Evolution of spinal cord injury treatment in military neurosurgery

Christiana M. Cornea, BS,1 Nicole A. Silva, MD,2 William Sanders Marble, PhD,3 Kristopher Hooten, MD,4 and Brian Sindelar, MD2

1University of North Carolina School of Medicine, Chapel Hill; 2Department of Neurosurgery, University of North Carolina Hospitals, Chapel Hill, North Carolina; 3US Army Medical Department Center of History and Heritage, San Antonio, Texas; and 4Department of Neurosurgery, Walter Reed Army Medical Center, Bethesda, Maryland

During the mid-1900s, military medicine made historical advancements in the diagnosis, stabilization, and treatment of spinal cord injuries (SCIs). In particular, World War II was an inflection point for clinical practice related to SCIs because of the vast number of devastating injuries to soldiers seen during World War I (WWI). The unprecedented rate of SCI along with growth in the field served as a catalyst for surgical and interdisciplinary advancements through the increased exposure to this challenging pathology. Initially, a tragic fate was assumed for soldiers with SCIs in WWI resulting in a very conservative approach strategy given a multitude of factors. However, soldiers with similar injuries 20 years later saw improved outcomes with more aggressive management interventions by specialists in spine trauma, who applied measures such as spinal traction, arthrodesis, and internal fixation, and with the significant developments in the complex rehabilitation of these patients. This article describes the historical shift in the management of SCIs through the two world wars. These historical lessons of SCI and the fundamental advances in their neurosurgical intervention have molded not only military but also modern civilian treatment of SCI.

https://thejns.org/doi/abs/10.3171/2022.6.FOCUS22255

KEYWORDS spinal cord injury; military neurosurgery; World War I; World War II

Although major advancements in treating spinal cord injury (SCI) were made in the 20th century, documentation of SCI dates back to the antique period, during which the very first external fixation and laminectomy were reportedly performed.1 At that time, however, SCIs were generally considered an “ailment not to be treated.”1–3 Although limited advancements were made in the way of spine surgery and SCI treatment in the Middle Ages and the Renaissance, developments in science, medicine, and spinal biomechanics set the foundation for the evolution of modern spine surgery in the 19th and 20th centuries.1 The unprecedented rate of SCIs experienced across military conflicts and during World War I (WWI) served as a means for surgical and interdisciplinary advancements. Much better outcomes were achieved for soldiers with SCIs transitioning into World War II (WWII) as a result of faster and improved evacuation from the field of combat, spinal motion restriction techniques, new imaging modalities, and improved pre- and postoperative care by medical professionals who had become experienced in dealing with spine trauma.1–6 It is the early military initiatives that set into motion the improvements in morbidity and mortality associated with SCI seen today and the expansion of neurosurgery as an independent surgical specialty.1

WWI: 1914–1918

WWI brought a new age of deadly trench warfare with advancements in artillery and armor and the invention of the machine gun. Given the use of these weapons, evacuation protocols and frontline surgical care became vital for wounded soldiers. In fact, when pioneering neurosurgeon Harvey Cushing was completing a surgical rotation with the British No. 13 General Hospital Royal Army Medical Corps during WWI,1 he experienced this focused emphasis on and the importance of medical evacuation, noting “23 cars carrying 250 stretcher cases and an additional 150 sitting cases. The trains carried 45 attendants, three doctors, and three nurses with an attached kitchen car.”7 Despite these significant evacuation resources, there were still challenges in getting patients off the battlefield to this
distant precious resource resulting in prolonged field care. Also, the distance between areas of combat and these medical trains led to protracted field litter ambulance evacuations through rough terrain in combination with poor spinal motion restriction techniques.

Further, WWI occurred at a time when neurosurgery as a subspecialty was just taking shape, orthopedists were transitioning focus from casting and bone setting to operating, and there were very few surgeon-physicians who were comfortable treating SCI. Therefore, patients with neurosurgical injuries were treated by field surgeons who were not accustomed to managing this trauma. Recognizing the limitations of the neurological examination by inexperienced providers, and given the infancy of radiographic imaging, military surgeons relied heavily on their experience and clinical judgment, which proved to vary from surgeon to surgeon. Surgeons who were specifically trained in neurosurgery served mainly as consultants for US Army hospitals because there were far too few to be deployed forward, and in 1918 only two neurosurgical teams were organized in Britain. Harvey Cushing further reported that those field hospitals that did have this invaluable resource were ironically limited in the tools required to perform spine operations, for example, the specialized anesthesia needed for neurosurgery cases and the neurosurgical instruments like rongeurs, drills, and perforators.

