A Forgotten Tale from the Great War: General Lorenzo Bonomo and the Birth of Italian War Neurosurgery

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Key words
- Gunshot
- Head trauma
- High velocity
- Traumatic brain injury
- WWI

Abbreviations and Acronyms
GrTBI: Gunshot-related traumatic brain injury

INTRODUCTION

Before and during the Great War, the employment of high-velocity rifles by armies, including the Italian Royal Army, had coincided with an increase in the rate of gunshot-related traumatic brain injury (GrTBI). Despite the advances in acute and long-term care for civilians and military, this remains one of the most severe conditions known. It is usually fatal within a very short time regardless of treatment.1-12

The Personality of Lorenzo Bonomo

Little is known of the advances in battlefield medicine achieved in Italy before and during the Great War. Some deserve wider recognition; this is especially true for the field of neurosurgery. There are a limited number of historical records currently available, fewer still in English, and most of the systematic investigations on field surgery have been in the form of monographs within science history reviews, which obviously lack a strictly clinical perspective. Together with shell shock, the gunshot-related traumatic brain injury (GrTBI) is considered one of the typical, or signature, lesions of the Great War. It was intrinsically linked to trench and mountain warfare: to view the battlefield from a trench/hiding area, soldiers’ heads and necks were repeatedly exposed, therefore making them the most likely target for snipers. Military physicians therefore focused their efforts in the clinical and experimental treatment of GrTBI. Among notable contributions of the military surgeons of the time, there is a volume of selected war-surgery lectures conserved in the archives of the Library of the Italian National Academy of Military Medicine. These lectures shed light over the work of General Dr. Lorenzo Bonomo. His incredibly advanced and modern ideas had unfortunately been forgotten. He pioneered research in the ballistic and forensic medical fields, building on first-hand experience, as he performed surgeries himself before the conflict and even while on the frontline, actively working to improve the chances of survival for the Italian troops fighting in the Great War.

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“War Traumatology”

The scientific observations of Dr. Bonomo were transcribed, edited, and then compiled into an anthology by his students, Drs. Forino, Durante, and De Ciarla. The anthology is split in different volumes (Figure 3), meant to be used as vademecum (handbooks) for military physicians. The subjects span from general practice to neurosurgery in war zones. Illustrations of brain injuries caused by gunshot wounds to the head found in “Traumatologia di Guerra” punctually and strictly reflect the neurologic, clinical, and pathologic descriptions provided by Dr. Bonomo.

The original papers are carefully preserved at the “Scuola di Sanità Militare” (School of Military Health) of the former military hospital of Florence, Italy (Figure 4).

Our aim is to bring to the fore the forgotten work of Dr. Bonomo on GrTBI. We analyze in particular the outstanding similarities between his considerations on the anatomic, clinical, and pathologic classifications and management of head injuries, and later works on the same subjects. All the excerpts quoted in this paper can be found in the treatise “Traumatologia di Guerra,” in the first section of the volume (“Head Injuries”), in the chapter Penetrating Injuries to the Skull. The volume is kept along with all the aforementioned extracts at the former Military Hospital of Florence, Italy. The edition we avail of dates back to a time before the Great War (1906–1907); nevertheless, the innovative concepts of his teachings were considered to be completely valid, and foreseeing of what the Medical Service of the Italian Royal Army would have experienced at the frontline, and coherent with the rest of the scientific production of the author during and after the Great War.

THE BULLET RIDE: BULLET HOLES AND SKULL FRACTURES

Lessons 119:22, “Bullet penetration affects the cerebrum more critically than other organs, because of the cerebrum’s structure enclosed in a bony box, and its scarce ‘molecular’ (see below for a translation note) cohesion. The substance the Cerebrum is an excellent propagation medium for ‘molecular’ concussion, whose outward force leads to the expansion of the braincase. [...] 103:13 How to explain, otherwise, the lack of explosion and wide cranial fractures in shots against empty skulls, encased in soft skin envelopes? The outward distribution of ‘molecular movements’ of the cerebral substance explains indirect fractures to the cranial surface.”

