History of spinal surgery: one neurosurgeon's perspective

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Spinal surgery has advanced from decompression procedures to complex spinal reconstruction and internal stabilization within the last 25 years, as a result of a broad-based technological boom that began in the 1970s with the advent of spinal computerized tomography and magnetic resonance imaging. These technological advances have coincided with, and developed as a result of, the concomitant rise of a complex, economically driven consortium of innovative surgeons and researchers, academic institutions, government agencies, and private industry, to form a Medical-Industrial Complex (MeIC). A major growth industry has formed, resulting in an overall societal benefit. Nevertheless, it has impacted graduate medical education and has significantly increased the cost of treating spinal disorders. Back pain and spinal disorders are a major societal health problem that is associated with a high demand for treatment services. There is a potential for abuse as well as a benefit in offering these services. The MeIC has contributed to the overall rise in the cost of health care insurance and in the migration of manufacturing jobs abroad as a solution for lowering production costs. The increased cost has had a negative impact on local and regional economies.

KEY WORDS • historical perspective • spinal surgery • Medical-Industrial Complex

This issue of *Neurosurgical Focus* is sponsored by the History Section of the American Association of Neurological Surgeons. An appreciation of history allows us to understand where we are today, to respect and realize our indebtedness to the contributions of those who preceded us, and to appreciate with insight our goals and aspirations for the future. The technical progress in the discipline of spinal surgery since the catalytic advances of diagnostic imaging, our understanding of spinal biomechanics and bone growth physiology, and the development of spinal fixation instrumentation have allowed exponential growth in this field. Authors of articles written for this issue of *Neurosurgical Focus* have combined to project useful and informative insights into the development of spinal surgery. We learn from Dr. James Goodrich that Greek physicians lacked an anatomical vocabulary and graphic illustrations or images, and that this retarded the development of a standardized approach to surgical treatment. A parallel could be made in our modern experience in which surgery for many conditions affecting the spine was not undertaken until the lesions could be reliably imaged by CT scans and/or MR imaging. The innovation of segmen-

tal fixation and the resultant explosion of entrepreneurial proprietary devices has spawned new industries that seem to be ever-expanding both in scope and number. A whole array of instrumentation suited to treat every spinal region is available to the surgeon, along with an instrumentation company representative, who is present in the operating room to assist in the use of a proprietary product that is being sold as it is being used.

A FORCE ON THE HORIZON

Dwight D. Eisenhower coined the term "Military-Industrial Complex" in his presidential farewell address in 1961. The cold war and the threat of world domination by Communism was a major preoccupation of his administration and subsequent administrations until the fall of the Soviet Union 30 years later on December 25, 1991. Risks to the international community and needs of national defense require:

a vital element in keeping the peace is our military establishment. Our arms must be mighty, ready for instant action, . . . We have been compelled to create a permanent armaments industry of vast proportions. . . . We recognize the imperative need for this development. Yet we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military industrial complex. The potential for the disastrous rise of misplaced power exists and will persist."⁷

Abbreviations used in this paper: CT = computerized tomography; MeIC = Medical-Industrial Complex; MiIC = Military-Industrial Complex; MR = magnetic resonance.

These warnings seemed possibly well founded at that time, yet this MiIC, guided by the checks and balances of a free democratic society, so far has proved to deliver beneficial innovations in technology and their applications, which have spurred the “computerization” of society and produced supersonic air travel, satellite navigation, nuclear energy-driven engines, radar-guided navigation, space exploration, and a continuing list that extends almost to infinity; in other words, “a collective modernity.”^{1,2} One could argue that the MiIC has been a catalyst for the development of the everyday technological amenities that we now take for granted. Nevertheless, there have been abuses that have driven up costs and there have been cost overruns that have been exposed by the press on many occasions.

