstrated improved survival for patients with high-grade glioma who underwent surgery and chemotherapy in addition to whole brain radiotherapy. Treatment progressed into the 1990s with the advent of Gliadel® wafers, the use of Temodar® and preliminary viral therapy studies. Greater awareness of toxicity issues related to treatment with cytotoxic therapies and the incidence of radiation necrosis developed at this time as well. With the success of the coordinated multi-disciplinary research initiatives like the NCI, TCGA and BTC has come the development of molecularly directed therapies such as Temodar® for treatment of high grade gliomas in patients with methylated O(6)-methylguanine-DNA methyltransferase (MGMT) gene status as well as Avastin® therapy in glioblastoma and radiation necrosis. Over the past fifteen years, the concept of brain tumor stem cells has become more clearly defined and efforts are underway to develop molecular targets which underlie tumor cell, specifically tumor progenitor or tumor stem cell biologic activity. Immunotherapy, viral and nano-sized drug delivery models are also in development.

Notwithstanding all of the aforementioned advances in surgery, imaging, radiotherapy, basic science and medical therapy over the last forty years, it is perhaps the paradigm shift that occurred over this same period which has resulted in the recognition of our patients as people in need of treatment for their brain tumors with a focus on both longevity and quality of life. This has resulted in a multi-faceted, more multi-disciplinary collaboration within hospitals in managing these patients, as well as an effort to foster education and research, pool data and tissue and collaborate between hospitals and centers of excellence to improve patient outcomes.
Neurotrauma has come a long way in the last quarter century. The post hospitalization mortality rate from traumatic brain injury (TBI) has steadily decreased from close to fifty percent in the 1970s to around twenty-five percent in recent studies (Zink et al). This is directly related to an improvement in the systems of care and treatment protocols for TBI.

Neurotrauma was one of the first groups in neurosurgery to develop evidenced based guidelines. In 1995 the Brain Trauma Foundation developed the first TBI guidelines. These guidelines were updated in 2000 and again in 2007 and endorsed by both the AANS and CNS (www.braintrauma.org/coma-guidelines). These guidelines are now exported and implemented all over the world. However, there is still significant variability in treatment due to the paucity of data for many of the treatment interventions, such as deep vein thrombosis (DVT) prophylaxis.

In the past 25 years we have obtained a much better understanding of the importance of pre-hospital and emergency management. The Traumatic Coma Data Bank identified both hypotension and hypoxia as risk factors for poor outcome. This observation led to the era of secondary brain injury prevention which remains a core tenet of our current management.

Imaging techniques have also come a long way in the past 25 years. Initially CT scan was just being embraced, and MRI was not available. More recently advanced MRI imaging (DTI, resting state fMRI, etc.) is being used with increasing frequency.

Twenty-five years ago neurocritical care was virtually non-existent. There has been vast improvements in ventilators, ARDS protocols, and antibiotics. Thus a major reason the ratio of post hospitalization mortality has decreased from half to under a quarter. With advances in neuromonitoring, such as brain tissue oxygenation monitoring, we have moved beyond just solely focusing in intracranial pressure.

Surgical management of TBI is much more aggressive. Patients were operated on late, which was often too late to save. Surgical guidelines, which were not initially available, have been developed with our understanding that Glasgow Coma Scale (GCS) should not be the sole indication for operative intervention. Other variables such as pupillary exam and imaging characteristics must be taken into account. Use of the decompressive craniectomy was non-existent.

Not only have we seen a significant improvement in mortality but also in outcomes. Despite no major advances in the pharmacological treatment of TBI, we have seen substantial improvements in outcome over the past 25 years. This is only likely to get better in time with improved diagnostics and more focus on complex outcome measures. With this in hand to properly account for the heterogeneity in TBI, comparative effectiveness research will be possible, guidelines will be supported by better data, and outcomes will improve.
Reflections on Advances in Nerve Surgery in the Last 25 Years: Then and Now

Then
After WWII and before 1987, major changes in the management of the three categories of peripheral nerve surgery (injury, entrapment and tumor) were well underway. Technological and technical advances across the breadth of nerve surgery helped fuel a recrudescence in interest in operating on peripheral nerves, but especially the brachial plexus.

Injury
In the field of nerve injury, it had been shown that undue tension in an end-to-end suture repair site was deleterious and grafts, especially interfascicular ones, were preferable to a repair where tension and subsequent distraction or excessive scar might be the outcome. In addition, an electrical method for evaluating the most common injury, one in continuity, by nerve to nerve recordings with nerve action potentials (NAPs) rather than inspection even with magnification, gave better guidance for the need for complete repair, split repair, or neurolysis.

Entrapment
In the area of entrapment, endoscopic release at the level of the carpal tunnel had just been described and was being introduced as a potential option to decompress the median nerve.

Tumor
In the discipline of tumors, it had been shown by operative recordings that most fascicles directly entering and leaving benign neural sheath tumors were not functional and could be sectioned usually permitting resection of the entire tumor rather than piecemeal, incomplete removal. This permitted not only the excision of most solitary schwannomas, but also neurofibromas, the latter which heretofore were felt to be inoperable without resultant, severe deficits.

Now
In the last 25 years since 1987, these earlier scientific and surgical contributions have not only been confirmed but in some instances expanded and/or added to. Technological and technical advances have been made. For example, high resolution MRI studies and ultrasound have been utilized increasingly by treating neurologists and surgeons, and have shown utility in the management of injury, entrapment and tumor. Novel new transfers are being introduced. The interest in peripheral nerve surgery has grown. It has become a necessary part of neurosurgical training, and a well-recognized area of subspecialty training.

Injury
Due to the utility of grafts, entubulation, where nerve ends have been placed in usually a biodegradable conduit, has received great notice. Such an approach appears to work best for small caliber, sensory nerves such as the digital, superficial radial or sural with short gaps, usually less than an inch. Its role is being expanded by some groups in larger mixed motor sensory nerves with short gaps. While nerve grafts are still considered the “gold standard” for nerve reconstruction, it is conceivable to predict that if the proper milieu of materials/factors within a conduit can be devised and shown to encourage and transmit robust regeneration across longer gaps in large nerves, then an “off the shelf” substitute could be envisioned which would replace the harvesting of autografts. The possible utility of end-to-side repair where the distal stump of a proximally irreparable nerve is sewn into the side of a healthy or less involved nerve has prompted a lot of interest. The reintroduction of this technique has found some experimental but admittedly more controversial clinical support. The introduction of both vascularized and newly neurotized muscle transplants to the upper limb for otherwise irreparable motor loss has provided hope in selected plexus patients when carried out, usually by multidisciplinary surgeons at some institutions.
Intraoperative electrical monitoring has expanded to include not only the previously described NAP recordings, but also improved methods to perform motor evoked potentials for evaluation of the motor roots in plexus cases along with the available sensory evoked potentials for sensory root testing. IOM studies have better defined both the expectations and limitations of electromyographic (EMG) studies, especially in the early months post injury and have helped to emphasize the importance of electrodiagnostic studies.

A major area impacting especially the brachial plexus but in some cases even more distal peripheral injuries has been the evolution of innovative nerve transfers. In addition to intraplexal transfers, transfer of less essential functioning nerves or their branches or fascicles into denervated nerves has been used frequently. This has changed the management of many plexus lesions, and has led to greatly improved outcomes. Techniques such as the transfer of accessory nerve to the suprascapular nerve have expanded on earlier methods using intercostal and upper cervical spinal nerves to substitute for irreparable plexus elements. More distal methods of nerve transfer have been introduced and quickly adopted. For example, the Oberlin procedure is one where fascicle(s) of ulnar nerve when intact are transferred to the biceps branch of the musculocutaneous nerve; double fascicular transfer for elbow flexion can also be performed when adding this technique to the transfer of a “redundant” fascicle of the median nerve to the brachialis branch. Similarly, the so-called Leechavengvongs procedure that has been introduced for transfer of a triceps branch to the distal axillary nerve has been successful. Because of improved outcomes with these new techniques, nerve transfers, once used solely for preganglionic lesions, are being used increasingly for postganglionic lesions as well. Although controversial, in this latter setting, some perform nerve transfers automatically and exclusively, while others believe that the best outcomes are obtained by exploring and assessment of the plexus, and then performing nerve transfers with direct repair, whenever possible. A very nascent field is that involving reimplantation or implantation of spinal nerves or grafts into the spinal cord in plexus avulsive injuries. It remains to be seen how this will evolve in the future.