It was at the end of World War II when Butler et al.15 described the peculiar effect of a shot to the head of a dead body, compared with a shot against an empty skull in controlled experimental settings. The former, in fact, showed wider bone fragmentation, compared with the empty skull. The author group concluded that the skull’s content, the cerebrum, was responsible for transmitting shockwaves to the cranial walls, therefore amplifying the blast wave and producing more extensive cranial fractures than those observed on empty skulls. These conclusions are still valid today. The kinetic energy of the percussion wave around a bullet or shrapnel transfers to the brain’s parenchyma and eventually to the cranial walls, therefore determining the typical GrTBI cranial fractures. From the aforementioned excerpt, it is clear that Dr. Bonomo had already made the same observations, and his experiments...
antedated Butler’s observations (Figure 5). As a translation note, we specify that the author used the Italian term molecolare, which recognizes “molecular” as the English translation. We presume that it meant “at a tissue level,” but the original text contains no further clarifications.

Lessons 120:1 “Shots at very close-range turn cerebral substance into mush. Bullet shrapnel, bone splinters and hair are commonly found within the trajectory wound, outwardly, towards the exit wound. These severe explosive effects on the cranium can be observed when the shot is fired through modern war rifles from within a 500 meters range. Beyond that range, cerebral damage is less acute. When a shot is fired from within a 1200 meters range, the cranium presents perforations and sometimes short, sometimes times long radial fractures. In the brain it is possible to observe approximately 1 or 2 cm wide bullet tracks with a limited extent of collateral hemorrhagic contusion. Within the 1600—2000 meters range, the cranium presents commonly simple cranial perforations, along with short radial fractures and a filiform blot clot.”

In this excerpt, the author anticipates one of the key concepts of the pathophysiology of GrTBI: the morphology of temporary and permanent cavities is determined by distance, velocity, and other features of a firearm, and the extracranial trajectory of the shot. Temporary and permanent cavities are the pathologic expression of mechanical energy conveyed onto the brain’s parenchyma by a penetrating bullet. Their formation and configuration have historically been described by Harvey16 and Kirkpatrick and Di Maio12: the bullet or shrapnel penetrates the cranial wall, and the percussion (shock) wave dilates the brain’s parenchyma and creates a temporary cavity along the bullet’s trajectory. When the mechanical energy is exhausted, the walls of the temporary cavity return in place like rubber bands, and the temporary cavity subsequently shrinks into a significantly smaller permanent cavity. If temporary or permanent cavities involve blood vessels, GrTBI is complicated by extravasation and consequent brain hemorrhage. As recognized and confirmed by later authors, the distance and direction of the shot, the firearm velocity and bullet caliber, or the shrapnel size all contribute dramatically to the final shape of temporary and permanent cavities10-12.

Lessons, 85:18 “The firearm produces a variety of cranial lesions: contusions, abrasions, perforations, and fractures, which can be incomplete, complete, linear, non-linear star-shaped, comminuted. […] Fissures radiating from a cranial perforation can run along the diameter of the cranial vault, halting at sutures, crossing over sutures, particularly when synostosis is already completed. When a shot is fired from within the ‘Explosive Zone’ (800–1000 meters range), radial fractures are found combined with circular fractures, which can form great triangular-shaped splinters around the exit wound. 901 […] The relatively small perforation of the pericranial tissues which however causes
outstandingly wide cranial fractures, demonstrates that the explosive effect of a projectile is transmitted almost instantaneously onto the braincase and its content. When impacting or penetrating the cranial base—the pyramid for instance—a bullet loses a notable amount of ‘live’ energy. The way entry and exit fractures radiate represent the most compelling evidence of the outward mechanism of diffused pressure from intracranial content, namely the cerebrum, onto the cranial walls. When a projectile hit the braincase perpendicularly, the perforation at the point of entry is a few millimeters smaller than its caliber; in the inner table, the perforation size grows and causes profuse symmetrical splintering, thus resulting in a loss of substance in the shape of a truncated cone. On exit, the perforation is wider and less regular, since the loss of substance involving the outer table is more extensive. There is no precise and constant relationship between the power of a weapon, the distance of a shot, and the main features of a cranial lesion.

In the present excerpt, Dr. Bonomo describes with noteworthy precision of 3 different morphologic expressions of gunshot-related cranial fractures: cranial entry and exit fractures, radial fractures, and skull base fractures. Other coeval and modern authors also provided similar descriptions: circular comminuted fractures of the cranial vault around entry wounds, which generate longer compounded fractures with the possible involvement of cranial sutures, and notably greater and more irregular fractures by exit wounds (Figure 6).