THE MEDICAL-INDUSTRIAL COMPLEX

A parallel can be made for the rise of an MeIC, which has exploited many technological advances produced by the MiIC. One example is the use of titanium, which is now the metal of choice for spinal implant instrumentation. This metal was originally developed for use in jet engines. Spinal surgery has benefited beyond measure from the diagnostic imaging provided by CT scanning with soluble contrast myelography, adopted in the 1970s, and by MR imaging, established in the 1980s, which provided three-dimensional images and anatomical delineation of spinal disorders. The latter also revealed the relationship of lesions to the neural axis and adjacent soft tissues. This, along with the development of internal fixation instrumentation, spurred a paradigm shift of spinal surgery from decompression alone to decompression, reconstruction, and fusion. During this time (late 1970s through the 1980s), innovations in anatomical approaches to the ventral spinal column were developed to include transcanal and extracanal approaches along the entire spinal axis. The advantage of ventral spinal reconstruction and fixation, as well as pedicle screw segmental fixation technology, became evident. As the aging population has grown, the incidence of degenerative, traumatic, inflammatory, and developmental spinal deformity has risen. Health care related to the spine is a growth industry driven by government subsidies.²⁹ Patients have benefited greatly from an appreciation of “sagittal balance,” the availability of technology for correcting lost sagittal balance and maintaining that correction by using internal fixation instrumentation. Remuneration for such instrumentation has been a potent incentive. Due to strong entrepreneurial incentives, industry began devoting developmental resources to surgeons and engineers to produce a vast array of instrumentation that enormously facilitates placement of these fixation constructs, greatly ensuring a successful fusion. Corporate profits have resulted from the universal acceptance and reliance on spinal surgeons by the community, which has spurred competition and expansion, as well as the improvement of products available to these surgeons.⁸ Out of such collaborations, an MeIC of vast proportion has developed.

The MeIC is a consortium of individual physicians/surgeons and research investigators, academic institutions, private industrial enterprises, and governmental agencies.

Ultimately, it is entrepreneurial private industry that brings new innovative devices from development to the marketplace and makes them available for daily clinical use to benefit the individual patient. Examples for spinal surgery include the following: cervical plates and screws; pedicle screws and couplers; vertebral expansion balloons; polymer bone cement; genetically engineered bone morphogenetic proteins; disc prosthetic replacement devices; and so forth. This venture capitalism is an economic phenomenon that exists in all fields of medicine. It is responsible for advances available today as well as those that will be developed in the future. It is in the marketing of these new devices by private enterprise that sought and unsought influences occur in clinical and surgical case management, sometimes resulting in increased costs and risks. In spinal surgery the MeIC is again evident in the innovations of minimally invasive procedures, artificial disc prostheses, implantable support devices (allograft bone and cages), and in the development of bone morphogenetic proteins. The clinical demand for such products is steadily growing, along with the age and faster-paced life style of our population.²⁶ As a result, spinal surgery has become a growth industry. The financial incentives are great, which is the obvious attraction for private industry.

Advances in instrumented spinal realignment and stabilization, replacement of a degenerated disc with a motion-saving prosthetic device, or reexpansion of an osteoporotic compression fracture by balloon kyphoplasty are attended by a greater increase in the cost of these procedures. One can argue, however, that the cost—both in money and human suffering—would be much greater if we were forced to rely on methods used prior to these advances. These are not discretionary or luxury items for the individual patient; they are a necessity. How does fair and just remuneration and earnings on an investment made by industry balance with extravagance and “charging what the system will bear”? Who pays for the uninsured?²⁹ The answer to that question will vary according to which sector of the MeIC provides it. Companies paying ever-rising health insurance premiums are already signaling “enough is enough” by moving their manufacturing assets out of the country. Instrumentation producers have a considerable investment and risk in research, development, manufacturing, and marketing. There is also a large capital infrastructure that must be maintained to bring products from expensive clinical investigation to Food and Drug Administration approval before the products become available in the operating room. Such a heavy investment justifies the prices charged for such products. Therein lies the dilemma between producers and payers, with the ever increasing demand of patients in the middle.