For many reasons, during WWI, there were very few operative interventions for spinal trauma, and injuries were treated with bedrest and potentially traction and casting. Spinal instrumentation and bracing, while described in the literature of the time, would not be widely adopted for decades. The morbidity and mortality rates of SCI during WWI in the pre-antibiotic era were still significantly high given the lack of knowledge about rehabilitation and preventative measures and the inability to treat infections in early hospital care, including those due to bed sores, urinary tract infections, or penetrating injuries. This situation was vividly described by Cushing.

80 per cent died in the first few weeks in consequence of infection from bed sores and catheterization. The conditions were such, owing to pressure of work, as to make it almost impossible to give these unfortunate men the care their condition required.... Only those cases survived in which the spinal lesion was a partial one.

Not until 1928 was penicillin discovered by Alexander Fleming. Overall, despite valiant efforts in evacuation, operating theaters, and antiseptic solutions, outcomes during WWI remained so dismal that it was generally accepted that conservative management was more appropriate than aggressive surgical interventions.

**WWII: 1939–1945**

Notably, WWII was an inflection point for patients with SCI for a multitude of reasons. Experiences from the First World War exposed the deficiencies in the care of SCI, and the military instituted policies for improvement. In 1944, the US Army sponsored courses for military physicians to treat wounded soldiers, specifically in neurosurgery but also in radiology, physical therapy, anesthesiology, and surgery/medicine. Furthermore, expedited transportation meant earlier access to expert care for the wounded. Faster train transport close to the battlefield reduced the associated risks seen in WWI, as bed sores and bladder infections decreased since this comorbidity corresponded with the time patients spent in transit between hospitals.

Another major development included a heightened focus on spinal motion restriction techniques applied in the field or at local field hospitals prior to transport. Such techniques primarily involved plaster casting, an immobilization method used by orthopedic surgeons to stabilize injured limbs. It provided durable stability, which allowed safer conveyance via poorly sprung ambulances, trains, and later air medical evacuation by reducing the risk of secondary SCI in an already unstable spine. Patients would often be transported across a considerable distance to base hospitals or more suitable treatment centers once the plaster was dry. Of note, patients would need to be periodically turned to avoid tissue necrosis against the surface of the cast.

Penfield detailed spinal immobilization techniques in the Canadian Army Manual of Military Neurosurgery, 1941 to educate field surgeons on how to stabilize patients prior to transport (Fig. 1):

He should not be lifted from the ground by shoulders and feet unless he is lying prone. The best routine is to turn the paraplegic over so that he lies face down upon a blanket spread upon the ground. He then can be lifted by means of the blanket onto a stretcher, and a coat or other object placed under his head to increase the extension…. Application of a plastic cast to immobilize the neck and trunk should be carried out as early as feasible…. When a cast is applied, the spine should usually be placed in extension, not in flexion.

These techniques are the basis of current modalities of spine motion restriction techniques such as spine boards and cervical collars.

As previously mentioned, the availability of antibiotics following the discovery of penicillin was likely the greatest driving factor behind the improved survival rates of soldiers suffering from SCI during WWII. The sequelae of life-threatening infections from either the surgery alone...
or the penetrating contaminated wounds, as well as postoperative infections such as urinary tract infection, could now be treated. For example, intraoperative antiseptic and antibacterial techniques, such as placing sulfonamides in the wound of penetrating injuries, improved source control and reduced morbidity and mortality. Moreover, better plastic surgery techniques could help with decubitus ulcers, and the role of nutrition and protein in wound healing was better understood.

The development of various imaging and diagnostic techniques and their implementation in surgical decision-making also contrasted with the situation in WWI, when clinical decision-making was guided only by thorough neurological examinations resulting in exploratory surgeries. Spinal radiography (discovered in 1895) and myelography (discovered in 1919 and improved in 1922 with the discovery of injectable Lipiodol) became more widely used during WWII. However, magnetic resonance imaging, which now dominates the sphere of spinal cord pathology, was not discovered until the late 1970s.

