The War of Independence: a surgical algorithm for the treatment of head injury in the continental army

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The American Revolution was a gruesome war that resulted in the independence of the United States of America from the British crown and countless casualties to both belligerents. However, from these desperate times, the treatment of traumatic head injury was elucidated, as were the origins of American neurosurgery in the 18th century. During the war, the surgical manual used by military field surgeons was titled *Plain Concise Practical Remarks on the Treatment of Wounds and Fractures*, by Dr. John Jones. This manual explains the different types of cranial injuries understood at that time as well as the relevant surgical treatment. This article seeks to review the surgical treatment of head injury in the Revolutionary War as outlined by Dr. Jones's manual.

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THE first shots that sparked the beginning of the American Revolutionary War took place at the battles of Lexington and Concord on April 19, 1775, between British regulars and a militia sanctioned by the Massachusetts Provincial Congress.^{1,24,43} A few days earlier, on April 15, 1775, General Thomas Gage had received a letter from Lord Dartmouth, the Secretary of State for the Colonies, ordering him to arrest key leaders of the Massachusetts Provincial Congress and confiscate military supplies that had been stored.^{1,24,43} In response to this, Gage made arrangements for approximately 800 British soldiers under the command of Lieutenant Colonel Francis Smith to move out on the night of April 18, destroy the military supplies at Concord, and arrest John Hancock and Samuel Adams.^{1,10,24,43,64} However, British troop movement had been spotted that night and Paul Revere and William Dawes were instructed to set out on their famously dramatized “midnight ride” to warn John Hancock, Samuel Adams, and the town of Concord of the threat. These events precipitated the battles at Lexington and Concord, and Bunker Hill, which marked the beginning of the American Revolution.^{1,3,10,23,24,64}

At the time of the Revolution in 1776, only two medical schools existed in the colonies.^{6,19,26,42,50} However, there were an estimated 3500 medical practitioners with varying degrees of training. Some had attended a medical school, others served apprenticeships, and many had little or no

formal training whatsoever.^{8,19,48,50,53,63} In fact, it has been estimated that in 18th-century colonial America, about only 350–400 physicians, or 1 in 9, had a medical degree.^{6,7,14,50} There were very few hospitals, tools and supplies were limited, and close military quarters were a nidus for poor sanitation and hygiene.^{19,34,42} In addition, contaminated food and water supplies contributed to the spread of illnesses among the soldiers.^{19,42} Therefore, injuries and infections that soldiers suffered led to a high morbidity and mortality rates.^{19,42,50} Head injuries in particular were considered a challenging injury to treat.^{35,56,61} Some of the major treatable head injuries included scalp lacerations, scalpings, concussions, and skull fractures.^{11,35,47,56,61} The treatment of wounds was largely in the hands of field surgeons who used their surgical field manuals as a guide.^{16,32,48,54,57} The field manual was composed of two sections, with the most critical section on surgical treatment titled *Plain, Concise Practical Remarks on the Treatment of Wounds and Fractures* (Fig. 1) by Dr. John Jones (Fig. 2), first published in 1775.^{16,52,60}

Dr. Jones was one of the original founders of King's College Medical School, now known as Columbia College of Physicians and Surgeons.^{32,45,52,58} He was also the first Professor of Surgery at King's College, and his text is considered to be the first all in one military medical and surgical manual written and published by an American in North America.^{16,32,41,48,53,54,57} Other surgical manuscripts existed

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FIG. 1. *Plain Concise Practical Remarks on the Treatment of Wounds and Fractures* (1775) by Dr. John Jones. Courtesy of The New York Academy of Medicine Library. Public domain.

at the time, but these texts would most likely have been known only to educated physicians or those with access to a book vendor, while Dr. Jones's text was the principal surgical manual used by the Continental Army, outlining the surgical treatment of injured soldiers.^{6,13,16,26,32,34,53,54,56,57} The manual draws on common surgical practices of the most highly regarded surgeons of the time, along with clinical cases of patients seen by Dr. Jones.^{13,17,35,55} Therefore, the manual can be thought of as a surgical review of the best contemporary practices, which Dr. Jones thought would be most useful to a military field surgeon.

