100 Years of British military neurosurgery: on the shoulders of giants

Surg Lt Cdr SAG Roberts RNR

Abstract

Death from head injuries has been a feature of conflicts throughout the world for centuries. The burden of mortality has been variously affected by the evolution in weaponry from war-hammers to explosive ordnance, the influence of armour on survivability and the changing likelihood of infection as a complicating factor. Surgery evolved from haphazard trephination to valiant, yet disjointed, neurosurgery by a variety of great historical surgeons until the Crimean War of 1853-1856. However, it was events initiated by the Great War of 1914-1918 that not only marked the development of modern neurosurgical techniques, but our approach to military surgery as a whole. Here the author describes how 100 years of conflict and the input and intertwining relationships between the 20th century’s great neurosurgeons established neurosurgery in the United Kingdom and beyond.

Introduction

“It has often been said that the two oldest professions are prostitution and neurosurgery” (1). Museum specimens demonstrate a variety of injuries, from square-shaped pterional entry points from war-hammers, to signs of healed linear and depressed skull fractures bearing the impression of arrows, swords and pole-axes. Archaeological recovery of armour shows that over the centuries this was adapted to the increasing power of the threat, with progressively thicker and stronger metals and the inclusion of cheek and jaw extensions (2). There is further evidence of primitive trepanning and latterly formal trephination and the increasing involvement of barber-surgeons.

In 19th-century conflicts, brain injury was largely considered irrecoverable and patients underwent little, if any, formal intervention by surgeons. There was little advancement in surgical methods, which were largely at the discretion of the operator. 18th-century surgeons such as François Quesnay and Percivall Pott favoured immediate surgery, whereas Pierre-Joseph Desault favoured no intervention at all. Napoleon’s surgeon and early innovator in battlefield surgery, Dominique Jean Larrey, performed surgery for depressed skull fractures and haematomas, but would not operate on the brain parenchyma at all (3).

Professor John C. Warren transformed surgery forever in 1846, with the first use of general anaesthesia. This came just in time for war in the Crimea (1853-1856), which saw the formal military field hospital feature more prominently. Prior to this, soldiers relied upon the financial benevolence of officers for their recovery. The Crimea also marked the first time that surgeons began to report results systematically. McLeod (1858) noted that 10% of all gunshot wounds involved the head, with an associated mortality rate of 18.5%. He recorded: “Of 19 cases in which the skull was perforated, all died. The trephine was employed 28 times and 24 ended fatally” (4).

Neurosurgery did not formally exist as a specialty in the United Kingdom at the turn of the 20th century. Neurology was well established, with pioneers such as Hughlings Jackson and Victor Horsley attempting to develop its offshoot, neurological surgery. Victorian society regarded patients with skull deformities, such as Joseph Merrick, the ‘Elephant Man’, as curiosities to be exploited and ridiculed. Operations on a visually normal skull were regarded with fear as a form of torture, compounded by catastrophic blood loss and complications associated with such procedures. Rickman Godlee (1849-1925) successfully removed the first brain tumour in 1884, but the patient subsequently died of complications from wound infection. The physician and surgeon were heavily criticised, with The Times running a damming editorial on the operation. A subsequent anonymous letter to the same paper prompted further criticism, particularly from anti-vivisectionist groups, of which Queen Victoria was a supporter. Such scepticism would persist until the need became driven by war (5).

The impact of the First World War

In 1914, stubbornly ignoring lessons from history, the First
World War (WWI) began with soldiers wearing no head protection. The French introduced the M15 Adrian helmet, named after General August-Louis Adrian, in 1915. The British subsequently introduced the Brodie helmet, which did not reach troops until late 1916. The Brodie was the mainstay of helmet design until the 1930s (6). Primarily designed to stop shrapnel from exploding shells, it was relatively ineffective against bullets, limiting its overall value.