Cost Examples

I obtained a list of prices for items necessary to create a lumbosacral fusion construct from my institution’s surgical procurement agent. The list, shown in Table 1, reflects the prices charged by two companies for a two-level pedicle screw-rod fixation device.

The cost differential between the two constructs is \$4489. Cost alone should not be the determining factor over ease of placement, profile, surgeon preference, or vendor service, but it is a consideration because both these

TABLE 1
*Comparative costs of a lumbosacral fusion construct**

Item	No.	Unit Price (\$)	Total (\$)
Company A			
screws	6	465	2,790
connectors	6	97	582
rods	6	192	384
securing nuts	6	39	234
transconnector	1	869	869
total	—	—	4,859
Company B			
screws	6	363	2,178
connectors	6	846	5,076
rods	2	291	582
securing nuts	6	102	612
transconnector	1	900	900
total	—	—	9,348

* — = not applicable.

constructs basically perform with the same effectiveness biomechanically. Surgical implant costs are only part of the costs incurred by the individual patient who undergoes a spinal fusion procedure, but they comprise 30 to 40% of the total cost. Another cost is the surgeon who has acquired the knowledge, skill, and expertise to perform the procedure safely. This requires special training and experience by way of a residency and fellowship in an accredited academic program, which is federally funded and part of the MeIC.

We will return to the 1970s for another historical perspective.

Threshold of Change

Richard Bergland³ expounded, in a rather dire tone, a general criticism of neurosurgical training in 1973 by stating: “neurosurgery has stopped evolving.” He described stagnation to the mundane of a production line that produces surgeons “capable of generalized practice at a standardized level.” The accusation arose from his belief that training programs lacked innovation in shaping new frontiers, that the increasing number of neurosurgeons entering practice had depleted the clinical material available, and that there was an overproduction of neurosurgeons. Dr. Bergland also stated “society has recently witnessed an overproduction of both teachers and engineers.”⁷³ I note that our society now suffers a shortage in both of these disciplines. Dr. Bergland’s statements were made just as CT scanning was coming on the scene and more than 10 years before the advent of MR imaging. He makes no mention of spinal surgery other than “disks are operated by orthopedists and peripheral nerves are repaired by plastic surgeons.” At approximately the same time, a renaissance in spinal surgery began, spurred on by the visualization of spinal disorders provided by CT and MR imaging. Ventral approaches to spinal surgery evolved, along with anterior and posterior stabilizing procedures, which were recognized to improve outcomes.^{4,5,10,14,15,17,18,25} Spinal surgery was the staple of neurosurgical residency training and would become the major product line for the practicing general neurosurgeon. Spinal surgery would be the focal

point of innovation and energy in neurosurgical training for which Bergland had yearned. Neurosurgical training programs would flourish as would disciplines of functional, pediatric, cerebrovascular, oncological, traumatic, and spinal and peripheral nerve surgery as subspecialties.

Residency Training

Sonntag and Theodore²⁶ have observed that spinal surgery is a part of the neurosurgical residency curriculum from the beginning of formal neurosurgical training.²⁶ Spinal surgery has expanded with the innovation and evolution of approaches, techniques, and biomechanics as an integral and major part of neurosurgical training.^{14,15,17,18,20} It has kept pace with and participated in the advances that have occurred. “All neurosurgery residents are spinal surgeons by definition, even if they ultimately migrate to another subspecialty.”²⁷ Kelly¹² has pointed out that “neurosurgeons are the only spinal surgeons that can be trained in their residency.”^{12,27} The competency-based objectives for spinal surgery in residency training include the entire spine, from the craniovertebral junction to the sacrum as a required curriculum, as published in *Resident Curriculum Guidelines for Neurosurgery*.²⁷ Since 1965 such training has been subsidized by the government in the form of grants made to residency training academic institutions by Medicare and Medicaid. The dollar amounts of the grants are based on the number of residents in training in each institution.^{28,29}