Because of the recent wartime conflicts, research centered on replacement prosthetic devices which have practical movements which can be initiated by the patient and used to substitute for amputated or greatly disabled limbs offer a good deal of future promise.

**Entrapment**

Evidence-based outcome studies have given some insight into the management of common entrapments, such as carpal and cubital tunnel syndrome. There has been a growing awareness of the less common entrapments, such as those involving posterior intersseous nerve (PIN) as well as some thoracic outlet syndrome (TOS) cases, such as the true, neurogenic type. Work is being done by some investigators to define possible neurologic causes of pelvic pain. Although remaining controversial, endoscopic methods for release of nerves beside the median, such as the ulnar in the cubital tunnel and the tibial in the tarsal tunnel have been described.

**Tumor**

High resolution imaging has played an important role in characterizing tumors. In many cases, this facilitates the distinction of masses from mass-like lesions, and in some cases, the distinction of benign from malignant peripheral nerve sheath tumors (MPNSTs), or “simple” (conventional) from more “complex” (multifascicular) benign nerve sheath tumors. In some cases, this type of high resolution imaging may even allow the diagnosis of rare lesions without a biopsy solely on imaging characteristics (e.g., lipomatosis of nerve, or “fibrolipomatous hamartoma”).

Advances have been made referable to the genetics and management of syndromes with nerve sheath tumors, including neurofibromatosis (NF-1, NF-2, and schwannomatosis). Lesions, besides those of neural sheath origin, such as hemangiomas, perineuriomas, localized hypertrophic neuropathy, and a large variety of lipomas, have received increased attention in the literature. The fact that intra-neural synovial cysts have been demonstrated to be joint-related (i.e., from the direct flow of synovial fluid into articular branches), has led to a surgical strategy that obliterates the connection in all cases in order to prevent recurrence. In some hands, operative fascicular biopsy of nerves having less obvious structural disease has shown a good bit of utility not only for suspected tumors but other structural and metabolic diseases involving peripheral nerves. The management of desmoids (a benign, but infiltrative process) and MPNSTs and other malignancies involving nerves or plexus remains challenging and often requires a multidisciplinary approach. The utilization of PET scans to diagnose intraneural malignancies has shown promise although it is not as yet free of false-negatives and false-positive results, or in universal use.

**FUTURE**

This is an exciting time to be a peripheral nerve surgeon. Without question, surgical nerve management will continue to evolve in the future.
The perception of painful stimuli is a defense mechanism that evolved to prevent ongoing injury and reinforce safe behavior that promotes survival. Chronic, unremitting pain however, often signifies the acute response is dysfunctional. Options for treating this dysfunction in pain perception have improved, but many are still left to suffer.

The surgical treatment of chronic pain is advancing on three relatively independent fronts with the shared goal to reduce suffering in those with chronic pain as a moral obligation, an economic imperative and a scientific quest. The first wave seeks to better control chronic pain across the population by widely disseminating existing knowledge through the education of caregivers. In addition, new diagnostic modalities will add objective measures that simplify treatment. By improving the identification of those with chronic pain and then establishing treatment recommendations and/or guidelines that include surgery, chronic pain at the population level will be reduced.

On an individual level, the second front is improving the control of chronic pain by refining and perfecting existing technologies. We have witnessed this with the evolution of electrical neuromodulation leads and implantable pulse generators over the last three decades. As we move forward, the most dramatic shift on this front will be the transition from open loop, passive systems to closed, responsive systems.

The third front, which is without precedent and represents the emergence of a new discipline in medicine is the true integration of neuromodulation systems with biology. The realization of this is evident in brain computer interfacing...
interface research. In its essence, the neural substrate and its computer counterpart (or other bio-engineered device) will merge and in so doing will evolve co-dependently.

Going forward then, the classification and reclassification of chronic pain will provide practitioners improved models for diagnosis and treatment. Although subjective pain scales have been shown to be reproducible and reliable, new and as of yet undiscovered biomarkers, including inflammatory cytokines such as IL-6 and tumor necrosis factor alpha (Marchi, 2009) may better quantify pain intensity. Other, currently available ancillary tests, especially MR imaging may add objectivity to a field only as good as its descriptors and numerical scales. Changes in brain function, structure and chemistry have been shown to correlate with chronic pain (Borsook, 2011). This may facilitate the titration of medications and other therapies and move the treatment of pain from the philosophical realm to the physical one.

So the understanding of the physiology of pain and the construction of elaborate, sophisticated models will enhance the use of existing surgical and nonsurgical treatments and may even resurrect some of the old ones. Unfortunately, controlling chronic pain from this approach alone may maintain our relevance but not our patient satisfaction scores.

Neuromodulation, the next renaissance in treating chronic pain, is underway and has been for nearly three decades. To say nothing of the pharmaceutical industry, opioids are the most widely used treatment for chronic pain, with little targeted specific type therapies on the horizon. And though frequent revisions of the medication recommendations and product reformulation have simplified management, the use of opioids in this fashion is neither popular with patients nor easily enforceable in today’s patient-centric system. This has led to a ‘quiet crisis’ in the U.S. health care system that periodically surfaces with the overdose of a celebrity on prescription painkillers whose visage marks but one of an estimated nearly 15,000 dead each year.

To be sure, the most cost-effective, efficacious and safest way to treat chronic pain across a population in the future would be simplified medication algorithms and the federal enforcement of the distribution of opioids. By strictly limiting the amount of medication available and establishing non-negotiable guidelines, this would effectively improve pain control in the under treated and probably anger those who were over medicated. More importantly however, it would shift the control of tolerance to an impartial and disinterested regulatory agency rather than face to face encounters that pit the pleading patient against the physician balancing his/her need to stay busy with risk of a revoked license. Barring such changes resource utilization will continue unabated and the death knell will continue to ring.

So at least in this sense market forces have worked as they should and surgical alternatives, specifically neuromodulation has filled in some of these gaps. Finding an alternative that actually reduces dependence on addictive painkillers is a victory and one that continues to be reimagined with incremental success. In addition to the elaborate and varied electrode arrays with a nearly infinite number of programming options, new devices are available with responsive features. This first generation of responsive stimulators may only respond to a change in one parameter (i.e., position) but the next may offer subtle shifts in stimulation that reduces pain intensity based on position, diurnal variations, weather conditions, activity level and serum cytokine concentration among others.

For example, it is not difficult to envision how biomedical engineering at the molecular scale will transform the treatment of chronic pain. Many of the early gains may be seen with the integration of biosensors (Choi CJ, Wu HY, George S, Weyhenmeyer J, Cunningham BT. Biochemical sensor tubing for point-of-care monitoring of intravenous drugs and metabolites. Lab Chip. 2012 Feb 7;12(3):574-81. Epub 2011 Dec 12.) with adjustments in the settings of existing neuromodulation devices. Microchip-based implantable devices will be able to regulate complex dosing schedules and automate adjustments based on chemical or electrical feedback (Staples, Microchips and controlled release drug reservoirs, Nanomedicine and Nanobiotechnology, 2010). The true integration of biology and technology is more difficult to predict. Presumably however, a highly specific, adaptable electrical or chemical source will be deployed to the region or regions of the dysfunction that give rise to the chronic pain. The patient will then either voluntarily or involuntarily re-learn how to cope with pain by restoring a more normal perception of pain. Though this may seem far off, normal signals generated from the brain are already being used as control features for brain computer interface. Now that a language that unifies the brain and the computer is available, realistic clinical applications should follow. ■
There has been tremendous growth, over the last century, in the spinal surgeon’s ability to comprehend, categorize and differentiate between the various spinal disorders. This categorization and differentiation has led to a diverse range of disorders from axial back pain to the various spinal deformities that we treat. Further advances have led to a great variety of diagnostic and surgical techniques to treat these different pathologies, from the implementation of minimally invasive surgical (MIS) approaches to the use of genetic assays to understand spinal deformities. Despite these recent strides, future advances in this field will be gained through a continued understanding of the etiologies and pathogenesis of these diseases. These future gains will most likely be achieved through three main fronts: improved diagnosis, improved imaging, and less-invasive, highly-targeted surgical approaches.

