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Review Article

Spinal fusion surgery: A historical perspective

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ABSTRACT

The vast majority of technological advances in spinal fusion surgery have occurred within the past 50 years. Despite this, there existed a rich history of innovation, ingenuity, and resourcefulness among the spine surgeons of centuries before. Here, we pay tribute to this history, highlighting the important characters, their devices, and their thoughts, as they sought to alleviate human suffering from spinal deformity.

The field of medicine has sought to extinguish or curtail deformities that damage health and wellbeing for thousands of years. Like many fields of study, the lineage of lumbar spinal fusion surgery can be traced to the Greeks of the Classical era in the 5th century BC. The most conservative and crude of techniques from the past laid the foundation for the development of modern lumbar spinal fusion. The purpose of this essay is to trace the roots, expose the greatest advancements, and organize the evolution of spinal fusion surgery. In his work, *History of Spinal Fusion*, an orthopedist, Dr. Richard Peek, recognizes the dependence of current orthopedic innovations on those who came first, writing, "many of the great advances seem to have been ready and waiting to be made. The basic groundwork had all been done, and when the discovery finally came, it often seemed to be accidental or at least serendipitous."[1] We must return to the Greeks in order to properly establish our historical ground zero, follow the trail of literature over centuries, and conclude with an understanding of the development and establishment of modern lumbar spinal fusion techniques.

Hippocrates described deformities of the spine consistent with scoliosis and proposed the first recorded treatment in the 5th century BC.[2] He appreciated that dramatic curvatures commenced or worsened during the fierce growth period in the preliminary stages of life. Hippocrates attributed such striking distortions of the axial skeleton to habitual poor posture and developed an extension apparatus for treatment. Two of his most prominent contraptions were the Hippocratic ladder and the Hippocratic board, both of which applied axial traction to separate the joint surfaces without displacement or rupture of the binding ligaments.[2]

Five centuries after the work of Hippocrates, Claudius Galen generated a vocabulary for scoliosis, kyphosis, and lordosis. Galen epitomized the multi-talented Greek, making groundbreaking contributions to medicine, philosophy, pathology, and numerous surgical fields. Utilizing his expertise in both anatomy and physiology, Galen designed and experimented with chest binders and jackets to temper scoliosis curvature. In addition to these stabilizing devices, he recommended loud singing and respiratory exercises to stimulate the rib cage musculature.[1,3] His advancements and numerous books remained staples of medical reference for centuries, until Andreas Vesalius replaced Galen's anatomical reports with drawings and diagrams of cadaveric human bodies in 1543. Despite this, the earliest publications of *De Humani Corporis Fabrica*, persistently displayed Galen's analyses alongside Vesalius' diagrams.[3]

Despite the progress of Hippocrates, Galen, and Vesalius, there was a halt of intellectual and artistic pursuits during the Dark Ages when medicine was not clearly distinguished from religion and mysticism. Many medical experts reverted to less scientific hypotheses regarding curvatures of the spine, believing that scoliosis could be a divine retribution. The standard of care at this time was to lay patients on "the rack" for curvature correction, which, similar to the devices engineered by Hippocrates, relied on principles of distraction. In 1741, Nicolas Andry de Bois-Regard continued to study the relationship between muscle imbalance and poor posture, agreeing with experts before him that scoliosis was the product of both. His infamous, *L'orthopedie*, is credited as the first work to discuss the art of correcting and preventing deformities in young children – the art of Orthopaedia.[4] Twenty years later, Francois LeVacher invented the first brace that allowed

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for axial distraction in an upright patient, permitting mobility during treatment. This was a leap forward for non-operative management of spinal deformity; after all, stationary bracing had been the standard for almost 2000 years. LeVacher's "jurymast brace" included a tight cap connected to a bar rising from the posterior aspect of the brace.[5] Throughout Europe, consideration for orthopedic medicine expanded and led to the formation of the first orthopedic hospital in Switzerland in 1780. Jean-Andre Venel founded this center to create an environment for crippled and deformed patients of all ages to seek treatment and to stimulate research in the field of orthopedics. The hospital provided a concentrated area of patients and resources for the study of bone and muscle development and led to the invention of a brace that combined both horizontal and extension forces for a greater curve correction than previous braces allowed.[6]