Spinal radiographs were used to understand fracture patterns and determine the need for traction. Hydrodynamic studies were used to determine the presence of compressive lesions requiring surgical decompression, an inherent limitation of radiographs, which can only assess bony anatomy. Spinal manometric testing was performed with the use of a blood pressure cuff around the patient’s neck to compress the jugular veins and raise intracranial CSF pressure. A glass manometer of Ayer was used to measure the spinal pressure. From Penfield W. Treatment of acute head injuries. In: Canadian Army Manual of Military Neurosurgery, 1941. Government Printing Office; 1941:22-64. Courtesy of the Osler Library of the History of Medicine, McGill University.

Patients who have had spinal injuries and have failed to improve, whether previously laminectomized or not, have: (1) A careful neurological examination and plan roentgenograms of the spine. (2) Fractional hydrodynamic studies in the x-ray

FIG. 2. Figure from Wilder Penfield’s book Canadian Army Manual of Military Neurosurgery, 1941 depicting spinal manometric testing. A blood pressure cuff around the neck was used to compress the jugular veins, raising intracranial CSF pressure. A glass manometer of Ayer was used to measure the spinal pressure. From Penfield W. Treatment of acute head injuries. In: Canadian Army Manual of Military Neurosurgery, 1941. Government Printing Office; 1941:22-64. Courtesy of the Osler Library of the History of Medicine, McGill University.
Spinal Surgery Advancements During WWII

By the start of WWII, early decompressive laminectomies had become the basis of SCI intervention, yet refinements through clinical experience made surgical techniques safer and more effective in the WWII era. For example, the technique of incising the pia within 12 hours of contusion to the spinal cord as a method of decompression, first described in 1918, was abandoned in 1940, with Penfield opining:

If the surgeon incises the pia at that time, he will be horrified to see the softened portion of the spinal cord extrude itself through the hole in the pia like paste from a tube when it is compressed...seems reasonable but clinical verification is lacking, and, even in the piping days of peace, it has not proved practicable to carry out such operations. Consequently, in military surgery early incision of the cord is not to be recommended.

Spinal traction, in the form of skull tongs or wires, had already been described by W. Gayle Crutchfield in 1933 and could assist with the reduction of cervical spine fracture dislocations. Manual closed reduction was performed by means of a chin-head halter and strong traction, an intervention still performed today with Gardner-Wells tongs. If open reduction and decompression were required, neurosurgeons described the importance and need for a watertight dural closure, which mitigated complications of CSF leakage, sinus tract formation, and bacterial entry.

Surgical efforts further evolved with the advancements of bony fusion and stabilization after extensive decompression. Advances in spine surgery were heavily influenced by colleagues in orthopedic surgery. Early instrumentation and bone grafting techniques were introduced by orthopedic surgeons who had spent the latter part of the 19th century treating congenital, traumatic, and infectious spinal deformities. Examples include Russell Hibbs’ bone grafting technique for spinal fusion and Paul Harrington’s system of distraction and compression rods and hooks—initially intended for scoliosis in civilian life but quickly adapted to the treatment of spinal fractures and dislocations, particularly of the thoracolumbar spine. In his “Spinal injuries” chapter in Canadian Army Manual of Military Neurosurgery, 1941, Penfield describes the importance of arthrosis of the facets and placement of morselized autograft to promote posterior fusion. The introduction of devices for internal fixation during the early 20th century allowed for better alignment and increased rates of fusion.

Postoperative immobilization to promote bony fusion was also an important part of the course of healing to reduce pseudarthrosis.

As surgeons obtained the appropriate tools and became more aggressive with surgical intervention, the controversy surrounding the appropriate timing of surgical intervention for SCI began. Some surgeons believed that there was definite greater improvement in patients with incomplete lesions who had been operated on than in those who had not, but they also believed that there was no noticeable difference in improvement in those who had received immediate treatment versus those who had received delayed treatment. During WWII, this sentiment is likely reflected by historical references that document the timing of surgery as ranging from as little as 8 hours to as many as several weeks postinjury. However, others emphasized the role of the neurological examination in understanding the potential for neurological recovery by identifying signs of an “incomplete SCI” requiring urgent decompression. Penfield firmly advocated for the role of urgent surgical intervention in patients with compressive pathology and evidence of incomplete SCI (Fig. 3). He further noted that in patients without compressive pathology and evidence of complete SCI “chances of recovery by means of operation is extremely unlikely... Nothing should be done in this case except immobilization and general care. The expenditure of time and labor beyond this may well prove to be fruitless.”