The greatest difficulty in the treatment of the spinal disorder patient is defining the exact etiology of their primary pathology or pain generator. This difficulty is illustrated in the care of patients with primary lumbar axial back pain. Despite these patients having “normal” or slightly degenerative disc disease lumbar spines on radiographs (plain, CT and MRI), the patients have refractory and unbearable pain. The use of lumbar discograms was a provocative test which was utilized, but recent data and trends has shown this to be a less dependable diagnostic tool. This has created another potential spinal disorder with limited diagnostic means leaving surgeons with a void to diagnose this disorder.

There is great hope that spinal diseases will be defined through improved diagnostic testing illustrating etiologies and providing optimal treatment for patients. In general, future improvements will most likely be pursued and gained through identifying specific sub-populations that are at an increased risk for certain spinal disorders. Recent literature has confirmed the ability to define spinal disease through the use of genetic assays. As spinal surgeons, we have known there is a high incidence of some spinal disorders, such as spondylosis or scoliosis, in certain families. DNA analysis has provided insight in identifying subpopulations of children that are at an increased risk for progression of their scoliosis. It is therefore conceivable, and most likely probable, that in the future we will be able to use DNA analysis to further define difficult diseases processes such as axial back pain. Once identifying sub-population, it is then hopeful that we can modify treatment algorithms. In the future, by identifying specific sub-classifications, future medications and treatment algorithms may be specifically chosen to maximize clinical outcomes. Additionally, DNA analysis could identify which medications could target specific patients’ exact genetic defect most precisely.

The ability to image the spinal cord parenchyma with MRI and CT imaging has enhanced our ability to treat patients. For example, in spinal cord injuries (SCI), the visualization of edema over multiple segments or hemorrhage has been shown to correlate with worse clinical outcomes. However, these modalities are only the beginning in terms of intraparenchymal imaging. Presently, the use of other modalities such as diffusion transfer imaging (DTI) is rapidly expanding. Further, DTI can provide information on neuronal tracts and may serve as an exceptional prognostic tool. This information may allow us to identify which patients will benefit from surgical decompressions and to what extent for cervical spondylotic myelopathy and spinal cord injury (SCI). In addition, these tools are being targeted to differentiate electrolyte and neurotransmitter levels in the parenchyma may spur significant improvement in our research and understanding of the pathophysiology of both acute and chronic SCI. Noninvasive imaging technology will also provide improved insight into spinal disc pathology, such as a better understanding of the degenerative disc cascade. These identified factors may delineate the etiology of axial low back pain and then better treatment algorithms can be employed.

One recent advance in the diagnosis of spinal disease has been through the use of imaging which appeared to be on its way out. Many centers, as they transitioned into digital imaging technology, eliminated the use of 36-inch cassette or scoliosis films. However, it has become apparent we need to globally assess the spinal patient rather than only focusing on one specific region. For example, the use of Harrington rods corrected the patient’s coronal deformities but through distraction and no rotation, this resulted in a population of patients with “flat back syndrome.” This problem was not fully appreciated until the importance of sagittal balance was established. Further understanding of sagittal balance, particularly in the lumbar spine, has illustrated that not only is the spine important but so too are pelvic parameters. Pelvic incidence, pelvic tilt and sacral tilt are only three newer terms in the neurosurgical armament to understand spinal deformities.

Surgical interventions and procedures will become less invasive and more targeted as we define etiologies better. Using an improved understanding of pathophysiology, define pain generators as well as target specific regions will allow surgeons to further direct therapies. It is therefore conceivable with the use of improved image guidance and real-time operative imaging, which is already present in several centers we will be able to provide more focused and earlier treatment. In the future, through collaborations with our colleagues in other fields, we will be able to identify patients’ diseases earlier, treat them quicker with a higher efficiency, and most importantly improving their quality of life to the highest degree.
FUTURE THERAPIES FOR THE PATIENT WITH A BRAIN TUMOR

Harvey Cushing gives a contemporary appraisal of the state of neurosurgery in his 1905 Johns Hopkins Hospital bulletin on the special field of neurological surgery. The first of multiple such bulletins, he describes the fear and trepidation with which most patients and their physicians regard the operating room at the turn of the 20th century. He goes on to report that the neurological clinic “stands largely on the therapeutic tripod of iodine, bromine and electricity.” Importantly, Dr. Cushing also offers a rationale for the practice of neurosurgery and a vision of the neurosurgeon’s role in the treatment of neurological disease going forward. There have been incredible advancements made in the field of neurological surgery, many of which have been outlined in our previous article (pages 11-12). Indeed, much of Dr. Cushing’s writing has proved prescient in our time. While we do not presume to write with as much clairvoyance as Dr. Cushing, we likewise endeavor to focus on where the future of neurological surgery lies in the coming decades.

Of foremost import to the future treatment of the patient with a brain tumor is the paradigm shift involving the concept of brain tumor treatment itself. The era in which a patient receives a standardized “one-size-fits-all” series of treatments for the pathologic diagnosis of a brain tumor is fading and movement towards an individualized cancer therapy paradigm is already underway. For example, the complexities of glioblastoma (GBM) molecular biology continue to be elucidated. The results of recent work related to The Cancer Genome Atlas (TCGA) demonstrate that GBM is not a homogenous entity and that it may, in fact, be comprised of subgroups based on gene and protein expression profiles which portend differing responses to treatment and ultimately different prognoses. Likewise, the development of tools that allow for the unlocking of the distinctive molecular characteristics of each brain tumor seen in clinic and in the operating room is currently underway, thus opening the door for truly personalized treatment in the coming years. With more informed, targeted mining of tumor banks across the country, including ours at Henry Ford, and in collaboration with integrated consortia such as the National Cancer Institute’s (NCI) Rembrandt and TGCA undertakings, a more comprehensive understanding of the genetics of brain tumor biology will result, eventually allowing for manipulation of currently unknown molecular targets to minimize brain tumor growth and invasion and maximize response to treatment.

Currently, treatment is guided by the known molecular susceptibilities of GBM to alkylating agents in the presence of epigenetic silencing of the O6-methylguanine-DNA methyltransferase (MGMT) DNA-repair gene. Similarly, the loss of heterozygosity at locus 1p19q (LOH 1p19q) in oligodendroglioma seems to correlate with more normal differentiation of tumor tissue and therefore a better prognosis than tumor tissue expressing an abundance of epidermal growth factor receptor (EGFR). Recent studies show that brain tumors often release genetic material, including RNA, as well as other proteins designed to alter the tumor’s local biochemical milieu in favor of tumor proliferation and invasion. This material is released in the form of exosomes, which are small membrane-bound sacs that can penetrate the blood-brain barrier and leak into the systemic circulation in quantities sufficient for detection by blood test. Imagine that by analyzing exosomal contents, a genetic profile of an individual’s brain tumor may be generated akin to a genetic brain tumor fingerprint utilizing a simple blood test in the neurosurgery clinic. This brain tumor fingerprint may then be matched to a specific treatment validated with the help of the aforementioned tumor banks and databases.

There are a variety of studies recently completed or currently in progress which will have important clinical implications over the next 5-10 years. These include work conducted at the National Cancer Institute Clinical Proteomics Program which involves biopsy of a patient’s brain tumor after which the specimen undergoes microdissection followed by gene and protein analysis via microarray, from which a patient/tumor-specific profile is created. Specific patient data can be cross-referenced to the ever-growing and increasingly available tumor bank and genomic data to select an individualized therapy for the patient. Additionally, studies being conducted at our own institution indicate that it is possible...
to obtain brain tumor biopsy material and, via the development of a highly specialized tissue culture technique, process it so as to form enriched undifferentiated neural cancer stem cell spheres in tissue culture. This is an elegant modification of the clonogenic assay which is designed to specifically target the progenitor or source tumor cell for therapeutic intervention. This *in vivo* neurosphere culture biochamber technique is capable of mimicking many known molecular tumor subtypes; cancer cells can be subjected to rapid throughput testing to determine which treatment modalities would be most beneficial for that particular patient/tumor without having years of delay in animal models. This information may be translatable to our practice in the near future for further treatment of patients in this highly individualized manner.

