2010 CNS Presidential Address Neurosurgical Pioneers: Foundation for Future Innovation

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This morning, I wish to briefly review with you the sputtering start of spine care and surgery dating back to ancient Egypt and Greece, through the Medieval period, up to the meteoric development occurring in the past few decades. Although a comprehensive review is not possible in such a short time, and although there are some well-known names I need to leave out, I would like to share with you some interesting highlights in the history of spine surgery. In recent decades, wise and forward-thinking leaders in neurosurgery realized the need to dramatically advance the education, training, and science of spine surgery. The technological advances have been astonishing. But the remarkable success of the past few decades has come with many problems, challenges, and roadblocks. Some pressures such as the federal government, the legal profession, the media, and even fellow physicians have been external. Many problems are internal, having been created by us. To ensure the continued success and development of the field of spine surgery, everyone in this room needs to accept important responsibilities as individuals.

Among the first medical writings ever discovered that describe the treatment of spinal disorders is an Egyptian papyrus from the mid-1800s BC.[1,2] This papyrus was acquired by a shady relics dealer named Edwin Smith (for which it is still named) and was ultimately translated by Henry Breasted in 1930. The papyrus presented 48 medical cases; 4 were related to brain and spine injuries. The Egyptians clearly understood the relationship between brain and spine injuries and their effect on the function of the body. Complete injuries were thought to be hopeless and were not treated. Incomplete injuries were treated with prostrate positioning and binding the area with fresh meat and then honey until recovery.

More than a thousand years later, the Alexandrian School was established in Greece. Cadaveric dissection and didactic teaching developed. War and other violent conflicts produced innumerable spine injuries. Hippocrates advocated treatment of incomplete injuries with rack and gravity reduction and sudden, violent ''jolting'' techniques known as ''succussion.'' If a patient was supine, a goat's bladder was filled with water and placed between the patient and the rack. External splinting was used to force spinal deformities into normal position. Actual surgery was rare. Hippocrates realized the relationship between spinal injury and paralysis and urinary retention.

The next great contributor to the advancement of spine care was Galen of Pergamon, who lived in the Roman era of Antonius Pius and Marcus Aurelius (129-200 AD). He was a forceful figure who adhered to the teachings of Hippocrates and the Alexandrian School. He was a physician to gladiators, so one can only imagine the horrific injuries he treated. Galen related the level of spinal cord injury with deficits. He was the first to use the terms scoliosis, lordosis, and kyphosis. He advocated surgery for traumatic bone fragments affecting the spine and brain. Infection was thought to be a sign of good healing, hence the term laudable pus.

Paul of Aegina was trained in the Alexandrian School in southeast Greece. He was the first to propose actual surgery on the injured spine. He wrote an epitome of 7 books that summarized Galen traditions and Greek medical thought. Known as a skillful surgeon, he performed trephination for the compressed spinal cord with removal of bone fragments. Paul of Aegina developed numerous instruments, including one called the ''red-hot'' iron. One can only imagine its use without adequate anesthesia.

After the fall of the Roman Empire, there were really no new ideas for a millennium. Avicenna of Baghdad was an important medical figure during the Arabic and Byzantine era, which lasted from 99 to 1037 AD. His works were translated into Latin. He emphasized bedside teaching. His greatest work, *Canon Medicinae*, contained a series of illustrations on how to reduce or stabilize a spinal injury with distraction. Overall, however, he had a hopeless outlook on spinal injuries and did not support the concept of surgical intervention.

There was a resurgence in spine surgery in the 1100s in Italy in the School of Salerno led by Roger of Salerno. Roger produced the first Italian surgical text, *Practice of Surgery* (a book later owned by neurosurgeon Harvey Cushing). This medieval textbook dominated the field throughout Europe. Later (in 1205-1298 AD) came Theodoric of Bologna and his

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textbook *Chiurgica de Theodoric.*[3,4] Theodoric outlined how to examine the spine-injured patient. He believed that pus hindered proper wound healing, and he promoted surgery using a wine-antiseptic method that contradicted Galen and Avicenna. This was considered very controversial, and Theodoric was vilified by his peers. This early concept of aseptic surgery was not valued until Lister in the early 1900s. To assist the patient in tolerating the surgery, a soporific sponge soaked with opium, wine, hemlock, flax, lapathum, and mulberry was applied to the patient's nostrils. Theodoric's practice of trying to realign fracture-dislocations by reduction and traction and to maintain correction with splinting is very similar to the management of spinal trauma today.