Anatomy

The history of the discovery of cranial anatomy, cerebral physiological function, and localization are expansive topics outside the aim of this paper. However, in regard to the understanding of cranial anatomy at the time of

FIG. 2. Portrait of Dr. John Jones (1729–1791). Courtesy of The New York Academy of Medicine Library. Published with permission.

the American Revolution, credit can be given to the efforts of 17th-century European anatomists as well as their predecessors.^{12,31,40,44,65} The general understanding of cerebral physiological function during the 18th century was largely derived from the work of Galen.³¹ The cerebral hemispheres were thought to produce animal spirits that were stored within the ventricles.³¹ This animal spirit was essential to the functioning of humans and represented the connection between the brain and body.^{25,31} Nerve function was also understood in galenic terms, in that it was believed that the animal spirit would travel through nerves to facilitate sensory and motor functions.³¹ Initial efforts at cerebral localization had been undertaken by Willis in the 17th century. However, the galenic concept of localization only began to be disproved at the end of the 18th century, first by the now defunct phrenological system of Gall, and then by others.³¹ Although it was becoming less accepted, the galenic explanation of nerve function with animal spirits as the medium persisted into the 19th century in spite of experiments with electrophysiology by Galvani at the close of the 18th century, who himself believed in galenic animal spirits.³¹

On review of the cranial anatomy covered by Dr. Jones, it is clear that the anatomy covered is very specific to what Jones felt that a field surgeon would need to treat cranial injuries, and not a formal text of anatomy.³⁵ In fact, in his

opening chapter on head injury he states that the surgical treatment of head injury is challenging and risky and that the chapter's goal would be to provide knowledge for the inexperienced surgeon.³⁵

The cranial anatomy seen in the head injury chapters is related to the scalp, bone, and meningeal coverings, and there is a brief mention of the left and right lobes of the cerebrum.³⁵ Jones also mentions the medulla and cerebellum in other chapters as being areas where injury usually causes death.³⁵ When explaining treatment for lacerations of the scalp, Dr. Jones states that the scalp should not be viewed in the same way as the skin on other parts of the human body.³⁵ This is because the scalp is made up of skin, adipose tissue, aponeurosis, pericranium, tendons of the cranial muscles, and communicating blood vessels.³⁵

The skull was understood to have sutures that interconnected cranial bones.³⁵ The frontal sinus is also mentioned in relation to a possible location of trephination when necessary.³⁵ Jones states that the diploe are features of skull thickness that should not be relied on because of variability from person to person.^{35,56} Jones recalls many cases in which inexperienced surgeons relied heavily on the diploe only to pierce the dura and cause damage to the brain when the operation began.³⁵ Two of the three meningeal coverings of the cerebrum are described accurately as the dura mater and pia mater.³⁵ Throughout Dr. Jones's three chapters relating to cranial pathology there is no mention of the arachnoid mater as a separate meningeal layer, despite its discovery in the 17th century by Humphrey Ridley.^{35,62} Intracranial and extracranial vasculature are not well documented in the text despite efforts of other 17th-century anatomists such as Thomas Willis.^{35,65} However, there is an understanding of dural venous sinuses and an indirect description of the middle meningeal artery as an artery that could hemorrhage when trephination of the temporal bone above the ear was performed.³⁵

Classification

During the War for Independence, the British standard issue musket was the Brown Bess.^{2,15,20,39} Therefore, one of the most common wounds sustained by Continental Army soldiers was by musket ball.^{18,20} Other weapons that were also used during the war included knives, bayonets, pistols, clubs, hatchets, sabers, and cannons.^{2,18,20,39} Jones discusses the treatment of head injury in the 1775 edition of his text in three chapters entitled: *Chapter VII: Of Blows On The Head*; *Chapter VIII: Of Injuries Arising From Concussion Or Commotion*; and, *Chapter IX: Of Injuries Arising From A Fracture Of The Skull*.³⁵