Surgical adjuncts in the form of improved surgical technology and ultra-specific advanced imaging modalities continue to evolve and will continue to do so at an increasingly fast pace in the future. These advancements are designed to better identify and eliminate abnormal tissue intra-operatively. More recently, high field intra-operative MRI (iMRI) suites—of which there are now roughly 42 worldwide—are enabling surgeons to achieve a better real-time understanding of the extent of tumor resection. iMRI, in conjunction with other surgical adjuncts like Cryo- or Laser-Heat ablation may lend themselves exceptionally well to the stereotactic and minimally invasivetreatment of spherical, well-circumscribed tumors potentially obviating the need for radiation in the treatment of some lesions. A multicenter clinical trial underway in 2011 examining the utilization of intra-operative 5-Aminolevulinic Acid (ALA), which allows the surgeon to literally see areas of tumor under fluorescent microscopy during resection, could revolutionize the way brain tumors are removed and lead to improved outcomes. At present, Raman spectroscopy, a technology which can identify brain tumor cells in vivo according to their molecular polarization potential, is sensitive enough to distinguish between areas of normal brain, brain undergoing invasion by tumor cells and brain tumor when used as an intra-operative probe device. The long-term goal would be to integrate portable Raman spectroscopy with surgical robotics and medical imaging to create an automated, comprehensive device capable of scanning the area of interest, identifying and guiding itself to the lesion and then determining precisely where brain tumor and normal brain exist, subsequently leading to maximally safe, efficacious resection, or even automated targeted cancer cell destruction via focused ultrasound or other modalities. Additionally, there are studies underway at our institution and at other centers in North America utilizing a Controlled Active Gene Transfer Platform (CAGT) intra-operatively to deliver a therapeutic gene via retrovirus eventually leading to tumor cell death.

Taken together, it is possible that therapies may become generally less invasive over time as more efficacious treatment regimens are discovered, however, much as Dr. Cushing observed in his 1905 bulletin on the *special field of neurosurgery*, there will always be a need for the neurosurgeon in the process of brain tumor management. Currently neurosurgeons perform more traditional procedures such as brain tumor resection for biopsy or decompression of mass effect upon the brain. Likely in the coming decades neurosurgeons will begin to operate on the patient with a brain tumor in order to inject tumoricidal viral therapy, perform stereotactic thermal ablation of formerly inoperable tumors and carry out more complete Raman-guided tumor resections. The discipline of neurosurgery is indeed a special field, one whose rate of progress continues to increase as we go forward and whose next 25 years represent an exciting time filled with hope for practitioners and their patients.
FUTURE OUTLOOK OF CEREBROVASCULAR NEUROSURGERY

Cerebrovascular neurosurgery has experienced a remarkable transformation over the last few decades. The invention of the detachable coil by Gugliemi in the 1990s was a transformative turning point in neurosurgery. From this humble beginning we have witnessed remarkable advancements in endovascular devices and techniques. Concurrently, improvements in operative microscopes and both pre- and intra-operative imaging techniques have made open cerebrovascular procedures safer. There is no question that cerebrovascular neurosurgery will realize significant and important changes during the years to come. This article will address the future of cerebrovascular neurosurgery as we see it.

The Next Five Years
More than any other area, endovascular neurosurgery will be the setting for considerable innovation and progress. Currently, flow diverter stents that reconstruct the parent vessel but preserve perforator flow are revolutionizing the management of difficult-to-treat, wide-necked aneurysms. As these devices mature, with a second-generation design to be released in the next few years, we are likely to see expansion of their use to other settings and aneurysm locations. Intermediate-porosity and retrievable stents are currently being developed that will provide further options in stent-assisted aneurysm coiling. Other coil-assist devices and completely new intra-saccular flow diverters, such as those utilizing intra-aneurysmal mesh and neck-bridging devices, will provide alternate means of treating complex aneurysms. Enhancements in coil and other embolic technologies will afford increased aneurysm occlusion and reduced need for re-treatment. Intravascular ultrasound is being studied as a means of better understanding the local vascular anatomy, and the results after treatment, during complex endovascular procedures.

The endovascular treatment of stroke will change the treatment paradigm through which patients presenting with acute stroke are managed. Two randomized controlled trials are currently underway comparing acute endovascular intervention to best medical management. Further device innovation in mechanical thrombectomy, particularly with retrievable stents, will improve vessel recanalization and outcome after intervention.

Advancements in angiographic imaging will include holographic 3-dimensional imaging which will transform the modern angiography suite where the surgeon will have added dimensions in the visualization of a patient’s angioarchitecture. The further development of hybrid OR-angiography suites and MR-angiography suites will facilitate the surgeon to perform multi-modality treatment in one setting, or multi-modality imaging during treatment, for example for the treatment of acute stroke.

The search for better and earlier diagnosis of cerebral ischemic injury will identify biomarkers which will signal impending vasospasm after subarachnoid hemorrhage or ischemia requiring revascularization. Clinical trials with new vaso-dilating or neuroprotectant drugs will hopefully produce better medical treatment to prevent or protect against ischemic injury from vasospasm.

Open surgery for cerebrovascular diseases will see refinements in intra-operative imaging, most notably the use of video ICG. Quantitative flow measurement devices will enhance the diagnosis and management of steno-occlusive diseases. New vascular bypass devices and techniques, such as vessel staplers will improve bypass times and reduce peri-operative stroke risk.

On the Horizon
In the decades that follow, cerebrovascular neurosurgery will continue to evolve in the direction of minimally-invasive techniques with an emphasis on disease prevention. Enhanced endovascular devices, imaging, and improvements in nanotechnology will lead to most cerebrovascular disorders being treated via endovascular or endoscopic techniques, obviating the need for open craniotomy. This will likely include endovascular arterial bypass and diseased vessel modification or reconstruction, as well as intra-arterial tumor therapies or endovascular tumor resection. Magnetic (or novel) imaging-guidance will obviate the need for radiation-based endovascular imaging. Biologic therapies such as stem-cells to treat stroke or other vascular diseases will be utilized as vascular regenerative medicine. Endovascular devices such as stents will be designed to recruit circulating progenitor cells to endothelialize the material’s surface to regenerate the vessel wall. Preventive medicine will substantially reduce risk factors for stroke with pharmacologic targeting of genetic factors associated with the development of atherosclerotic plaques or cerebral aneurysms. Microsurgical nanotechnology will be used to minimize surgical morbidity for those procedures still requiring open surgical or endoscopic treatment.

An Exciting Time
Cerebrovascular neurosurgical devices and techniques will continue to progress and refine at an exciting speed. Although improvements in the endovascular treatment of aneurysms and stroke will be the focus of the next five years, innovation in vascular imaging, minimally-invasive therapies and preventive medicine will define the decades that follow. We are still in the midst of a cerebrovascular Renaissance — a period of significant progress, innovation and discovery — that will have immeasurable impact on the way we treat neurological disorders in the future. It is truly an exciting time to be a cerebrovascular neurosurgeon.
FUTURE OUTLOOK FOR PERIPHERAL NERVE SURGERY: IMPROVING CLINICAL OUTCOMES VIA INTERDISCIPLINARY COLLABORATIONS

For treatment of peripheral nerve injuries, surgeons made great advancements in the 20th century by improving operative techniques. In the 21st century, we expect that nerve surgeons will collaborate within the interdisciplinary clinical and basic science programs to encourage creativity and innovation to improve the overall functional recovery of the patient after peripheral nerve injury.

Collaboration Among Clinical Specialists Improves Recovery

Current peripheral nerve surgery derives its rich history from individual pioneers including neurosurgeons, orthopedic surgeons, plastic surgeons, pain specialists, physiatrists, and therapists. Recently, collaboration among these specialists led to novel strategies and techniques to maximize recovery of function. Conditions once thought to be unrecoverable — e.g., flail arm (brachial plexus palsy) or actual loss of the arm (amputation) — are now plausible targets for interdisciplinary clinical efforts.