Adjunct Therapies for SCI During WWII and the Post-War Era

One figure who became a pioneer of neurosurgery in WWII and the post-war era was R. Glen Spurling, who held the position of European theater consultant in neurosurgery, analogous to the position Cushing had held 25 years earlier. Spurling, a founder of the American Board of Neurological Surgery and the American Association of Neurological Surgeons, had worked on lumbar and cervical intervertebral disc diseases and peripheral nerve injuries and was a proponent of aggressive surgery. Early SCI treatment was primarily neurosurgical; however, Spurling acknowledged that treatment beyond the acute phase was a multidisciplinary task (Fig. 4). This program [multidisciplinary care and rehabilitation of SCI...
patients in the army] was participated in by urologists, orthopedic surgeons, rehabilitation staff, physical therapists, and other specialists, who deserve much credit for its success, while special mention must be made of the nursing service, in which I include the trained enlisted attendants who assisted in the nursing care. This expanded team of health professionals had developed in clinical centers around North America and Europe in the interwar years and thus was available for much wider utilization in WWII than in previous wars. The war also generated SCIs at a rate unparalleled in civilian life, and since the army concentrated patients with similar injuries, the care teams could readily develop their skills in ways that civilian practitioners could not.

With higher SCI survival rates in WWII, the importance of long-term rehabilitation and physical and psychological therapy was evident. After the war, SCI patients would continue to require multidisciplinary rehabilitation including “mental and physical orientation of the patients, physical therapy, physical reconditioning, vocational and educational guidance, exploratory prevocational shop courses, occupational therapy, and recreation.” Thus, their care was eventually transferred over to the Veterans Administration (with SCI centers influenced by neurosurgeon Dr. Donald Munro), where they could receive care until their discharge into civilian life.

Conclusions

As discussed, there was a significant paradigm shift in SCI treatment from WWI to WWII that continued to reverberate and ultimately became the foundation of SCI management that is still used today. Lessons learned from the battlefield guided surgeons to become experts in spinal trauma, expose the importance of a multidisciplinary approach, and push for improved rehabilitation of soldiers who suffered an SCI. Trailblazer neurosurgeons like Munro, Spurling, and Penfield brought hope to patients with SCIs, and the military program revolutionized their care. In subsequent decades, technological advancements in spine imaging, biomechanics, instrumentation, and improved understanding of neurocritical care in SCI only continued to further push the needle in improved outcomes for patients with an SCI. Unfortunately, in recent years, there has been stagnation in the continued improvement in functional neurological outcome for these patients, as there are numerous questions that still need to be answered. For example, conflicting research and limited class I level evidence continues to stir the debate on the ideal timing of surgical intervention for this pathology, specifically in patients with complete SCI (American Spinal Cord Injury Association [ASIA] grade A). As mentioned, this debate began more than 80 years ago. Our greater understanding of the pathophysiology of SCI has revealed new areas for surgical and pharmacological therapies that could provide the next significant change in SCI management, but these experimental modalities are in their infancy. These include regenerative therapies such as neural stem cell transplantation, bioengineered neuronal cell, spinal disc transplants, mitochondrial stimulation techniques, and brain-machine interface technologies. Only through a collaborative academic and clinical military-civilian effort will we see another revolution in how to approach SCI.

References


FIG. 4. Figure from Wilder Penfield’s book Canadian Army Manual of Military Neurosurgery, 1941 depicting a bladder draining system used for patients with urinary bladder paralysis due to SCI. This apparatus gradually added (under low pressure) sterile solution or, in the case of cystitis, a silver nitrate or potassium permanganate solution to the urine in the bladder. When pressures in the bladder rose, the system completely drained it. From Penfield W. Spinal injuries. In: Canadian Army Manual of Military Neurosurgery, 1941. Government Printing Office; 1941:74-84. Courtesy of the Osler Library of the History of Medicine, McGill University.