The field of spine surgery continued to languish well into the 19th century. Nearly 1500 years had gone by since Paul of Aegina introduced the role of laminectomy and removal of bone fragments, and surgery of the spine was still thought to be uniformly fatal. Scottish surgeon John Bell stated in 1820 that ''The cutting into a vertebra is a dream.'' His younger brother, Sir Charles Bell, also a physician, denounced laminectomy and the terrible pain it inflicted on the patient for only dismal results. Henry Cline performed what was called a trephination of the spine in 1814. He removed a fractured spinous process in a patient with complete paralysis and a thoracic fracture-dislocation. The patient promptly died. He was severely criticized by his colleagues, and Cline's case alone seemed to sound the death knell for spinal surgery for the remainder of the 19th century. A lack of adequate pain relief drove surgeons to operate as fast as possible. With hurried surgery, mistakes, poor techniques, bleeding, infection, and death, surgery of the spine was considered inhumane.

The acceleration phase of spine surgery appears to have begun with Percival Pott's experience with tuberculous paravertebral abscess, which was by far the most common primary source of spinal infection. In London, he reported good results debriding these spinal infections. Other developments added to the momentum such as Louis Pasteur's advances in bacteriology, Joseph Lister's concepts of antiseptic surgery, and Crawford Long's experience in Jefferson, Georgia, in 1842 using ether anesthesia. On December 22, 1895, the German physicist Wilhelm Roentgen took this first ''medical x-ray'' of his wife's hand, and anterior-posterior spine images soon followed.

American surgeon and pioneer Alban Gilpin Smith is thought to be the first surgeon to perform a successful laminectomy for trauma in Danville, Kentucky, in 1829.[5] This was the first successful report since Paul of Aegina 1500 years earlier. The patient was a young man with progressive paraparesis over 2 years after falling from a horse.[6] The spinous process and laminae were removed in the area of injury, and the patient's neurological function improved.

Victor Horsley is well known for his contributions to brain surgery, but he also had a significant impact on spine surgery. At Queen's Square, Horsley performed the first successful laminectomy and removal of a spinal cord tumor in 1887. (For historical reference, this was the same year that Gottlieb Daimler introduced the world's first 4-wheeled automobile and the same year in which the professional baseball Detroit Wolverines defeated the St. Louis Browns in a 15-game, multicity World Series.) In Horsley's surgery, antiseptic bone wax was used for hemostasis, as were deep anesthesia and an extensive array of spinal instruments. The 43-year-old patient made a complete recovery. In 1895, Horsley presented a series of 7 patients who underwent laminectomy for either cervical tuberculosis or fracture.[7] Although 1 died, the remaining patients recovered well from surgery, and he brought 4 of them to his lecture at the annual British Medical Association to attest to his success.

Entering the 20th century, Pott disease and associated deformity and traumatic injury remained the primary spinal pathologies treated by surgeons. Surgical debridement as described by Pott remained the mainstay of treatment until surgical stabilization techniques began to emerge. Posterior fusion techniques were greatly advanced by the contributions of Fred Albee, a New York City surgeon. Albee's famous monograph *Bone-Graft Surgery* was published in 1915. Using a technique he described as akin to grafting fruit trees, Albee used sections of autologous tibial bone placed inside split spinous processes to fuse across the deformity of Pott disease. He thought it was important to use the patient's own bone or bone from a close relative, and he emphasized the need for decortication of important surface area. He understood biomechanical factors and the Wolff's Law, and he cited Murphy's beautifully simplistic but meaningful statement, ''The amount of growth in a bone depends on the need for it.'' To put these advances into better historical perspective, this was the same year that President Woodrow Wilson watched the Boston Red Sox with Babe Ruth defeat the Philadelphia Phillies in the World Series, and the Model T was the state-of-the-art automobile.