Brachial plexus palsy is a dramatic condition resulting in sudden loss of arm function. Often associated with motor vehicle injury in young adults, recovery is typically poor, resulting in lifelong disability and economic loss.

Figure 1a. Perinatal brachial plexus palsy: note the immobile left arm and shoulder.

Figure 1b. Clinical structure of interdisciplinary brachial plexus program.

Forty years ago, brachial plexus surgery was shunned, and presentations regarding surgical nerve repair to major medical societies were met with disdain. However, the number of patients suffering brachial plexus lesions continued to increase, stimulating Dr. David Kline to pioneer the concept of nerve or brachial plexus repair assisted by intraoperative electrophysiological monitoring. Significant
improvement in functional outcomes ensued, inspiring a new generation of surgeons to pursue alternately effective strategies (e.g., nerve transfers) to treat patients of all ages dealing with devastating brachial plexus palsy.

When brachial plexus palsy occurs in the perinatal period (Figure 1a), it is particularly stark. Only in the last 20-25 years has significant progress been made. The strategy to maximize functional recovery has evolved from isolated nerve surgery to planned interdisciplinary care (Figure 1b); nerve repair or transfer followed by therapy and rehabilitation, and then secondary procedures such as joint stabilization, tendon or free-muscle transfers, when needed.

Not uncommonly, vascular injury accompanies a brachial plexus/peripheral nerve lesion (<≈30%), and diagnosis and treatment become more complex with a poorer prognosis. Early collaboration between vascular and nerve surgeons improves functional outcomes for this complex injury, approaching those of isolated nerve injury.

The extreme case of nerve palsy is the amputation injury. Highly innovative engineers and physicians have applied nerve surgery to achieve impressive multifunctional agility of the artificial arm (Figure 2). Surgeons create new surface electromyogram signals by moving residual arm nerves to available muscles. Targeted muscle reinnervation regains access to the neural-control mechanism and significantly improves dexterity of the prosthetic arm.

Clinical collaborations have improved functional outcomes, as surgical techniques are approaching the limits of human dexterity. Further refinement of nerve surgery will depend upon translating basic neuroscience into clinical application.

Applying Laboratory Neuroscience to the Clinic

Peripheral nerve regeneration is complex. Nerve trauma separates the cell body from the axon, inhibiting movement and sensation. Functional recovery must include 1) survival of the injured neuron, 2) axonal outgrowth while overcoming inhibitory influences, 3) elongation along permissive pathways, and 4) targeting to the appropriate muscle/end organ. This stepwise concept seems deceptively simple, yet recovering normal limb function remains a challenging chronic problem, but potential solutions are emerging.¹ Current interdisciplinary efforts merging information technology and neuroscientific concepts are being championed by the United Kingdom Medical Research Council, United States Armed Forces Institute of Regenerative Medicine, and major national neuroscience centers.

Clinicians and basic scientists are approaching a solution for bridging gaps in nerve continuity. The repair of injured nerves necessitates the use of nerve autografts, but the number of available autografts is limited by donor site morbidity. Biomedical engineers are offering bioresorbable tubes and bioartificial grafts to improve the likelihood and speed of nerve regeneration. Scientists facilitate the initiation of peripheral nerve allografts into the operating room with immunosuppressive advances.² Artificial grafts are particularly valuable in the perinatal brachial plexus palsy patient, as use of nerve autograft leaves scars on the baby’s leg, even with improved harvesting techniques.

Nerve regeneration with or without graft requires the proximal nerve segment to extend and elongate its axon after Wallerian degeneration occurs in the distal segment. Time and distance are critical factors affecting the irreversible degeneration of the target muscle. Regeneration is slow 1 mm per day, often with further delays in axonal outgrowth. Biophysical principles encouraged the application of electrical stimulation in animal models. The time needed for regenerating motor axons to cross the injury site was reduced and the accuracy of regeneration was increased as motor axons preferentially reinnervated motor, not sensory, pathways. Translation by applying electrical stimulation in the immediate postoperative period in humans with severe carpal tunnel syndrome demonstrated significantly improved manual dexterity.

Analogous basic science and clinical concepts underlying peripheral nerve regeneration have been applied to spinal cord regeneration research, e.g., peripheral nerve graft to repair injured spinal cord (Figure 3a,b) or nerve transfer of intercostal nerves to cauda
equine to bypass thoracic spinal cord injury. However, a major difference lies in the inhibitory influences that exist in the central nervous system environment; inhibitory molecules like chondroitin sulfate proteoglycans and myelin-associated glycoprotein represent significant barriers for axons to regrow into or out of the spinal cord. Therefore, current research aims to develop potential pharmacological interventions that render the injured neuron’s environment more permissive for regeneration, like chondroitinase ABC or sialidase. The combination of surgical and pharmacological treatment underlies future treatment of peripheral and central nervous system injury.

The reciprocal contributions of the clinic to basic science are no less significant. Classical teaching denies plasticity of the adult brain and insists that mapping of a body part on the brain cortex is firmly established. Clinical observations in patients who have undergone nerve transfers (e.g., use of intercostal nerves to innervate the biceps muscle) and nerve repairs indicate that the brain has an unexpected capacity for functional reorganization. Refutation of fixed cortical functional localization has revived investigations into neural plasticity in the laboratory. Translation of newly discovered scientific phenomena to the clinics will improve functional recovery after nervous system injury.

**Conclusions**

Nerve surgeons in the 21st century have a unique opportunity to engineer interdisciplinary collaborations with other medical specialists and neuroscientists. The focus for treating nerve palsies has shifted away from the isolated optimization of nerve surgery techniques to comprehensive function of the affected patient. We must continue to challenge long-held beliefs to discover novel neuroscientific concepts and the power of combined expertise to improve outcomes using an interdisciplinary approach to peripheral nerve surgery.

**References**

DEVELOPING TRENDS IN PEDIATRIC NEUROSURGERY

Introduction

This article is designed to stimulate discussion on topics in pediatric neurosurgery that may alter how we practice and transform the field. While there is not space to include all of the ideas of my respected colleagues, it is hoped that consolidating some of their collective foresight here will serve to make us better aware of developments. Broadly speaking, three major spheres of influence – clinical technologies/techniques, research advances and socioeconomic forces.

Clinical Technologies and Techniques

Twenty years ago, pediatric neurosurgery was interested in technologies and techniques that could directly impact patient care, and that focus remains today. In the operating room, major efforts are underway to improve visualizing pathology and navigating safely through the central nervous system (CNS). Of particular interest is the potential to combine novel forms of functional imaging – such as tumor specific fluorescent dyes or MRI tractography. Exciting advances in neuroendoscopy, such as 3D cameras and smaller, more flexible tools will expand the range of “traditional” endoscope-based intraventricular surgery to potentially include skull base approaches, Chiari operations and spinal cord interventions, such as percutaneous release of tethered cords. (Figure 1) Ongoing work through the use of surgical robots – with particular utility for multi-articulated “snakes” that can safely move within narrow spaces without flexing and compressing adjacent structures.

Pediatric neurosurgeons will also deliver new treatments to the CNS. For example, delivering stem cell and gene therapies to children and also administering novel therapeutics, such as focused ultrasound for tumors and biosynthetic constructs for synostosis and spine disorders. Perhaps the most pediatric neurosurgeon-dependent therapy - and most immediate window to the future - is prenatal surgery for CNS disease.

While use of this approach remains controversial, the related process of obtaining imaging during pregnancy foreshadows the much larger issue of improved diagnostic technologies yielding unexpected incidental findings. Advances in imaging, coupled with increased utilization, will undoubtedly force pediatric neurosurgeons to develop management strategies for dealing with patients who discover CNS lesions.