Dr. Jones provides a succinct description of his three chapters:

The first, comprehending the injuries to which the scalp and investing membranes of the skull are liable. The second will treat of the symptoms arising from a commotion or concussion of the brain; and the third, shall comprise those complaints which are occasioned by a fracture of the bones of the skull, and its effects on the parts beneath.³⁵

However, because the same injuries are discussed as they occur in different locations, the chapters are not isolated from one another, and so rather than an analysis of

the chapters, treatment of individual injury types will be reviewed. The figures throughout this article were created after carefully reviewing Jones's manual. They therefore do not necessarily represent Jones's thought process, but are useful in elucidating probable steps in the treatment of head injury as outlined in his manual. Figure 3 shows the initial classification of head injury into injury type.

Until the 18th century, the treatment of head injury had largely been based on the Hippocratic concepts of *De Vulneribus Capitis*, which can be considered to be one of the first systematic works on the subject.²¹ Beginning in the 18th century, more significant literature specifically devoted to the effects of trauma on brain function began to appear.²¹ We would like to note that what follows is not a review of 18th-century surgical treatment of head injury, but is instead based upon Dr. John Jones's manual, which was used by the Continental Army during the War of Independence. As evidenced by his introduction and his numerous references to practices and recommendations of other surgeons, Dr. Jones reviewed the work of various preeminent European surgeons, some of whom had been his teachers, to construct what he felt would be a useful manual for a war-time field surgeon.³⁵ In particular, the teachings of Petit, Le Dran, and Pott, all of whom had been his teachers, are represented in his views on trephination and also within the three chapters on head injury.^{22,37,66} Jones could not have been more fortunate in his studies to have had the opportunity to learn from three such men who are all regarded as key figures in the rise of neurological surgery in the 18th century.^{21,22} However, although Dr. Jones understood that the symptoms associated with head injury were a direct result of damage to the brain and not the skull, he, similarly to Pott, also believed in the prophylactic trephination of undepressed skull fractures to prevent the development of symptoms.^{21,22,35} It would not be until Benjamin Bell's publication of *A System of Surgery* that the idea of prophylactic trephination would come to an end.^{4,21,22}

In comparison with other surgical texts of the time, Jones omitted many extraneous surgical treatments in his text that he believed a war time surgeon would most likely not use.^{9,11,29,35,47,56} Hence the name of the manual begins with the words "plain, concise, and practical," and with the added notation on the title page stating that its use was intended for young military and naval surgeons.³⁵

Scalp Injuries

Scalp injuries were classified according to cause as incisional, puncture, contusion, or laceration.^{9,11,35,47} With all scalp injuries, there is a possibility of underlying intracranial injury as well.^{11,35,47,56} Therefore, a contusion was an example of an injury to the scalp that could have life-threatening consequences, despite the potential absence of physical injury.^{11,35,47,56} Common superficial scalp wounds caused by incision were in general not treated; however, when necessary, larger incisions could be treated by suturing or bandaging to ensure that the wound edges would meet.³⁵ Punctured scalp wounds were more often surgically treated than were simple incised scalp wounds because of the accumulation of fluid within the

FIG. 3. Algorithm for initial treatment of head injuries. ¹With scalp injuries, fractures and concussions, it is important to understand that there can be concomitant intracranial injury. ICP = intracranial pressure.

wound.^{11,35,47} But after drainage, punctured wounds were treated the same as incision wounds even if complications followed.³⁵ When complications of scalp wounds, such as significant inflammation, delirium, lock jaw, or fever arose, the algorithm changes to consider medical treatment with anodynes, purgatives, antispasmodics, and bleeding.^{27,35,46}

Dr. Jones does not delve into great detail about the differences of scalp injuries, but Percival Pott, one of the surgeons whom Jones held in high regard and whose teachings are clearly reflected in his manual, goes into greater detail in differentiating scalp injuries.^{35,47} In particular, Dr.