It would still be many decades before the understanding and treatment of degenerative conditions of the spine would blossom. Although Mixter and Barr are often cited as the first to link lumbar disk herniation with sciatica, it was actually Walter Dandy who first reported 2 such cases 5 years before Mixter and Barr's landmark article.[8] He made a preoperative diagnosis of a spinal ''tumor'' using iodinated oil myelography. In both cases, he performed a transdural resection of the cartilage ''simulating tumor,'' with excellent relief of symptoms as the result. He proposed that the loose fragment of disk was related to trauma, and he had the great foresight to suggest that the ''trauma at onset is relatively trivial and perhaps repeated.''

I think most everyone in this audience would agree that one of the greatest figures in the treatment of degenerative conditions of the spine was Ralph Cloward. Cloward was the first practicing neurosurgeon in Hawaii, where he spent his entire career. As a volunteer civilian surgeon, he performed > 40 craniotomies in the 4 days after the attack on Pearl Harbor, and he received a special commendation from President Roosevelt. He was a gifted surgeon. Cloward was the father of posterior lumbar interbody fusion. He first reported his work in 1943 at a local Hawaii medical meeting and then in the *Journal of Neurosurgery* in 1953. His results with posterior lumbar interbody fusion were excellent, but few could replicate his technical expertise until the 1980s, when technological advances made it possible for many surgeons. His anterior cervical procedure (published in 1958) was often criticized by staunch proponents of the traditional posterior Scoville techniques. Cloward argued that more pathology could be approached with the anterior technique compared with the 4 distinct posterior approaches. Reflecting on the criticism he often received, he remarked, ''You can always tell a pioneer…he's the one with arrows in his back.'' For reference, in the year Cloward published his anterior cervical diskectomy and fusion paper, the Chevrolet Impala was the hottest new car, and Manager Casey Stengel, Yogi Berra, Mickey Mantle, and Whitey Ford led the Yankees to their 18th World Series title.

In the decades that followed in the 20th century, development occurred at a dizzying speed. Diskography was introduced. New anterior and posterolateral approaches emerged such as the transoral, transsternal, costotransversectomy, and lateral extracavitary approaches; transperitoneal approach to the lumbar spine; and transthoracic approaches to the anterior thoracic spine. The science of biomechanics developed, along with a better understanding of metallurgy and bone healing, setting the stage for better instrumentation.

Up through the 1950s, treatment of scoliosis yielded poor results. Paul Harrington of Houston, Texas, devised a compression/distraction hook and rod system that changed the face of scoliosis surgery. The basic concept was to lengthen the short or concave side of the deformity. Perhaps his greatest contribution was elucidating the principle of the race between the time to instrumentation failure and the time to successful fusion. The limitations of the Harrington system were that the construct had to be long, the hooks tended to dislodge, and it was designed for posterior approaches only.

Sydney, Australia, native A.F. Dwyer introduced a ventral instrumentation system in 1964, the same year in which the new Ford Mustang was unveiled at the World's Fair in New York and in which fearsome Bob Gibson and the St. Louis Cardinals mowed down the famous Yankees in the World Series.[9] Dwyer's system could provide compression of the convex side of the curve and allowed sparing of motion segments (shorter fusion). The early system consisted of screw-cable, multisegmental fixation that distributed the load more evenly over the scoliotic curve. The main disadvantage of the Dwyer system was that it was limited in axial loading and often allowed progressive kyphosis to occur. It resisted tensile forces but not shear forces.

The pace of technology quickened rapidly in the 1960s, 1970s, and 1980s. Klaus Zielke replaced the cable of the Dwyer system with flexible rods, allowing better control of sagittal balance. Eduardo Luque from Mexico introduced segmental fixation via sublaminar wires, L-shaped rods, and coupled cross-links. A quantum leap in posterior thoracolumbar instrumentation was made with the introduction of Cotrel and Dubousset instrumentation from France. This was the first system to allow fixation of all 3 columns of the spine with any combination of pedicle screws, hooks, rods, and cross-links. The Cotrel and Dubousset system provided maximal rigidity to maintain coronal- and sagittal-plane balance. During this period, however, neurosurgeons contributed little to the advancement of the field.