Research Advances

Neuroimaging serves as an example of a field that bridges the gap between research and clinical application. Pediatrics stands to benefit from novel methods to visualize and understand the developing CNS. Non-invasive CSF flow analysis, assessment of ventricular shunt patency, localization of functional neural tissue and delineation of complex developmental anomalies are ongoing areas of study that will substantively impact our field. Perhaps more exciting is the nascent development of new methodologies to test for the presence of disease and guide therapy based on molecular and genetic signatures, complementing existing anatomic-based imaging technology in a completely unique way. Future applications may include replacing traditional histologic assessment of tumors with genetic “fingerprints” to more accurately predict phenotype and guide therapy. In addition, the advent of non-invasive biomarkers – as may be found in the urine or saliva - may facilitate earlier detection of CNS disease, including tumors, stroke and traumatic brain injury, while also enabling cost-savings and delivery of patient-specific “tailored” treatments. (Figure 2)

With intensifying demand for clinical productivity and cost constraints (see below), pediatric neurosurgeons face increasing impediments to meaningfully contribute to scientific advances necessary to our field. While no single “cureall” for these problems exists, the combination of efforts nationally by organized pediatric neurosurgery, coupled with individual institutions considering a “hybrid” model of pairing a neurosurgeon with a more established laboratory (as opposed to having neurosurgeons start unmentored, with limited resources) may work to mitigate current socioeconomic forces pulling neurosurgeons away from research.

Socioeconomic Forces

All of neurosurgery is – and will continue to be – irrevocably changed by the influence of myriad socioeconomic forces. The current debate over universal insurance coverage, accountable care and quality-based medicine has impacted the practice of physicians nationwide. Pediatric neurosurgeons will be required to participate in quality measures, justify clinical decision-making and costs. These pressures, added to existing perceived concerns about malpractice in the pediatric population, will likely conspire to drive increasing consolidation of pediatric neurological practice to fewer centers, as smaller hospitals and individuals become unable or unwilling to shoulder the financial and regulatory burdens of maintaining pediatric neurosurgical practitioners. Ultimately, this may result in increasing subspecialization among pediatric neurosurgeons, increased use of “physician extenders” and a rise in the adoption of telemedicine.

The revolutionary influence of communication technology and social media will be transformative to pediatric neurosurgery. Increasing demands for physician accessibility – and ac-
countability – will drive secure e-mail, Facebook-like referral tools for patients and creation of new ways for surgeons to document and be reasonably compensated for complying with these new demands on one’s time.

From these negative forces, a number of positive changes are likely to occur. The need for evidence-based medicine will stimulate cooperative, multicenter studies nationally. Access to information on the internet will facilitate engagement with the rest of the world in ways not previously possible – increasing the role for pediatric neurosurgeons to educate and treat globally, especially in third-world countries. Subspecialization may produce “transitional care” neurosurgeons, providing unprecedented continuity of care from childhood to adult.

**Conclusions**

Pediatric neurosurgery – as always – exists in a period replete with challenges and unique opportunities. While many advances will come from individuals, larger efforts can be directed by organized neurosurgery. The smaller size, specific focus and collaborative nature of pediatric neurosurgery affords it the opportunity to serve as the vanguard for all of organized neurosurgery in many areas. The pediatric section leadership has already done a laudable job “leading from the front” and can continue to do so with emphasis on:

1) Fostering collaborative research efforts nationally
2) Encouraging physician involvement in the development of quality metrics
3) Focusing on leveraging social media in new ways to benefit patients and surgeons alike

Like any forecast, there is always a chance that the predictions about its future here may not come to pass. However, unlike the weather – which cannot be changed by the weatherman – the future of pediatric neurosurgery can be shaped by those who participate in its growth. Together, pediatric neurosurgeons can choose to actively craft the best possible future for our field.

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**Figure 1. Endoscopic Transsphenoidal Resection of Craniopharyngioma**

Advances in imaging, navigation and intraoperative tools facilitate surgical access to lesions in ways not previously possible. The ability to remove a craniopharyngioma using transsphenoidal endoscopy in a small child is an example of convergence of these technologies – all of which are likely to improve in the near future. In this figure, the top and bottom left hand images demonstrate the lesion (red arrow) on MRI and CT, respectively. On the right, an intraoperative photograph reveals the right and left optic nerves (black arrows), as seen from below using the endoscope following resection.

**Figure 2. Urinary Biomarkers**

Increasing demand for accurate, non-invasive and novel methods of disease detection will become more prevalent in pediatric neurosurgery. Here is an example of the use of biomarkers to identify the presence – and subsequent response to therapy (surgical resection) – non-invasively, by simply performing a urine test. Image A is a zymogram, a gel that tests for the presence of specific biomarker activity as evidenced by bands. Note the presence of activity on the preop lane, and subsequent clearance when the tumor has been removed on the postop lane. Image B shows representative pre- and 1 year postop axial MRI images, demonstrating interval resection of a cerebellar tumor. The right hand graph represents the high sensitivity and specificity for this urine test to detect brain tumor presence when compared to healthy, matched control patients.
THE FUTURE OF TRAUMATIC BRAIN INJURY: NO CURE FOR RETROGRADE AMNESIA

In the not so distant future ...

The paramedic sighs as he reaches the base of the ski lift. As billed, teenage male skier crashed head first into a tree. The paramedic slips a silver helmet over the unconscious patient’s head, straps on wrist and ankle monitoring bracelets, and starts an intravenous (IV) line. An emergency department (ED) doctor monitors from 150 miles away.

This silver helmet was designed for the diagnoses and treatment of the acute deleterious effects of traumatic brain injury (TBI) (Figure 1, Table 1). First, the helmet non-invasively assesses the patient by scanning with infrared, computed tomography and magnetic resonance imaging modalities. This gives basic physiologic parameters (e.g., brain tissue oxygenation) and diagnostic brain images.

The ED doctor notes a dilated, non-reactive right pupil and large right temporal epidural hematoma (EDH). The decision is made to deploy transcranial microcatheters. She circles the EDH with her finger and hits the return key.

Several hundred telescoping microcatheters

Table 1. Capabilities of futuristic TBI helmet.

**Instruments**
- Light source for pupillary response
- Infrared light emitter and detector (pulse oximetry for the head)
- Ultrasound, assist lysis of life-threatening hematoma
- Magnetic resonance imaging, complete with DTI and perfusion technology
- Rapid cooling of carotid arteries
- Implantable microcatheters for ICP measurement, EEG, drug delivery and/or removal of clot
- Nanoparticles for drug delivery, clot scaffolding and instrument making

**Non-invasive monitoring**
- Cerebral oxygenation and blood flow
- Coagulation cascade
- Non-invasive EEG
- Inferred ICP

**Invasive monitoring**
- Microdialysis sampling
- Biomarkers, serum, CSF, brain tissue
- Coagulation cascade
- Intracranial pressure

**Therapeutic interventions:**
- Administration of brain protective drugs
- Treatment of life threatening hematomas (EDH, SDH, IPH)
- MRI/US/CT guidance of nanoparticles for hemorrhage

**Key:** EDH = epidural hematoma; SDH = subdural hematoma; IPH = intraparenchymal hemorrhage; MRI = magnetic resonance imaging; US = ultrasound; CT = computed tomography; ICP = intracranial pressure; EEG = electroencephalogram
are housed within the inner lining of the helmet. These can be advanced through the skull to specific targets for either monitoring and/or drug delivery. Housed within the tip of each microcatheter are sensors that give data ranging from tissue oxygenation to TBI biomarkers. Drug delivery can occur through one of the several catheter ports to locally correct coagulopathies, lyse blood clots, and provide therapies that promote a neuroprotective environment (e.g., drugs to sequester extracellular neurotransmitters to prevent excitatory neurotoxicity) (Table 1).

With the microcatheters in good position, the ED doctor delivers a lysing agent and watches in real time as the EDH is evacuated through the many microcatheter suction ports. The right pupil begins to react, but no improvement is seen in spontaneous limb movement as monitored by the wrist and ankle bracelets. Suddenly, the right temporal lobe shows spike and wave activity that quickly generalizes. Remotely, the ED doctor delivers an IV anti-seizure medication, as well as hyperpolarizes the right temporal lobe.

The microelectrode portion of the microcatheter allows for continuous electroencephalogram (EEG) to monitor for seizure, patient sedation, and brain activity before- and after-treatment maneuvers. Also, electrodes placed near the motor and sensory gyri in combination with the wrist/ankle bracelets provides for real time somatosensory and motor evoked potentials. Finally, the seizure focus can be hyperpolarized via locally placed microelectrodes.