The rest of the paper includes meticulous descriptions of how bullets bounce and slither in the intracranial compartment, showing Dr. Bonomo’s deep interest in studying the ballistic of gunshot to the head.

**EXPERIMENTAL GrTBI**

**Lessons, 97:15** “With the following experiment we demonstrate the extracranial deviation of a projectile. The weapon is firmly fixed to a vise at 40 cm. At the end of the barrel and exactly perpendicular to its course, a block of soap is interposed between the weapon and a cardboard target. Upon shooting, the bullet hits a precise point of the target; however, if we interpose between the barrel and the target a fresh cadaveric head, we notice that the second hole does not coincide with the first: the difference is around 4–5 millimeters, but it can reach up to 10, 15 and 20 millimeters.”

“The same I discovered with a revolver shot through the ear and temporal region, shooting in the direction of the pyramid. The bounce trajectory varies according to the incidence of deformations on the projectiles. The width of the rebound is greater, when the shape of the bullet remains intact. A service revolver projectile perforates 2 cms above the zygomatic arc, hits the contralateral pyramid, on which it determines a radial fracture, and stops in the contralateral parietal bone.”

As military medicine in Italy was gaining structure and organization, similarly to the rest of Europe and the United States, experiments on the ballistic effects of bullets were deemed critical for...
interpreting cranial wounds, for understanding the pathophysiology of GrTBI, and for subsequently planning and executing effective treatment on the frontline. In these excerpts, a block of soap and a cadaveric head were used to simulate a living head (Figure 7).

Nowadays, the most appropriate material to approximate the ballistic effects of GrTBI is still a matter of debate.9 Prototypes include cylinders made of plastic/wood/polymer with or without brain-like gelatin inside, polyurethane spheres filled with 10% gelatin conditioned at 4°C, and polymeric spheres containing 10% gelatin.a,b,9 Assembling the most realistic possible prototypes was important back then, and still remains today. Among the reasons is the need for accurate assessment of effects on the brain’s parenchyma of different bullets—for instance, how low- or high-velocity rifles determine different temporary cavities—and the investigation of the shielding effects of helmets, which are still of paramount importance in preventing GrTBI fatalities in combat.

**BRAVE NEW WORLD, OLD COLD STEEL**

**Lessons, 118:11** “The high lethality of intracranial infections is one of the reasons in favor of debridement of cranial wounds, until the cranial vault is systematically exposed. Before the Russian-Japanese conflict, it was widespread opinion, among those writing on war surgery, that the new high velocity rifles would significantly reduce wound contamination in comparison to the old cold steel weapons. But this great war (Russian-Japanese conflict, t.n.), has outlined the fallacy of these assumptions, since high velocity and long-range rifles do not exclude the eventuality of close combat. After long and fierce fighting across vast expanses, it is frequent to resort to short blades. […] 118:26 When a weapon vigorously stabs cranial walls, a perforating wound becomes likely. Bony hemorrhages and concussions events are therefore expected, as well as cerebrospinal fluid outflows in the event of the dura mater involvement. […] 119:6 Pupillary asymmetry is pathognomonic: when ipsilateral to the wound, the hemorrhage is extra- or subdural; when it is on the opposite side, the lesion is purely cerebral.”

In these excerpts, Dr. Bonomo accurately describes to his students the harsh reality on the frontline. Despite notable advances in artillery technology and the introduction of new weapons such as the machine gun and high-velocity rifles—along with systematical employment of relatively new combat strategies, like the deployment of snipers—the use of blades was still praised and glorified in combat tactics manuals as the symbol of infantry charge, and was seen as the only solution to trench warfare deadlock (Figure 8).18 Therefore, blades still caused a relatively high number of wounded and casualties among the fighting divisions.16,22 Besides, it is of note that other important authors, such as Cushing and Keen, contemporary to Dr. Bonomo, also discussed wound debridement. Even though Anglo-American influence might have played a role in Dr. Bonomo’s statements, it should be noted that although there are references in the manuscript to dozens of other Italian and international authors of the time (e.g., Durante, Nimier, König, Cruvellier, Turk, Tillmans, Reger, Kroenele, D’Antona), the “Brain Injury” section of the original manuscript makes no direct reference to the works of Cushing or Keen. Studies that established with certainty the importance of accurate wound debridement came several decades later, from the investigations of Aarabi in 1989,22 who analyzed a cohort of soldiers with GrTBI serving in the first Iran-Iraq war, and Pitlyk et al.23