For the Tommies standing in trenches with heads skylining above the parapet, the contribution of head injury to fatalities was around 25% (7). When helmets were finally employed, head wounds increased, as previously soldiers had been killed outright. This was further complicated by a new problem: sepsis. In 1918, Keen noted: “the soil of Belgium and France has been cultivated for over twenty centuries, since even before the days of Caesar’s Gallic Wars. The fields have been roamed by cattle, horses, swine and other animals including man; the soil has been manured thousands of times, and so is deeply impregnated with faecal bacteria in addition to ordinary pyogenic bacteria … it was no wonder that infection from pyogenic organisms and the bacteria of tetanus and gas gangrene ran riot” (8). It was into this quagmire that Harvey Cushing arrived (Figure 1).

Cushing (1869-1939) was 45 years old when he arrived in Paris as a volunteer to the privately funded Ambulance Americaine, one of 700 such hospitals in France at that time (9). Attached to the British Expeditionary Force, he initially spent time moving between French and British units, and was shocked by the failure of surgeons to cope with both the nature and extent of intracranial injuries, with incomplete surgery complicated by poor triage and disorganised transportation. This was in spite of a unified triage system purportedly in place for evacuation of both the British Expeditionary Forces and the French (Figure 2).

Cushing reflected: “… that the farther back a man with a cranial wound goes, the more gloomy becomes the prognosis, as confessed by all, for abscesses and meningitis are notably slow to develop and I believe that an imperfect, hurried or incomplete operation in a field ambulance merely serves to delay the victim’s entry to the base hospital where a more through, composed and better planned operation might be done” (10).

Initially, limited surgical exploration was encouraged to provoke dural adhesions and reduce the spread of infection. Disastrous outcomes resulted in preclusion to elective non-intervention. Importantly, Cushing recognised the importance of outcomes: “… one of the lessons that has been taught is that operations are easily performed but that judgment only comes from special experiences, and there is a scant margin between the conditions of repair which may leave a wounded man incapacitated for further service or may restore him to the army” (11). Cushing also saw the importance of definitive intracranial surgery at specialist units, even if this meant waiting longer to perform surgery. Cushing later used his case studies to petition for this in addition to evacuation routes being improved via robust implementation of the unified triage system (9, 11).

After the United States entered the war, Cushing returned to France in 1917 as director of Base Hospital 5, known as the Harvard Unit, whereupon he was immediately detached to the British Expeditionary Force. Commanding a small casualty clearing station in a non-surgical role close to the Belgian Front left him frustrated, and he was relieved when the British ordered him to relocate to Casualty Clearing Station 46, located near Proven, Belgium. This was nine miles from the front and expanded to accommodate 1300 beds during battle.

It was patients treated here, during the Third Battle of Ypres (Passchendaele), who formed the basis for his case reports. Cushing standardised intracranial injuries into nine categories with separate mortality rates (Table 1). This allowed him to put into practice his techniques, putting him at odds with his British masters. Cushing’s contemporary Whitaker wrote: “From the very early days, I arranged with the anaesthetist that he should warn me fifteen minutes prior to the start of the procedure, and decided that the patient should invariably be off the table at the end of twenty minutes…” (12). Contrast this with the approach of Cushing: “… at best, most of the more critical operations deservedly require upwards of a two-hour period; and as one team, eliminating all delay can hardly expect to do more than eight major cases a day …. ” (10).
Figure 2. British evacuation lines during Cushing's time. Cushing worked at Casualty Clearing Station 46 near Proven, Belgium, which would have been around 5 miles from the front. (Adapted from a sketch attributed to Col Godwin, British Expeditionary Force) (9)