The ED physician notes several real time laboratory studies that just went from “green” to “red.” The patient has an increase in the biomarker for delayed neurotransmitter excitotoxicity. Remotely, a nanoparticle-drug carrying agent to scavenge extracellular neurotransmitters is delivered.

Nanoparticle technology has resulted in small particle carriers that easily cross the blood brain barrier, and can be driven to brain targets by magnetic pulses and/or charged microelectrodes. By conjugating nanoparticles to various drugs, targeted delivery of agents can be delivered to injured brain. Thus, ensuring correct drug delivery in time and space.

The paramedic slowly drives back down the mountain with the injured skier, wondering when the new iUniverse teleportation system will be on line.

The iUniverse teleportation system will not only allow the injured to be teleported from accident to the hospital, but upon rematerialization the patient will be in a pre-accident body state. Since teleportation rematerialization returns patient’s to their last archived whole body scan, hospitalization admissions are for reorienting people to current affairs. Unfortunately, this iUniverse future does not hold a cure for TBI associated retrograde amnesia.

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INSIDE THE CNS

NEUROSURGERY® IN 2012

The Neurosurgery® Editorial Office regularly summarizes and reviews its initiatives in the form of committee reports and editorials published in Neurosurgery®. Hopefully, this brief will provide a snapshot of the current state of the journal, as well as an introduction to some of the exciting initiatives that are underway.

Review Process
The Journal’s online submission and review system, Editorial Manager, provides ample data on key points within the review process. Internally, we analyze the review process in order to better understand where the journal is succeeding or falling short in providing authors the most attractive forum for their work.

The number of submissions to Neurosurgery® has continuously grown annually since its inception—from 1,202 submissions in 2004 to 1,805 submission in 2011—a 50% increase over seven years. Even with the escalating burden on the review process, the average time from initial submission to first decision has dropped, from a high of 90 days in 2004 to a low of 35 days in 2011. There is still significant work to be done to achieve our stated goal of an average initial submission to first decision time of 28 days; however, the review process is under constant evaluation, and each change implemented, no matter how minor, moves the needle in the right direction.

In early 2011, an article took about two months to appear online following acceptance. Working with our publisher, Lippincott Williams and Wilkins (LWW), an article is now online, indexed in PubMed, and citable on average within 23 days of acceptance. This aggressive Publish-Ahead-of-Print schedule has been a tremendous boon to authors, for whom online indexing has become the official starting point of publication, rather than the appearance of an article in print.

The time for an accepted article to appear in print has also dropped considerably. The production time required for any article means that the minimum time from acceptance to print is rarely going to be less than 90 days. Realistically, the goal would be for an article to appear in print within 120 days of acceptance. In May 2010, the average time from acceptance to print was 204 days. By the February 2012 issue, that number had dropped to 142 days, an almost two month improvement. We expect to see this number continue to shrink over the course of 2012.

Education
The Journal has introduced two strategies that seek to better connect Neurosurgery® content with CNS educational initiatives. Firstly, free articles online are now linked to corresponding content available in the CNS University of Neurosurgery (http://univ.cns.org). Look for the “CNSU” button on Neurosurgery Online articles at www.neurosurgery-online.com.

Secondly, selected articles in Neurosurgery® are now linked to SANS questions, offering readers the opportunity to earn up to 6 hours of CME credit annually. For more information, please visit the SANS website at http://sans.cns.org. CME articles are identified in the print Table of Contents and on the article’s title page, while online articles are tagged with a “CME” button.

Journal Club
Neurosurgery® is pleased to announce the introduction of an exciting new feature—Journal Club common to all neurosurgical training programs, where resident and fellows critically review published articles under the guidance of faculty.

The specific aims of this new feature are to foster the education of residents and fellows and provide an enhanced opportunity for the next generation of reviewers to hone their skills, and publish the best scholarly reviews by neurosurgical residents/fellows based on top-ranked articles recently published in Neurosurgery®.

Quarterly, the best Journal Club review, adjudged by our dedicated Journal Club Review Panel, will be published in the print edition of Neurosurgery®, and the “winning” program and institution will be prominently highlighted in the Table of Contents. The four runner-up reviews will be featured online.

iPad Application
According to a May 2011 survey performed by LWW, 30% of physicians were using iPads, and a further 28% planned to purchase an iPad within the next 6 months. For 2011, the iPad accounted for 72% of mobile traffic to Neurosurgery Online. With these numbers in mind and the adoption of the iPad showing no signs of slowing, Neurosurgery® launched a dedicated iPad application in February 2012.

The Neurosurgery® iPad application allows for the downloading of entire issues, and the ability to read them offline at your leisure. In addition, the iPad application issues contain all supplemental digital content, including video files, as well as social media connectivity and archiving. The application is free from the Apple iTunes Store, and to date has been downloaded over 5,000 times.

Finally, Neurosurgery® extends its gratitude to those members of our professional community who contribute their time and energy to both submitting and reviewing for the Journal. In 2011, authors representing 62 countries chose to submit their work to Neurosurgery®, with reviews being performed by more than 1,500 reviewers. Without these efforts, the journal would not exist in any form, let alone its current successful iteration.
Neurosurgery® is pleased to announce the introduction of an exciting new feature: Journal Club. This feature will capitalize on and extend the existing practice of Journal Club common to all neurosurgical training programs where resident and fellows critically review published articles under the guidance of faculty.

The specific aims of this new feature are to:

1. Foster the education of residents and fellows and provide an enhanced opportunity for the next generation of reviewers to hone their skills.

2. Publish the best scholarly reviews by neurosurgical residents/fellows based on top-ranked articles recently published in Neurosurgery.

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Eligibility
Current neurosurgery residents and fellows in any Neurosurgery ACGME-accredited program may contribute to Journal Club reviews. We particularly encourage submissions that reflect the participatory nature of the traditional journal club setting familiar to all programs. Thus, faculty guidance and participation are appropriate, but the work must be done by the resident/fellows.

Authors of Journal Club submissions may not be from the same institution or have any real or apparent conflict of interest with the authors of the Journal Club article being reviewed. Journal Club articles are chosen from among the top-downloaded Neurosurgery articles of the previous calendar quarter. Programs will be notified by email and on the journal website of upcoming articles selected for Journal Club review 3 months ahead of the deadline for submission for competitive review.

Format
To maintain uniformity and for ease of adjudication, we have outlined a strict format. Comments must be accurate, well reasoned, and scholarly.

Journal Club commentaries must include all 11 main components:
- Significance/context and importance of the study
- Originality of the work
- Appropriateness of the study design or experimental approach
- Adequacy of experimental techniques
- Soundness of conclusions and interpretation
- Relevance of discussion
- Clarity of writing, strength and organization of the paper
- Economy of words
- Relevance, accuracy and completeness of bibliography
- Number and quality of figures, tables and illustrations
- Future/next steps

Journal Club submissions should provide a thoughtful critical review of the elements in the article, rather than simply rehashing the paper, and should focus on the most important results. Submissions are limited to 2,000 words with no more than five references. Authors should follow the accepted style of Neurosurgery®, as defined by the Instructions for Authors.

To submit your program’s Journal Club article, please visit the Neurosurgery Online Manuscript Submission web site at http://www.editorialmanager.com/neu

For any other questions, please contact the Editorial Office at 404.712.5930.

I hope that you will participate regularly in this feature.
The CNS/AANS Washington Office continues to be extremely busy on a number of advocacy fronts. Recently we have made progress on several issues critical to neurosurgeons and their patients.

U.S. House of Representatives Repeals IPAB, Adopts Medical Liability Reform

On March 22, 2012, the U.S. House of Representatives passed legislation to repeal the Independent Payment Advisory Board (IPAB) and adopt meaningful medical liability reform. The Protecting Access to Healthcare Act (H.R. 5) passed by a vote of 223-181, with seven Democrats joining their Republican colleagues in voting in favor of the amendment. Four republicans joined 153 democrats in opposing the amendment, one member voted “present” and 22 did not vote.