Pott classifies lacerations into two separate types: one in which there is laceration that results in detachment of the scalp from its underlying structures, and the other in which there is no detachment.⁴⁷ For lacerations with pericranial detachment, Jones recommends that the wound should be carefully cleaned and reapproximated as much as possible with interrupted sutures, ligature, and slip knots, and then dressed with bandages.³⁵ Complications that could arise, especially when reapproximation was not perfect, were the development of small abscesses, which were treated by drainage.³⁵ The treatment algorithm for scalp injuries is shown in Fig. 4A.

FIG. 4. A: Algorithm for treatment of scalp injuries. B: Algorithm for treatment of scalping injuries.

FIG. 5. Algorithm for treatment of concussion. ¹Symptoms of concussion included vertigo, vomiting, restlessness, and fever. ²Medical treatment includes bleeding, purgatives, and anodynes.

Scalpings

Among the British allies were also Native Americans who would use knives to scalp their fallen enemies.^{18,30,61} Although most cases of scalping resulted in the victim's death, some individuals did survive and required treatment.^{33,59} Despite there being different surgical treatments that had been established by Celsus, Galen, Hippocrates, Belloste, and Boerhaave, the treatment for a scalped head is nowhere to be found in Jones's three chapters describing the treatment of head injury.^{35,38,49,59} However, this does not mean that scalped heads were not successfully being treated during the war.

In the military journal that he kept throughout the Revolutionary War, Dr. James Thacher recorded the case of a man who had been scalped by British-allied Iroquois tribesmen.⁶¹ Although the method of treatment is not described, it was successful and the man's scalp was restored, albeit without hair.⁶¹ There is another case where the method of treatment is properly laid out. A scalping case occurred in 1777 in Tennessee in which treatment was delivered and the scalp restored successfully.^{33,38,51,59} An awl was used to bore small holes into the diploe of the skull soon after the scalping.^{38,59} The holes were placed approximately 1 inch apart, and after granulation had begun, additional holes were placed between the previously bored holes.^{38,51,59} This method would completely re-epithelialize the scalp in about 2 years.^{38,51,59} The technique

of puncturing holes in the skull soon after a head injury that had caused significant loss of the scalp in order to accelerate granulation and re-epithelialization has been attributed to Belloste and is described in his surgical text of 1696.^{5,38,49,59} Figure 4B details the treatment algorithm for scalping injuries.

Concussions

Concussions were another head injury suffered by soldiers during battle, and it was understood that the injury was to the brain and did not necessarily present with signs of visible physical injury to the cranium or underlying fracture.^{11,35,47,56} There was also a distinction made between symptoms arising from a concussion and those associated with intracranial extravasation of fluid or inflammation.^{11,35,47} According to Dr. Jones, a concussion would result in vertigo, vomiting, restlessness, difficulty sleeping, and occasional fever.^{35,47} Medical treatment used bleeding, purgatives, and anodynes rather than surgery.^{35,47,56} If, however, symptoms of the concussion should return after proper treatment, it was believed that this was a sign of possible intracranial pathology.³⁵ The next step would then be to shave the head and examine the skull for a possible missed contusion.^{35,47} If nothing was found, then medical treatment would continue,^{35,47,56} but if there were any irregularities of the skull that might indicate intracranial pathology, the trephine would then be used.^{11,35,47,56}

FIG. 6. Algorithm for treatment of skull fracture. ¹Prophylactic treatment of undepressed fractures was advocated by Dr. Jones because he felt that the number of deaths attributed to nontreatment was greater than deaths after treatment.