It wasn't until the late 1980s that neurosurgeons began to increasingly use spinal instrumentation. In the cervical spine, more and more fractures were being treated by neurosurgeons with wiring techniques, lateral mass fixation, and anterior plating. Leaders such as Caspar, Cooper, Sonntag, and Haid led the charge. Trauma patients who traditionally had been treated for months in Halo vests were instead fixated internally, put in a simpler neck brace, and returned to life activities more rapidly. Up to this point, neurosurgeons almost exclusively limited instrumentation to the cervical spine. When it came to the thoracic and lumbar spine, intense territorial battles emerged with our orthopedic colleagues, who felt that thoracolumbar instrumentation was their turf alone.

The Spine Task Force assembled by the AANS (and under the leadership of David Kelly) in 1987 was instrumental in expanding the scope of spine surgery and education in our field. The goal was to teach neurosurgeons to treat the entire spine. In addition to producing guidelines for resident and fellow education in spine surgery, the task force emphasized that neurosurgeons should be trained to operate and instrument the entire spine. The American Board of Neurological Surgery confirmed that neurosurgeons had received training equivalent to orthopedic spine fellowship training. Similarly, the American Board of Neurological Surgery and Residency Review Committee amended their definitions of neurosurgery to emphasize the aspect of spine surgery and fusion with instrumentation.

Many of you here today fought battles in your own hospital for privileges to do spinal instrumentation. Neurosurgical organizations pushed forward with new training courses, and the scientific programs of our meetings expanded

to include more presentations on spine. The Joint Section on Disorders of the Spine and Peripheral Nerves was formed and held its first meeting in Greenleaf, Florida, in 1985. The first spine practical course was held in 1987 at the CNS meeting in Baltimore, Maryland. As Volker Sonntag pointed out in his excellent article on the development of spinal neurosurgery, the highlight of the course was learning how to twist 2 strands of 24-gauge wire 3 times per centimeter, a braided configuration that was easier to handle than 18-gauge wire when performing posterior cervical fusion.

Thoracolumbar instrumentation, however, had started and remained within the domain of orthopedics. Many orthopedic surgeons fought fiercely to prevent neurosurgeons from placing instrumentation. On one occasion, I was the only neurosurgeon who attended a spinal instrumentation course put on by a respected international orthopedic educational organization in 1994. At that meeting, I was singled out and told in front of the crowd that I did not need to learn these techniques because I should always plan to simply perform the decompression and then step aside. Frustrated and outnumbered, I packed my bag with a few complimentary hotel postcards and bottles of shampoo and flew home later that same day. We have come a long way from that era of hostility.

An extremely important historical event that broke down the barriers between orthopedic surgeons and neurosurgeons was the pedicle screw litigation of the 1990s. Surgeons of both backgrounds united with spine implant corporations in their defense of pedicle screw technology. Edward Benzel recently pointed out to me the pertinent 19th century proverb that describes this situation well: ''Adversity can, indeed, odd bedfellows make.'' This was a hard-fought battle, and the ultimate victors were patients who were finally granted access to these tools via Food and Drug Administration approval (or downclassification to Class II). Certainly, this battle brought together our 2 fields. Orthopedic surgeons increasingly accepted that neurosurgeons were irreversibly entering the arena of more complex spinal stabilization. Greater cross-fertilization took place in organizations such as the Spine Section, the North American Spine Society, the Scoliosis Research Society, the AANS, the CNS, and many more. More emphasis was placed on spine in our existing neurosurgery journals. The *Journal of Neurosurgery, Spine* was introduced in 1999. And through the efforts of the CNS, AANS, and Spine Section, important guidelines were put together, summarizing our best medical evidence.

Concurrent with this blossoming relationship between orthopedics and neurosurgery was an explosion in spinal implant and instrument technology…and surgery. What then followed in the history of spine surgery is simply astonishing, and the main protagonist at the start of the story is a horse. Orthopedic surgeon George Bagby devised a cylindrical metal ''basket'' or ''cage'' to stabilize degenerative disks in the spines of horses that otherwise would be destined to become paralyzed (called Wobbler's syndrome). This concept caught the eye of surgeon-inventors such as Michelson, Ray, and Kuslich, and the interbody cage explosion was on. The Ray cage and the Bagby and Kuslich cage were approved in 1996 by the Food and Drug Administration.