Fellowship Training

Graduate Medical Education funding was drastically reduced when the Balanced Budget Act of 1997 was passed by Congress. This placed financial pressure on institutions to reduce the number of residents in training.²⁸ Further proposed schemes have been linked to measures limiting the total number of residents who are trained, with a bias to reduce the number of specialists and increase the number of generalists due to a surmised oversupply of physicians in specialties. In fact, estimates of the projected specialist-to-population numbers and the demand for specialist services must take into account the increasing demand for specialty services in response to new technologies.^{19,21} These estimates have been unreliable and there is a tendency toward underestimates. The current ratio of neurosurgeons to population is 1.5 per 100,000 persons. Available data from neurosurgeon opinion polls, advertised job opportunities, and the ease at which new graduates obtain positions do not suggest an oversupply of neurosurgeons.²⁸ The majority of neurosurgeons entering community practice are spine surgeons. Neurosurgical participation in the ever-expanding and evolving field of spinal surgery is crucially important as counterparts to our orthopedic spinal surgeon colleagues who are trained in postgraduate fellowships. Formal neurosurgical fellowships following residency offer additional in-depth training and research opportunities for those neurosurgeons who pursue academic careers devoted to spinal surgery.²⁶ Such fellowships are not a substitute for an incomplete foundation in spinal surgery during residency training. Neurosurgeons bring a unique insight in homeostasis and handling of adjacent neural tissues, as

well as in the management of cerebral spinal fluid hydrodynamics, which must always be an integral part of spinal surgery.¹² Societal needs for spinal surgery services continue to increase because of a larger aging population. If the number of spinal surgeons, including neurosurgeons, does not keep pace, some proportion of the population will be underserved.

New Technologies

The MeIC is a steady source of technological progress and expansion. There is a trend toward minimization in surgical procedures, including percutaneous discectomy, intradiscal electrothermal coagulation, percutaneous fusion, vertebroplasty, kyphoplasty, discography, zygapophysial blocks, and epidural blocks for the treatment of lumbar pain syndromes.⁶ Kelly¹² warns us about the “quick fix” and the “bake, fake, and massage” approach to spinal disorders, noting the need for controlled studies to verify the efficacy of new procedures. A healthy skepticism needs to be kept in mind for the individual surgeon when new and unproven ventures are proposed.

Endoscopic procedures on the spine that include the use of video-assisted high-resolution cameras to visualize surgical anatomy are being performed now with more frequency; these include procedures for thoracoscopic sympathectomy, thoracic discectomy, interbody fusion, tumor resection, and deformity corrections.^{13,23} Intervertebral disc nucleus replacement and total disc arthroplasty are currently being reviewed in clinical trials, and will most likely replace arthrodesis in many cases.^{16,22} Application of bone growth facilitators such as bone morphogenetic proteins are already approved by the Food and Drug Administration; these aids are currently on the market and are being used universally.^{11,24}

CONCLUSIONS

The unending curiosity surrounding scientific investigation and discovery, which are funded by government agencies and private corporations, coupled with entrepreneurial competitive enterprise, under the auspices of the MeIC, will bring these new technological innovations and yet-to-be discovered breakthroughs to clinical fruition. Hopefully, these breakthroughs will include successful procedures in neural regeneration, which will aid patients to regain effective function after spinal cord injury. The history of spinal surgery so far has been a fascinating prologue to even greater innovations and better recoveries for patients suffering the ravages of all forms of spinal and spinal cord derangements. Nevertheless, as new technologies unfold, we will need to bear in mind the caveat posited by President Eisenhower.⁷ We must beware of the unwarranted influence—whether sought or unsought—by the MeIC. After all, we surgeons have already been relegated by the MeIC from the status of “doctor and physician” to the more generic status of “care provider.” That is just a small thing, though; is it not?

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