In 1839, Jules Guerin was the first to attempt surgical correction in patients with scoliosis. Guerin supplemented his bracing protocol with percutaneous myotomies of vertebral musculature and reported great success. After publishing results from 1349 patients, colleagues of Guerin ignited controversy over the frequency of revisions necessitated by his technique. Following a momentous lawsuit, *Guerin vs Malgaigne*, Guerin was banned from practicing medicine and exiled from his native France to Belgium. Surgical intervention in patients with scoliosis would not be attempted again until the 20th century.[7]

An orthopedic surgeon, Dr. Lewis Sayre is best remembered for improving the quality of sanitation in medical hospitals in the United States and halting the spread of disease from incoming ships to the eastern coast.[8] However, he was also particularly influential in the field of orthopedics, specifically in advancing non-operative management of scoliosis. In the 1880s, Dr. Sayre used Paris Plaster casts, also known as body casts, to realign curvatures of the spine. His casting technique involved a tripod-like contraption that suspended patients while a corrective plaster hardened and formed to the patients' bodies. Dr. Sayre occasionally used a jurymast extension when more head traction was necessary, further incorporating the work of his predecessors. Sayre's success led to the widespread implementation of body cast management in the late 19th century, which is still used today in patients with early onset scoliosis. Two other orthopedic surgeons, Dr. Bradford and Dr. Brackett, enhanced Dr. Sayre's casting technique by applying lateral pressure with a horizontal distraction frame to recreate a three-point fixation during body cast application.[9]

Improvements to the brace and its derivatives continued, oscillating between promotions of vertical or horizontal distraction mechanisms, until society's acceptance of invasive surgery in the early 1900s. In 1885, the German physicist Wilhelm Roentgen won the Nobel Prize in Physics for inventing the Roentgen Rays, better known as X-rays. Roentgen's invention provided the medical world with a better understanding of the form and function of the human skeletal system and an unprecedented view of natural anatomy. X-ray imaging prompted many surgeons to propose various new spinal fusion methods that utilized exogenous metal, or bone, to aid in stabilization of the spine after surgery.[10]

An American orthopedic surgeon, Dr. Berthold Hadra, was one of the first surgeons to successfully fuse the spine in a patient with a fracture dislocation; which he accomplished by wrapping wires around the spinal column for stabilization.[11] Dr. Hadra credited his inspiration to a colleague, Dr. Wilkins, who performed a similar procedure three years prior on a patient with tuberculosis spinal deformity. In 1909, a German surgeon, Dr. Fritz Lange, was the first to do spinal fusion surgeries in scoliosis patients. Dr. Lange revolutionized spinal fusion practice by straightening the spine with celluloid bars, steel, and silk wiring—very similar to modern stabilization techniques.[12] Dr. Lange understood the mechanical aspects of the human body and focused on the replacement of the parts that were necessary for movement and support. He developed two procedures for developing his "artificial spinal column of steel":

> In [the first] procedure 4-mm-thick steel wires, one on each side of the spinous processes, were placed under the muscles and fastened using silver wires from above and below. This method, however, led to infection and irritation from the wires' sharp edges. Lange began research in animals to determine an appropriate metal that would reduce these two complications. In 1908, he again tried using steel wires, this time 5-mm thick and 10-cm long, coated with tin, and with tin knobs on either end to reduce irritation; he fastened these to the spinous processes by using paraffin-sublimate silk.[13]

Many orthopedic surgeons were simultaneously working toward the development of a scoliosis correction procedure, building on successes and learning from failures. In line with the millennia-old tradition of incorporating past advances in current practice, Dr. Lange applied Sayre's Paris Plaster casts to his patients for six weeks following surgery.[12,13]

In 1900, Dr. Russel A. Hibbs the surgeon-in-chief at New York Orthopedic Hospital decided to shift his focus toward a major cause of death in western society: tuberculosis.[14] Dr. Hibbs opened a medical center in White Plains, New York, that served patients suffering exclusively from tuberculosis or Potts disease, which is a form of tuberculosis commonly found in the vertebrae. In "The Treatment of Joint Tuberculosis in the Open Air," Hibbs theorized that joint ailments would be positively affected by a change in environment, similar to the lungs of tuberculosis patients. Hibbs gained extensive control over research and patient care in the new hospital he helped to open, affording him the resources to make huge developments in orthopedics. By 1911, Dr. Hibbs had developed his own novel technique of spinal arthrodesis that drew from operations previously performed on the knee.