Soon there were dozens and dozens of different permutations of interbody cages, pedicle screws, and thoracolumbar plates and rods in flavors of titanium, stainless steel, cobalt chromium, polyetheretherketone, and more. Cervical and lumbar disk arthroplasty has arrived, and advances in the biology of bone fusion have been tremendous. After almost 4 decades of research on the family of human bone morphogenetic proteins, the commercial availability of recombinant human bone morphogenetic protein-2 has revolutionized certain spinal fusion procedures. It has been an incredibly rewarding time to be a spine surgeon. But we also have created a cloud looming over us that must not be ignored.

Coincident with the introduction of fusion cages in 1996, rates of spinal fusion rose in this country by 77% through 2001, according to Medicare data published by Weinstein et al in 2006.[10] In contrast, hip and knee replacement increased by 13% during the very same interval. Medicare spending for fusion increased more than 500% from 1992 to 2003. The spinal implant business back in 1994 was around $264 million per year. In 2008, spinal implant sales exceeded $7.45 billion, and the industry is estimated to grow around 7% this year. Quite simply, the growth of fusion surgery and the implant market has been staggering. Despite clinical indications for fusion being relatively well defined in the medical literature and in the AANS/CNS Joint Spine Guidelines published in 2005, the indications in degenerative conditions started to blur. Surgery has expanded beyond that which is supported by the medical evidence. The rates of lumbar fusion are more variable across the United States than for any other form of surgery, and the clinical indications have become inconsistent. Findings of disk dehydration or degeneration at $\geq$ 3 levels in a patient without deformity and only back pain do not justify a 3- or 4-level fusion. Without any medical evidence to support such extensive fusions, it is unethical to perform them. Dr James Robertson warned us early on in his 1993 article in *Surgical Neurology* aptly titled ''The Rape of the Spine.'' Robertson expressed his concern and strong convictions about the growing number of lumbar fusions done for low back pain with ill-defined clinical and radiographic criteria. He stressed that we as neurosurgeons have a ''serious responsibility to put the patient first and to insist on participating in clinical studies to establish the indications for, and demonstrate the efficacy of new procedures,'' and he called for a registry of complications with spinal instrumentation.

We are all aware of surgeons in our communities who perform fusions in cases without instability or other

acceptable indications, who perform ≥ 3-level fusions for axial back pain, or who perform circumferential fusions in the elderly despite the increased risks and morbidity and lack of proven benefit. Between 2002 and 2007, Medicare data demonstrated an increase in complex fusion procedures for spinal stenosis and a decrease in decompressive surgery and simple fusions. We all have a responsibility in our own practices, in our own hospitals, and in our own communities to police ourselves. I urge you to challenge a partner or colleague directly when questionable indications or overly extensive surgeries are used. Critically review cases of excessive surgery at hospital quality assurance rounds. We need to get the issue out in the open and discuss it openly and honestly at regional or national neurosurgery meetings. It can no longer be the 800-pound gorilla in the room that everyone is ignoring. We all need to make it a personal mission to call out those outliers who are threatening our ability to care for our patients in the future with treatments that are supported by medical evidence. We as spine surgeons know the difference best; the government and private insurers do not understand the difference. For example, private insurers in my home state of Georgia have begun to deny payment for procedures that are well supported by the medical evidence such as 1-level posterior fusions for grade I spondylolisthesis or 1-level anterior lumbar fusions for isolated degenerative disk disease.