### Table 1

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Cases</th>
<th>Deaths</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Scalp wounds with intact cranium</td>
<td>22</td>
<td>1</td>
<td>4.5%</td>
</tr>
<tr>
<td>II</td>
<td>Skull fractures with intact dura</td>
<td>54</td>
<td>5</td>
<td>9.2%</td>
</tr>
<tr>
<td>III</td>
<td>Skull fractures, dura lacerated</td>
<td>18</td>
<td>2</td>
<td>11.8%</td>
</tr>
<tr>
<td>IV</td>
<td>Gutter wounds with indriven fragments, often extrusion of brain (local contusions, fungal abscess and encephalitis)</td>
<td>25</td>
<td>6</td>
<td>24%</td>
</tr>
<tr>
<td>V</td>
<td>Penetrating wounds with lodged projectile and bone fragments (extrusion and abscess common)</td>
<td>41</td>
<td>15</td>
<td>36.6%</td>
</tr>
<tr>
<td>VI</td>
<td>Penetrating wounds entering ventricles (a) bone or (b) projectiles (CSF leak, ventriculitis common)</td>
<td>(a) 14</td>
<td>(a) 6</td>
<td>(a) 42.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) 16</td>
<td>(b) 16</td>
<td>(b) 100%</td>
</tr>
<tr>
<td>VII</td>
<td>Craniofacial track involving (a) orbitonasal and (b) auropetrosal</td>
<td>15</td>
<td>11</td>
<td>73.3%</td>
</tr>
<tr>
<td>VIII</td>
<td>Perforating wounds with severe cerebral injury (haemorrhage and compression)</td>
<td>5</td>
<td>4</td>
<td>80%</td>
</tr>
<tr>
<td>IX</td>
<td>Craniocerebral injury with diffuse skull fractures (widespread contusions and compression)</td>
<td>10</td>
<td>5</td>
<td>50%</td>
</tr>
</tbody>
</table>

Table 1. Cushing’s tabulation of intracranial injuries based upon his case reports, standardised into 9 categories with mortality rates.
Cushing advocated the surgical techniques of en-bloc bone resection under local anaesthetic (LA) with suction debridement and primary two-level closure. Beginning to realise the importance of removal of foreign bodies, Cushing commented: “First or last, these missiles apparently must come out” (10).

How these foreign bodies were being removed did not escape Cushing’s ire, with the propensity for using a finger to probe bullet tracts drawing particular criticism (13). He commented: “The brain of course is not a pie, even though in the past it may have been treated as such by the little Jack Horners of surgery; and subcortical explorations which entail undue damage are of course prohibitive” (11). This desire to not cause further damage led Cushing and his associate Cutler to explore innovative use of magnets to extract metal foreign bodies (10, 13).

Cushing’s legacy remains today. His case reports advocate a complete shaving of the area of operation, broad based skin flaps and en bloc bone removal with suction. He also recommended careful dural closure and two-layer skin closure without drains, believing that elimination of dead space was key (9). Finally, he advocated thorough debridement and saline irrigation, rather than the previously advocated antiseptic solutions. Through reducing infection and secondary complications, Cushing reduced mortality from penetrating head injuries from over 58% to 28% (14). After the war, Cushing presented at the American College of Surgeons, where William Mayo commented: “Gentleman, we have this day witnessed the birth of a new specialty, neurosurgery” (6).

Meanwhile, pioneer British neurosurgeon Victor Horsley (1857-1916) made telling contributions to hygiene and infection control. Horsley shared many of Cushing’s observations; however, the respect may not have been mutual. When Cushing visited Horsley in London in 1900 he was distinctly unimpressed with his surgical methods (15, 16). Gazetted as a Captain in the Royal Army Medical Corps (RAMC) in 1909, Horsley was intensely frustrated with not being mobilised at the onset of conflict, and petitioned his superiors to deploy him many times. In November 1914 he wrote to The Times responding to an article entitled ‘Specialists Required’. He advised that experienced hospital surgeons should be sent to France, writing: “The condition in which the wounded arrive, the statements they make of the want of surgical attention during transport, especially in trains, the fact that many cases are prejudiced (some have even died) by being put onboard ship when they should have been treated at a base hospital, is all clearly due to a shortage of experienced surgeons on the other side of the Channel” (15).