> "His original technique included subperiosteal exposure of the involved spinous processes and division of these processes at their base. The mobilized spinous processes were subsequently transposed longitudinally to bridge the interspinous gap in contiguous contact. The reflected periosteum was then repaired and the skin was closed without drainage."[14]

Hibbs published this method after successful operation on a nine-year-old boy with tuberculosis spinal deformity. Though long-term results remained undetermined, Hibbs' publication was a monumental stride in the surgical correction of spinal deformities. Hibbs honed his method until 1914, when he finally applied it to patients with scoliosis as a validated surgical therapy for improving quality of life. Dr. Fred Albee of the New York Postgraduate Hospital later read of Hibbs' results and incorporated the technique into his own practice, altering it to utilize bone grafts from the tibia into spinal fusions.[15]

However, after the excitement surrounding the inception of the Hibbs method had faded, patients began to report poor recovery experiences and loss of curvature correction. This prompted another surge of research and improvements to spinal fusion protocols as we entered the mid-20th century. In the 1950s, Dr. Joseph Risser introduced the localizer cast, which consisted of a rigid frame with pressure applied to the ribcage, and was intended for use immediately after surgery. Dr. Risser combined fusion techniques with postoperative immobilization to render patients ambulatory while maintaining surgical correction during the recovery period.[16] During this same decade, Dr. John R. Cobb described the measurement that forms

the basis for assessing severity of curvature deformity in patients with scoliosis still in use today. The Cobb angle measures coronal deformity on an anterior-posterior radiograph, with larger angles denoting larger curves. The Cobb classification is an efficient way for surgeons to understand the extent of deformity, monitor changes in curvature, and classify different types of curves.[17] In 1946, Dr. Walker Blount and Dr. Albert Schmidt developed the "Milwaukee Brace" to minimize progression of scoliosis to an acceptable level and to immobilize patients after surgery. This brace is still in use today.[18]

During the mid-20th century, many surgeons focused their careers on the development of novel bracing and surgical techniques for the management of spinal deformity. However, patients during this time period typically experienced six to nine months of immobilization and frequently reported infection, fusion failure, and loss of correction. In 1955, Dr. Paul R. Harrington, an American orthopedic surgeon, devised the "Harrington Rod," which appeared to draw from Lange's work regarding its application of celluloid bars, steel, and silk wire. The original design was individualized to the patient, with instrumentation custom-manufactured prior to each surgery. Dr. Harrington attached the rod to a series of ratchets that, when tightened, would realign the curvature of the spine and hold it rigid while fusion occurred. Although failing to align the skull and pelvis, the Harrington rod formed the basis for modern scoliosis correction and was used until the late 1980s.[19] Dr. Eduardo Luque of Mexico City improved on Harrington's rod in the early 1970s with the "Luque" implant, utilizing flexible rods and wires threaded through each vertebral level to achieve tighter, more stable fixation. The Luque implant was unprecedented in that it did not require patients to wear a corrective brace after surgery; however, there was greater risk of neurological damage due to the wires passing through the spinal canal.[20] In 1984, two French orthopedic surgeons, Dr. Yves Cotrel and Dr. Jean Dubousset, introduced the multiple hook and contourable rod system, consisting of bilateral rods manipulated to approach the desired profile of the spine and fixed to the vertebrae using hooks and/or screws. This system was the first to address the problem of thoracic "rib hump" associated with vertebral body rotation, and paved the way for a series of similar fixation systems used in clinical practice today.[21]

In conclusion, the current status of spinal fusion surgery maintains similar goals to those of the Greeks in the 5th century BC: to correct the curvature of the spine in order to improve quality of life. There has recently been a large increase in the number of patients who undergo surgical correction of their spinal deformity, likely due to the enhanced techniques and improved outcomes that are the product of centuries of orthopedic work and research. As surgical management becomes less evasive, patients report greater comfort with spinal fusion options. With sustained commitment to spinal fusion research and further procedural enhancement, perhaps in future centuries, physicians will scarcely remember the times when screws and rods were the standard of care in spinal deformity management.

1. Conflicts of interest

The authors have none to declare.

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