Concussions during the war were treated with great caution and thoroughly examined, because if a more severe intracranial injury was suspected, a potentially lifesaving trephination might be necessary.^{35,56} Figure 5 details the treatment algorithm for concussions.

Fractures

Fractures of the skull were fundamentally considered under one of two headings: depressed and undepressed.^{35,47,56} Depressed fractures would always be treated with trephination due to cerebral compression, while treatment for undepressed fractures varied.^{35,47,56} It was understood that head trauma resulting in skull fracture was not dangerous by itself, but that the resulting intracranial pathology such as direct injury/compression, inflammation, and hemorrhage were of concern.^{28,35,47,56} Jones and Pott believed that treatment of undepressed skull fractures by trephining should be executed to release fluid buildup that was raising intracranial pressure, for evacuating an accumulation as a result of dural inflammation, or prophylactically to prevent potential complications.^{35,47} Symptoms of traumatic head injury were well documented and could include nausea, vomiting, fever, delirium, drowsiness, seizures, aphasia, incontinence, paralysis, and bleeding from

the orifices of the cranium.^{11,28,35,47,56} However, when none of these symptoms were present from an undepressed fracture, the question of prophylactic surgical trephination arose.^{35,47} According to both Pott and Jones, the trephination of an undepressed fracture before any worrisome symptoms appeared was a prudent decision.^{35,47} Jones felt that when comparing the numbers of people without treatment who died of complications of undepressed fractures against those who died after treatment, the death rate was higher from nontreatment.^{35,47}

Depressed fractures were always treated because the depressed bone fragments could cause cerebral compression and associated symptoms as described above.^{11,35,47,56} The general treatment algorithm required trephination to access the depression; an elevator would then be used to lift up the depression and relieve impingement on the underlying dura and brain.^{11,35,47,56} Any bone fragments that could cause further injury were also removed with forceps.^{11,35,47,56} In addition, a lenticular was used to smooth the edges of the trephined hole.³⁵ Depending on the injury, elevation could cure all symptoms; however if it did not, further treatment was necessary.³⁵ When the depressed fracture was significant and the segment isolated from the surrounding skull, treatment entailed removing either a part or the whole section of skull depression.^{35,47} Other than surgical treatment,

FIG. 7. Trephination algorithm. Jones identifies a “fungus” as a potential complication after trephination is complete.

medical treatment for cranial fractures used anodynes and bleeding to help reduce inflammation.^{35,47} Figure 6 shows the treatment algorithm for cranial fractures.

Trephination

Trephination was performed for cases of head injury with and without fracture when the patient displayed worrisome symptoms of cerebral injury.^{11,28,35,47,56} Trephination was ordinarily avoided in locations such as the sutures, the occipital bone, the sinuses of the frontal bone, and the temporal bones.^{35,47,56} However, Jones firmly believed that the dangers of nontreatment were far greater than an attempt at trephination in these risky locations. He argued that those patients who died when trephination was attempted died of the extent of their injury as opposed to the insults introduced by performing the trephination.³⁵

During the War for Independence, an established method for trephining was already in practice.³⁵ Before the operation began the patient was either lying down or was sitting in a chair with the operator's assistants firmly holding the head in place.^{11,35,56} The operator would then proceed to cut through the scalp down to the skull with a scalpel.³⁵ During dissection of the scalp, bleeding was a common complication that could be controlled with dry lint and pressure to the area or, if necessary, a ligature.³⁵

If a fracture was discovered, it would be completely exposed to ascertain the type of fracture as well as the best position for trephination.³⁵ Enough of the scalp and pericranium would then be removed to trephine the necessary area.³⁵ For undepressed fractures, the trephine would be placed in a position such that the fracture was centrally aligned with equal portions of unfractured bone on either side.³⁵ One hole was in general considered to be enough for the treatment of undepressed fractures.³⁵ On the other hand, for depressed fractures, the trephine was placed so that only a portion of the depression was within the trephine's drill so that the depression could be raised by the elevator after successful surgery.³⁵ The number of holes necessary to properly treat depressed skull fractures was left up to the surgeon because it varied from injury to injury.³⁵