Horsley (Figure 3) finally mobilised in 1915, with a brief spell in Wimereux, France en route to Egypt. An advocate of debridement and irrigation, he shared Cushing’s contempt for antiseptic irrigation of head injuries. A direct character lacking the tact of Cushing, he described Godlee and Watson-Cheyne’s recommendation to use carbolic acid irrigation as ‘terrible’, enraging his contemporaries. Shortly after this, however, the War Office recommended no further use of antiseptic pastes. Posted to 21st General Hospital, Ras-el-Tin, Alexandria, Egypt, he found the hospital infested with flies, cockroaches and rodents. Horsley led by example, personally taking part in the deep cleaning. Over 400 wounded from the Gallipoli campaign were in a hospital staffed to accommodate 150. Fiercely teetotal, Horsley was furious (he served as President of the British Medical Temperance Association), and wrote letters contrasting the money spent on alcohol against the lack of staff and equipment. In spite of such agitations, he was promoted to full Colonel and granted a roving commission. Upon inspection of the hospital at Damanhur, his complaints incensed the chain of command, with the Director of the Public Health Department in Egypt reminding Horsley; “…Egyptian hospitals had never been intended for European patients” (15).
Horsley received further letters from medical officers returning on leave, denouncing conditions encountered in Mesopotamia. Doubtless his agitations led to the approval of his request to transfer to Basra, though this did not dent the vigour with which he confronted his superiors. Finding similar shortcomings, he again wrote highlighting the lack of X-ray facilities and sterile dressings, inadequate staffing and very poor transport arrangements. In this way his complaints strongly mirrored that of Cushing, albeit in a different theatre. Focusing on evacuation routes, he denounced the lack of appropriate road and rail provision. The only passable route was by barge via the great rivers Tigris and Euphrates, in conditions that Horsley considered inhumane and unhygienic (15).

By July 1916, a now 58-year-old Horsley was in Al-Amarah, one hundred miles north of Basra, where paratyphoid was rife. Complaining of a headache following a walk of several miles, his temperature climbed steadily, reaching 103°F. His fever proved uncontrollable, and by the morning he was dead. The cause of death was uncertain, with opinion divided as to heatstroke, paratyphoid or both. Throughout his deployed service, Horsley had made a telling contribution to sterility and cleanliness in theatre. Victor Horsley still lies in Al-Amarah, and his gravestone was poignantly acknowledged during the return of British forces to modern day Iraq during Operation TELIC (17).

The legacy of the First World War
Military neurosurgical performance was discussed in the inter-war period and some of those discussions remain pertinent, particularly the differing approach between the United Kingdom Defence Medical Services and the United States regarding the deployment of forward surgical teams. Cushing’s intention during his time with the British Expeditionary Force was to have a group of well-trained neurosurgeons at large centres; however, this came to be thwarted by the very difficulties he identified. On entering the conflict, the United States initially followed the British plan at the Western Front: one hospital in Deuxnouds was selected with several teams concentrated there. The arrangement was analysed retrospectively by the US Army Surgeon General’s Office. General arrangements and staffing levels were inadequate. One difficulty was that centres devoted exclusively to neurosurgery became overwhelmed with general work. Another difficulty was the slowness of neurosurgical operations. This, and major difficulties with triage and evacuation routes, resulted in the concept of district centres being abandoned. Henceforth, the United States recommended a new plan of having special forward hospitals. Specialists arrived from the United States with additional instruments. Prior to the St Mihiel operation each hospital in the forward area had an experienced forward deployed surgical team (7).

In the inter-war period, an ageing Harvey Cushing busied himself writing the biography of Sir William Osler. While he was doing so, Lady Osler spoke to Cushing about a young Australian neurosurgeon, Hugh Cairns. Cairns (1896-1952) was subsequently awarded a Rockefeller fellowship with Cushing between 1926-1927, noting “Cushing’s Machiavellian attention to his reputation”, his angry outbursts, public humiliation of his assistants and his lying. Cairns, however, admired his hard work, “amazing persistence”, courage, disregard for his own personal comfort and his distress at seeing a patient die (18). Of Cairns’ stay, Cushing wrote, “for of all my many pupils he is facile princeps” (Figure 4) (19).