**DEPLOYMENT OF TECHNOLOGY ON THE BATTLEFIELD**

**Lessons, 127:11** In order to localize shrapnel inside
the cranial cavity, two X-Ray images are required: lateral and frontal. In a suicide, a bullet penetrated through the right Pterion, without an obvious exit wound. The Plain films localized the projectile in the contralateral mastoid area, where later, during the trephination, before the necropsy, it was found.

Roentgen introduced plain film radiography in Würzburg in 1895; since then, several major studies recognized and investigated its advantages in localizing radiopaque foreign bodies as a result of incidental trauma or aggressions. Among war physicians belonging to the Central Powers, the validity of x-ray to localize and extract foreign bodies was recognized and discussed from the earliest stages of the war, and relevant observations were made regarding bullets to the head. The first portable device was introduced after technical improvements made by Marie Curie, while actively involved in war service with the French Army. Dr. Bonomo pioneered the employment of the same French portable x-ray device in Italy. It was movable and easily setup along the Italian frontline, and it was used for early diagnosis and prompt treatment of GrTBI, directly at the camp hospitals. The model of the device was the "petit marie curie," a rudimental but fully operational portable machine (Figure 9).

**THE SUBTLE AND DECEITFUL GrTBI INFECTIONS**

Lessons, 129;18 "An abscess can grow around a foreign body: projectile, shrapnel, or because of necrotizing suppurating osteitis of the cranium. Often a bullet remains for months without causing any symptoms of infection; the abscess..."
progresses deceitfully. A focal suppuration of the cranial bones, for instance the mastoid and middle ear, can provoke a cerebral or cerebellar abscess. [...] Such abscesses can reach notable dimensions without provoking significant functional disturbances. [...] The Cerebrum, similarly to other organs, like the Heart, demonstrates a notably prolonged tolerance, in regard to projectiles jammed in the cranial base, enveloped by a fibrous tissue or piercing the cranial wall. If a bullet is locked inside the brain’s parenchyma, because of its weight, because of the softening of the cerebral substance, it usually sinks deeper and penetrates the ventricles. After a silent period of tolerance, an inflammatory process is unleashed, working as a favorable ground for the development of locally latent germs, or other bacteria carried by the bloodstream."

Through direct personal experience with GrTBI, Dr. Bonomo recognized infection as a major cause of delayed mortality in this subgroup of patients. Most importantly, in a pre-antibiotics era, he described the interval between the traumatic event and the development of signs of infection; that is why, as previously mentioned, Dr. Bonomo supported accurate and meticulous debridement of the scalp and cranial and eventually brain lesions, which was later endorsed by modern, more scientifically solid trials. Still, brain infections, such as brain abscesses, meningitis, and encephalitis, account for up to 21.3% of delayed casualties from gunshots to the head. Furthermore, Dr. Bonomo recognized one of the most common complication for patients with GrTBI, namely an increased incidence of post-traumatic epilepsy.

**LIMITATIONS OF THE PRESENT INVESTIGATION**

Dr. Bonomo is thought to be the author of 40 original papers on the field of medicine and war surgery, of which only few are currently digitalized. A further part of his contributions could be kept in private libraries or archives, in form of private medical correspondence or military dispatches. The original manuscript inspiration for this paper is part of a collection of lectures conserved at the Military School of Health. The collection is handwritten, the papers did not undergo extensive editing, and the collection may be incomplete, namely, being handwritten, excerpts or even pages could have been irreparably lost. Nevertheless, because of the richness and variety of the topics, the historical value of the original manuscript, and the scientific worth of Dr. Bonomo’s work in neurotraumatology, these lectures deserved extensive and focused investigation.
CONCLUSIONS

Dr. Bonomo significantly contributed to the genesis of Italian military traumatology, with special and outstanding contribution to the study of GrTBI. His observations, some of which predate contemporary ballistic and forensic concepts, came from his firsthand medical experience in a military setting, working tirelessly and intelligently to improve the survival chances of the Italian troops during the Great War.

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