After the trephined bone was removed, the edges of the hole would be smoothed with a lenticular if necessary.³⁵ The surgeon would then look for hemorrhage between the skull and dura and evacuate it.³⁵ Symptoms would normally subside after a few hours.³⁵ However, if nothing was found and the patient's symptoms persisted, the dura would be divided to release whatever lay underneath it.³⁵ After the operation, lint was used to fill the hole created by the trephine and dressings were applied to the wound.³⁵

One complication that Jones specifically mentions from trephination or when portions of the skull were removed

FIG. 8. Trephination kit circa 1780. Courtesy of the Rose Melnick Medical Museum, Youngstown State University. Published with permission. Figure is available in color online only.

is a “fungus” that came from the dura mater.³⁵ What Jones is describing is cerebral herniation, which he unsuccessfully treated in one case presented in his text.^{13,35} The case involved a 14-year-old boy who had fallen from a window and fractured his left parietal bone.³⁵ Jones performed trephination 2 days after the incident and was able to remove an epidural hematoma; however, several days later he noticed a “fungus” rising up out of the trephined bur

FIG. 10. Instruments in a trephination kit. **A:** Forceps, which are used to remove loose or broken pieces of skull. **B:** Lenticular, which is used to file the edges of the trephined opening smooth. Courtesy of the Rose Melnick Medical Museum, Youngstown State University. Published with permission. Figure is available in color online only.

holes.³⁵ The method he used to treat the herniation was to perform a repeat trephination to release the “fungus” from skull impingement and then apply compression with dressings.³⁵ However, when this failed, he tied string around the herniated segment allowing it to necrose and fall off.³⁵ The young boy developed a fever and then a larger second herniation, which was treated in a similar fashion, and ultimately died.³⁵ Autopsy performed by Dr. Jones revealed that the entire left cerebral hemisphere was destroyed and half the right hemisphere converted to pus.³⁵ Of note, in the 1775 edition of Jones’s manual, a typo exists stating that what was destroyed was the left cerebellum.³⁵ However, this was corrected to cerebrum in the 1776 edition and persisted as cerebrum in the 1795 edition of the manual.^{36,37}

It is clear that trephination was used to treat epidural hematomas, subdural hematomas, and increased intracranial pressure, and was imperative for the survival of soldiers who suffered from traumatic head injury. Figure 7 details the treatment algorithm, and Figs. 8, 9, and 10 show the instruments from a trephination kit used in the 1780s, which are representative of instruments used during the Revolutionary War.

Conclusions

In a time period that has been heralded as an enlightened era of neurosurgery, Dr. Jones’ manual represents a period of transition from osteology to surgical neurology.^{21,66} Were it not for Dr. John Jones’ manual, the Continental Army field surgeon would be ill-equipped in dealing with the surgical treatment of scalp, skull, and intracranial inju-

FIG. 9. Instruments in a trephination kit. **A:** Wooden handle of the trephine. **B:** Circular drill head, which fits into the metal shaft of the wooden handle. **C:** Bristle brush used to clean the teeth of the circular drill head. **D:** Elevator, which is used to lift depressed skull fracture fragments. Courtesy of the Rose Melnick Medical Museum, Youngstown State University. Published with permission. Figure is available in color online only.

ries. *Plain Concise Practical Remarks on the Treatment of Wounds and Fractures* can therefore be considered one of the earliest examples of American trauma and neurosurgical literature.

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Disclosure

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Author Contributions

Conception and design: Sabourin. Acquisition of data: Sabourin, Shah, Yick. Analysis and interpretation of data: Sabourin, Shah, Yick. Drafting the article: Sabourin, Shah, Yick. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Administrative/technical/material support: Prestigiacomo, Gandhi.

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