The Second World War
This period saw the ascendancy of Cairns in the field of neurosurgery. Cairns had briefly been involved in WWI as a medical student in the Australian Army Medical Corps (AAMC). On leave from the 2nd Australian General Hospital in Wimereux in 1917, he attended Oxford and was granted an audience with Sir William Osler who gave him early career advice; he met Cushing on several occasions over this period at Sir William Osler’s home. On return to the UK, he established the Department of Neurosurgery in The London Hospital, but moved to Oxford as the first Nuffield Professor of Surgery. His exchange programme resulted in the establishment of neurosurgery in Australia (18). In 1938, with war once again approaching, Cairns was chosen by the War Office to advise on head injury care within the Forces (20).

In the lead-up to the Second World War (WWII), the expectation was that patient outcomes would be better. Neurosurgical training was now established, with antibacterial treatments more widespread and effective.
Cushing’s work was being revisited as the minimum standard expected (21). One group that did pay attention to Cushing’s meticulous case reports and follow up was the Germans. Their understanding of his work ensured that Wehrmacht helmets were modified with temporal and occipital flares, giving the characteristic shape to the WWII Stahlhelm, something overlooked by the Allies (9). Importantly, the evacuation of wounded, a major weakness in WWI, was far more satisfactory, particularly via the air bridge.

Cairns’ first act was to establish the Combined Services Hospital for head injuries at Oxford, where neurosurgeons, anaesthetists, theatre sisters and ward nurses were trained specifically in scenarios mirroring the number and type of neurosurgical injuries expected in war. This was not unlike the modern day Hospital Exercise (HOSPEX) as practiced by the UK Defence Medical Services. HOSPEX in its current form involves complete and realistic simulation of an entire field hospital, where teams work through real-life scenarios in real time. This remains one of the few examples of military medical macro-simulation existing worldwide (22). In this regard, Cairns was years ahead of his time.

Cushing had noticed Cairns’ propensity for leadership and analytical reasoning. It was this that allowed Cairns the foresight to predict the shortage of steel in the build up to WWII. This led him to bulk order neurosurgical instruments in anticipation of future supply issues, and henceforth facilitated his greatest contribution to the war effort, the Mobile Neurosurgical Unit (MNSU) (Figure 5) (19).

Mirroring the Combined Services Hospital model, the MNSU consisted of a neurosurgeon, neurologist, anaesthetist, nurses, general duty RAMC officers and drivers. Units were deployed with the aim of treating head injuries within 48 hours of wounding. Lord Nuffield gifted a vehicle for the creation of the original unit, equipped with electricity, suction, diathermy (NB: diathermy was first presented after WWI by Harvey Cushing and Dr Bovey as the “Bovey Electrocautery Tool”) and, thanks to Cairns’ foresight, instruments for over 200 operations. A MNSU was to be attached to a casualty clearing station or to a base hospital (6, 20).

The MNSU concept took inspiration from the teachings of Cushing. The first neurosurgical operation was to be definitive, with subsequent operations considered unsatisfactory and carrying greater risk of complications. Preceding modern military resuscitation strategies such as Battlefield Advanced Trauma Life Support (BATLS), there was little place for first-aid neurosurgery in the field, aside from control of catastrophic haemorrhage (23). Through definitive surgery, the incidence of infection, brain abscess and meningitis was reduced from 25% to 5%, with 90% of wounds healing by primary intention (20).