Though efforts to pass these measures are stalled in the U.S. Senate, the House continues to explore additional strategies for moving federal medical liability reform legislation forward. On April 25, 2012, both the House Judiciary and House Energy and Commerce Committees passed versions of medical liability reform as part of the budget reconciliation process. The CNS and CNS continue to work with the Health Coalition on Liability and Access (HCLA) on medical liability efforts. According to the Congressional Budget Office (CBO), these medical liability reforms will save the federal government $48.6 billion.

Medicare Care Cuts Loom — Contact Congress to Support Medicare Private Contracting

Physicians face Medicare payment cuts of 32 percent on Jan. 1, 2013, and patients are finding it increasingly difficult to see the physician of their choice. To help ameliorate this situation, the CNS and AANS are working to pass legislation to create a new Medicare option that will allow patients and physicians to enter into private contract arrangements without penalties to either party. The bills currently have over 32 cosponsors and support is growing so neurosurgeons are highly encouraged to contact Congress and urge your elected officials to cosponsor H.R. 1700 and S. 1042, the Medicare Patient Empowerment Act (MPEA), introduced by Rep. Tom Price (R-GA) and Sen. Lisa Murkowski (R-AK), respectively. To send an e-mail message to Congress, go to the CNS/AANS Legislative Action Center. We have created a draft letter that you can personalize. (This is highly encouraged.) In addition to sending a letter to Congress, please take a moment to visit the MyMedicare-MyChoice website, where you can add your name to a petition supporting the Medicare Patient Empowerment Act and obtain additional educational materials about the MPEA.

CMS Announces One-Year Delay of ICD-10 Coding System

On April 9, 2012, the Center for Medicare and Medicaid Services (CMS) announced a one-year delay for physicians to comply with the new ICD-10 diagnoses codes. The new deadline is Oct. 1, 2014. The CNS and AANS, along with other medical organizations, have repeatedly pointed out that the initial implementation deadline was not viable for many physicians, and we therefore support this delay. The one-year delay is proposed as part of a larger rule related to administration simplification provisions in the Patient Protection and Affordable Care Act (PPACA).

During the debate on the bill, several amendments were considered. Supported by the CNS and AANS, Reps. Charlie Dent (R-PA) and Pete Sessions (R-TX) offered an amendment that would address the crisis in access to emergency care by extending liability coverage to on-call and emergency room physicians under the Federal Tort Claims Act. This amendment passed by voice vote. In addition, Reps. Cliff Stearns (R-FL) and Jim Matheson (D-UT) offered an amendment to grant limited civil liability protections to health professionals that volunteer at federal declared disaster sites. The CNS and AANS also supported this amendment, which passed by a vote of 251-157. Twenty-seven democrats joined the republicans in voting in favor of the amendment. Four republicans joined 153 democrats in opposing the amendment, one member voted “present” and 22 did not vote.

Though efforts to pass these measures are stalled in the U.S. Senate, the House continues to explore additional strategies for moving federal medical liability reform legislation forward. On April 25, 2012, both the House Judiciary and House Energy and Commerce Committees passed versions of medical liability reform as part of the budget reconciliation process. The CNS and CNS continue to work with the Health Coalition on Liability and Access (HCLA) on medical liability efforts. According to the Congressional Budget Office (CBO), these medical liability reforms will save the federal government $48.6 billion.

Medicare Care Cuts Loom — Contact Congress to Support Medicare Private Contracting

Physicians face Medicare payment cuts of 32 percent on Jan. 1, 2013, and patients are finding it increasingly difficult to see the physician of their choice. To help ameliorate this situation, the CNS and AANS are working to pass legislation to create a new Medicare option that will allow patients and physicians to enter into private contract arrangements without penalties to either party. The bills currently have over 32 cosponsors and support is growing so neurosurgeons are highly encouraged to contact Congress and urge your elected officials to cosponsor H.R. 1700 and S. 1042, the Medicare Patient Empowerment Act (MPEA), introduced by Rep. Tom Price (R-GA) and Sen. Lisa Murkowski (R-AK), respectively. To send an e-mail message to Congress, go to the CNS/AANS Legislative Action Center. We have created a draft letter that you can personalize. (This is highly encouraged.) In addition to sending a letter to Congress, please take a moment to visit the MyMedicare-MyChoice website, where you can add your name to a petition supporting the Medicare Patient Empowerment Act and obtain additional educational materials about the MPEA.

CMS Announces One-Year Delay of ICD-10 Coding System

On April 9, 2012, the Center for Medicare and Medicaid Services (CMS) announced a one-year delay for physicians to comply with the new ICD-10 diagnoses codes. The new deadline is Oct. 1, 2014. The CNS and AANS, along with other medical organizations, have repeatedly pointed out that the initial implementation deadline was not viable for many physicians, and we therefore support this delay. The one-year delay is proposed as part of a larger rule related to administration simplification provisions in the Patient Protection and Affordable Care Act (PPACA).
Neurosurgery Asks CMS to Reconsider Timelines for Regulatory “Onslaught”

The CNS and AANS joined the American Medical Association (AMA) and others in sending a letter11 asking the Center for Medicare and Medicaid Services (CMS) to re-evaluate certain financial and regulatory timelines. The letter to the CMS Administrator highlighted our concerns about the budget-neutral value based payment modifier, e-prescribing penalties, Physicians Quality Reporting System (PQRS) penalties, electronic health record (EHR) incentive program and ICD-10 transition. The letter also urged CMS to use its discretionary authority provided by Congress under these programs and criticized CMS for back-date reporting requirements under the e-prescribing, EHR incentive program, and PQRS. The CMS proposals will penalize physicians based on activity that occurred prior to the year of the penalty specified by law. Furthermore, the letter emphasized that CMS needs to establish exemption categories to protect physicians facing hardship from penalties and provide a “strong appeals process” for all penalty programs.

CMS Releases Pilot Physician Resource Use Reports to Select States

The Centers for Medicare & Medicaid Services (CMS) recently released resource use reports to 20,000 physicians in Iowa, Kansas, Missouri and Nebraska. The reports provide individual physicians with their patients’ average healthcare costs and quality of care. They also show cost and quality comparisons with other physicians based on administrative claims measures and Physicians Quality Reporting System (PQRS) measures. The reports are part of the Physician Value-Based Payment Modifier program mandated by the Patient Protection and Affordable Care Act (PPACA), and Medicare payments made in 2015 will reflect the value adjustments based on care provided in 2013. By 2017, the program is expected to include most Medicare participating physicians.

Organized neurosurgery is interested in reviewing these reports, and if problems exist we will work with CMS to make the reports more transparent and valid. If you have downloaded a report or received a request to obtain a report, please contact Koryn Rubin, AANS/CNS Senior Manager of Quality Improvement at krubin@neurosurgery.org.

Give Our Online Advocacy a Boost: Follow @Neurosurgery on Twitter

In March, the AANS/CNS Washington Office launched its new Twitter handle, @Neurosurgery12. Since the launch, we have reached over 350,000 individuals on Twitter and garnered more than 200 followers. This outlet allows the AANS/CNS Washington Office to communicate health legislative updates, policy positions and provide links to positive stories about neurosurgery. In the near future, the AANS/CNS Washington Office will be launching its new blog, Neurosurgery Blog: More than Just Brain Surgery.

By entering the Twitter and blogospheres, organized neurosurgery will be able to actively engage in policy debates by reaching key Members of Congress, the media, other advocates and the general public to promote our advocacy message. We encourage you to follow @Neurosurgery and look forward to connecting with you online. If you are interested in these communications activities, please contact Alison Dye, AANS/CNS Senior Manager of Communications, at adye@neurosurgery.org.

For supplemental information on this article, please review the following links:

2. To see how your representative voted, visit http://clerk.house.gov/evs/2012/roll126.xml.
3. To see how your representative voted on this amendment, visit http://clerk.house.gov/evs/2012/roll124.xml.
39-year-old healthy Nepalese female presents with 1 day of severe headache, nausea, and vomiting. She underwent a CT head that demonstrated a left frontal horn lesion (Figure 1) and an MRI that demonstrated a lesion suspicious for intraventricular neurocysticercosis (Figure 2). The patient was brought to the OR for an interhemispheric, transcallosal approach for removal of the cyst (Figure 3). The unruptured cyst was removed (Figure 4) and pathology was consistent with neurocysticercosis.

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