If we do not eliminate the outliers, if we do not improve the medical evidence for our treatments, and if we do not improve our training process to better standardize the rates and indications for spinal surgery, the federal government and private insurers will certainly redefine how we care for patients. The challenges will come from several sources. In the Affordable Care Act passed by Congress and the Obama administration last March, a new institute for comparative effectiveness research (called Patient-Centered Outcomes Research) has been established, and spine surgery will surely top the list of future studies. The new Independent Payment Advisory Board, whose members will be entirely appointed by the President, will review Medicare expenditures and propose cuts. Spine surgery will certainly be targeted. The new Public Reporting of Physician Performance will begin in 2013, and this will include patient outcomes, resource use, and efficiency. We as individual surgeons, as individual practice groups, and as academic departments must rise to the occasion and meet these challenges. The time has come for us as surgeons to take the lead in collecting outcomes data and to participate in comparative effectiveness research—research designed by surgeons, not federal bureaucrats. Some of our colleagues such as the cardiothoracic surgeons are well ahead of us. At this time, it is still unclear whether this would be best accomplished by neurosurgeons alone or whether we should combine with our orthopedic colleagues. The North American Spine Society recently held a meeting with all interested parties—surgeons, private insurers, employer groups, medical societies, policy makers—to discuss potential models to achieve this goal. The NeuroPoint Alliance is a new neurosurgical organization aimed at collecting outcomes data and performing comparative effectiveness research. It is made up of individual neurosurgery practices. Although grant money has been obtained for the first trial project looking at lumbar degenerative disease, the costs of this type of effort will likely ultimately be borne by us, practicing neurosurgeons. It will be important for all of us to make this commitment of time, money, and effort in the near future to properly and safely guide the ship of spine care through these treacherous waters. I urge you to follow communications coming by e-mail and in the *Congress Quarterly* and *AANS Bulletin* regarding these efforts. It soon will be essential to have data that show what is beneficial for patients and what is not effective.

My last comments about the looming cloud we have created during this amazing evolution of spine surgery concern physician-corporate relationships. We all have seen the attacks on many honest and ethical physicians by our elected officials, agents of the Department of Justice, the Office of Inspector General, and the court of public opinion laid out in the press. The inappropriate behavior of a few has endangered the future of surgeon-driven corporate technology development. Many highly creative surgeon-designers have been vilified in the press or interrogated in US Senate subcommittees or have been the subject of frivolous lawsuits. As a result, many universities (including my own) have overreacted in dramatic fashion to take away or limit the rights of physicians to consult and design with industry. This must stop. Products and tools that help make patients' lives better do not emerge ready for market from inside the cubicle of a corporate engineer. Genuine surgeon ideas and input based on knowledge, training, and clinical experience are essential to the creative process. This relationship must be forever preserved, and I encourage all neurosurgeons with this talent and interest to fight this battle locally and nationally with passion and fortitude. It is an essential right as an American. The responsibility is on us to do it in accordance with the very best in business practices, with full disclosure and transparency, and with honesty.

As we have just reviewed, the sputtering start of spine surgery over the centuries has been followed by a meteoric rise and development just in recent decades. Paul of Aegina would be stunned by how much more effectively we can treat the patient with a fracture-dislocation. It is truly an exciting time to be alive and in the practice of surgery of the spine. I personally (and I am sure many of you) feel very fortunate to have my career coincide with this era of spine surgery. It has been exciting, stimulating, and groundbreaking. It is important, therefore, to celebrate the work and accomplishments of those before us on whose shoulders we now stand.

In Cooperstown, New York, stands the Baseball Hall of Fame. There lie the busts of the greatest players of the game. Neurosurgery has its own list superstars. These are the men who have laid the foundation for our field and to whom we owe a great debt. The modern Neurosurgery Spine Hall of Fame would likely begin with this original class of surgeons who contributed so much to the development of surgical surgery and spine education in the later 20th century (in approximate chronological order): William Scoville, Ralph Cloward, Sanford Larsen, Richard Saunders, George Sypert, Russell Hardy, Alan Crockard, Ulrich Batzdorf, Paul Cooper, Edward Benzel, Edward Connolly, Arnold Menezes, Ronald Apfelbaum, David Cahill, Narayan Sundaresan, Philip Weinstein, Dennis Maiman, Volker Sonntag, David Kelly, Charles Branch, Richard Fessler, Kevin Foley, Regis Haid, Paul McCormick, and Christopher Shaffrey. They provided national leadership and foresight at a critical time in our history. Ultimately, they helped us all provide better care for our spine patients. On their coattails are the next generation of men and women neurosurgeons who will help bring new, untold advances.

It is a challenging time to be a neurosurgeon. We face many external pressures not seen in generations past. But we all are so fortunate to be able to intersect in the lives of those in need, debilitated by pain and loss of function, and be able to do good. In the words of my grandfather and physician Adolph Sellmann, MD, ''Never forget that it is a great privilege.''

Disclosure

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