There were nine MNSUs in total, but the programme had inauspicious beginnings. The first, unnumbered prototype was captured in France along with 800 patients during the Dunkirk evacuation and never deployed again. Others failed due a lack of understanding of their usage and potential. Number 4 MNSU was arguably the most successful during its advance with the 8th Army. Adapting the MNSU concept, a captured Italian coach was modified to facilitate a greater throughput of serious cases, with the original MNSU vehicle working further back on more minor head injuries (Figure 10). In addition, using Numbers 4 and 5 MNSU, Cairns and his Oxford associate Howard Florey conducted one of the most important trials in 20th century surgery. In spite of the impurity of the early samples, the first large-scale trial of penicillin was performed in five hospitals at Tripoli and Sousse in 1943. As a result of this trial, Numbers 4 and 5 MNSU used penicillin in mainland Italy, where its value became apparent in the treatment of infected wounds, pyogenic meningitis and prophylaxis of brain abscess. Consequently, MNSUs developed an antibiotic regimen that became the standard treatment. Of particular note was the ability of Cairns’ team to maintain meticulous records of the penicillin trial, including swabs, pus and cerebro-spinal fluid (CSF) samples whilst under fire. The strength of Cairns and Florey’s results proved beyond doubt the significance of penicillin and, although initially classified, they ultimately facilitated international support for mass production and distribution of the drug (24, 25).

Figure 5. The British Army’s first mobile brain surgery unit, which consisted of five specialist doctors and two sisters, 25 April 1940. (Imperial War Museum)
Cairns published outcomes from the MNSUs in 1947. The seven active MNSUs dealt with over 20,000 casualties. Eighty percent of head injuries in all theatres were treated by a MNSU, demonstrating the overwhelming success of the concept. Around 90% of those with scalp wounds and simple skull fractures returned to their units and 70% of those with penetrating wounds returned to employment. Brigadier Cairns was awarded a knighthood in 1946 (26).

The legacy of the Second World War
The success of the MNSUs had far-reaching significance. Retired United States Army Medical Corps (USAMC) neurosurgeon Michael Carey described the impact of the MNSUs, writing: “So successful was the British MNSU concept that it was adopted by the Canadian Army during World War II and borrowed by Colonel Arnold Meirowski for the American Army in Korea. The American Army neurosurgical detachments and their overall configurations used in Vietnam, Desert Storm and maintained to this day, are direct descendants of the British MNSUs in World War II” (20). Carey was awarded the Order of Military Medical Merit in 1993 for his contributions to military medicine.

It was not only the Allied side that produced innovators. Ludwig Guttmann (1899-1980) was a German Jew, who between 1917-18 in WW1 worked as a medical orderly in an accident hospital in Königshutte, before embarking on a successful career in neurosurgery. Resisting the rising tide of anti-Semitism, he was finally forced to leave Germany with the aid of the Academic Assistance Council in December 1938. He relocated to England, taking a post in the John Radcliffe Hospital at Oxford under the patronage of Hugh Cairns. Working in paraplegia research as a naturalised British citizen, Guttmann discussed offering his services to the Army. Cairns felt that he would be better continuing his work in paraplegia, and in September 1943 Guttmann became Medical Director of Stoke Mandeville Hospital. This appointment allowed Guttmann to implement his belief that sport was a major therapy for injured military personnel, both in terms of physical strength and self-respect. Modern neuro-rehabilitation was born. Guttmann organised the inaugural Stoke Mandeville Games on 28 July 1948 to coincide with the opening day of the London Olympic Games. As an annual event, and gathering global recognition, these games were eventually endorsed by the International Olympic Committee as the Paralympic Games (27).

Conclusion
Cushing was responsible for establishing neurosurgery, but it was Cairns, and those he inspired, who led the development and advancement of the specialty within the United Kingdom and beyond, through his unyielding leadership and passion for teaching. Cairns was known as the great teacher of British neurosurgery. He was heard to emphasise the need to hold specialist skills in reserve, especially between conflicts, as they cannot readily be obtained after the outbreak of war. Cairns’ work showed that early deployment of neurosurgeons improved outcomes and quality of survival beyond all doubt (20). After 100 years of service and the sacrifices of so many, military medical leaders and neurosurgeons of today must never let the lessons of these giants go unheeded, nor fail in the duty as guardians of their legacy.

Author
Surgeon Lieutenant Commander Stuart Roberts RNR
The Computational, Cognitive and Clinical Neuroimaging Laboratory (C3NL),
3rd Floor, Burlington Danes Building, The Hammersmith Hospital, Du Cane Road, London, W12 0NN
stuartroberts@nhs.net

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