The treatment of wounds during World War I

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SUMMARY

The First World War was a huge tragedy for mankind, but, paradoxically, it represented a source of significant progress in a broad series of human activities, including medicine, since it forced physicians to improve their knowledge in the treatment of a large number of wounded soldiers. The use of heavy artillery and machine guns, as well as chemical warfare, caused very serious and life-threatening lesions and wounds. The most frequent causes of death were not mainly related to gunshot wounds, but rather to fractures, tetanus and septic complications of infectious diseases. In the first part of this article, we describe the surgical procedures and medical therapies carried out by Italian physicians during the First World War, with the aim of treating wounded soldiers in this pre-antibiotic era.

Antibacterial solutions, such as those of Dakin-Carrel and sodium hypochlorite and boric acid, the tincture of iodine as well as the surgical and dressing approaches and techniques used to remove pus from wounds, such as ignipuncture and thermocautery or lamellar drainage are reported in detail.

In the second part of the paper, the organization of the Italian military hospitals network, the systems and tools useful to transport wounded soldiers both in the front lines and in the rear is widely discussed. In addition, the number of soldiers enrolled and those who died, were wounded or missed during the great War on the Italian front is estimated.

Keywords: wound infection, second world war.

INTRODUCTION

The Italian physician and historian Giorgio Cosmacini, the author of the book “War and Medicine”, in a recent interview during a major cultural event in memory of the centenary of the outbreak of the “World War I” stated: “the Great War was a turning point for medicine, a paradoxical source of progress. The need to treat an enormous number of casualties forced physicians to make significant progress. People died from septicemia and gas gangrene. The wounds were not the only cause of death, but it was often the result of tetanus or septic complications of the fractures” [1, 2].

The first World War (1914-1918) caused a senseless slaughter (as it was defined by Pope Benedict XV) in a large number of European fronts1 and it was responsible for about 26 million deaths, among civilians and soldiers and for almost an equal number of wounded and mutilated individuals, as well as for subjects who were stricken by epidemics and mental diseases.

This terrible tragedy forced to consider a series of new problems. Their resolution has produced results, that up to now are still remarkable. Without any doubt, the massive introduction of heavy artillery with the

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1 The First World War involved the French-Germanic front in the Western Europe, the Central Empires vs Russian Empire in the Eastern Europe, the Austro-Italian front in the southern Europe, the Dardanelles (where the Turkish soldiers fought against the Anglo-French troops, who landed there) as well as the South-Eastern Europe and Caucasian front, where the Russians fought against the Turks.
use of shrapnel and machine guns, as well as the use of chemical warfare was paradoxically a stimulus for physicians. They were forced to deal with a large number of wounded young soldiers. The most statistically frequent causes of death were not associated with the single shot rifle, which was shot by a sniper, but they were otherwise related to septicaemia, tetanus and fractures with septic complications. Mortality was not only correlated to poor medical knowledge, available in that time, but also to the precarious health conditions of the soldiers. They lived in the mountain and in plain trenches, where the cold and damp, systematically undermined the body for long periods. Food was scarce and of poor quality, soldiers had generally the possibility to eat by night, because of connection problems between the fighting front and the rear. When the food was dispensed in the trenches, the mess-tins had not been washed, therefore the risk of intestinal infections, mainly enteric typhus, became higher and higher. In addition, the trenches were infested by mice and men exposed to bites of lice. At that time sulfa drugs or antibiotics were not available, so human mankind had only extremely limited tools to counteract the incumbent infections. In case of injury only antibacterial medications could be helpful and the solution of Dakin-Carrel could be used. This compound was a solution, including boric acid and sodium hypochlorite, which was achieved thanks to the brilliant insights of the French surgeon Alexis Carrel (Nobel Prize in Medicine in 1912) and by the American chemist Henry Dakin. The tincture of iodine was used to dress soldiers’ infected wounds, whereas they were still at the front. This antiseptic compound had been introduced by Italian physician Antonio Grosch in the pharmacopoeia, since 1908. The massive use of sodium hypochlorite and boric acid solution reduced the number of deaths from untreated wounds, whereas untreated patients had a poor survival. Cosmacini reports that in Verdun, on French-German front, where the bloodiest battles of the first World War were fought, the statistics of French Doctors reported that 90% of the wounded soldiers, who were not treated with the solution Dakin-Carrel, died; on the other hand mortality rate fell to 10-15% in treated patients. An important point was represented by the rapidity of rescue and the transfer of wounded soldiers from the front lines. They sometimes were stationed in no man’s land, in the mud for hours before the bearers could retrieve them, and also the evacuation of the trenches and the transportation to the first health and aid structures were characterized by very important difficulties. Despite these remarkable difficulties, which were associated with logistics and organization, military surgery improved significantly in a short time, because of the need to treat a large number of wounded soldiers, who were transported to the hospitals in the rear. In an article published in 1917, Captain doctor Guido Lam wrote “the increasing experience, concerning the attempts made in the laudable aim of achieving this ideal of war surgery, has shown that a septic wound may be turned into an aseptic one, most frequently in the first few hours, whether it is managed with a radical purpose, treating the wound core like a tumor and removing it, en bloc, by means of the incision of healthy tissues” [3]. Unfortunately the situation was not so simple. Captain doctor Lam himself wrote, “In a large and busy hospital in the rear, we had to cure many serious sepsis and extensive festers. We had no chance to treat a so wide number of wounds in our previous 15 years of surgical practice in a large hospital of a populous city and we believe that most of war surgeons worked in a similar conditions” [3]. This type of radical surgical approach was possible only when the wounds were limited to the distal portion of the limbs and the disability was limited, but in most cases the wounds involved the chest, the abdomen or the proximal portion of the arms and legs. In these cases - in the absence of antibiotics and sulfa drugs - the goal of the wound treatment was to limit the aggressiveness of infections in tissues, by reducing the toxic condition. Prevention of germs proliferation and promotion of tissues vitality, by means of the limited current available resources, were the key approaches of the treatment. The reduction of pathogens virulence would have induced a more benign course of the infection. When an abscess or a phlegmon were identified in a clear way, ac-

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2 The shrapnel is a hollow bullet, filled with lead or, in war economy, steel spheres, and provided with a bursting charge connected to a time fuse
cording to the clinical practice, pus had to be removed from infectious foci, by means of drainages positioning. The most important problem to be solved was to prevent the progression of infection by avoiding pus persistence in tissues. As Guido Lerda explained, military surgeons’ experience led him to consider that, in the hospitals located in the rear: “every tissue injury, even small and sterilized and every bleeding, may promote sepsis development. It is common to observe patients, in whom even the lightest dressing is associated with fever development. In addition, I was seldom able to obtain fever decrease in patients, reducing the number of dressing or no longer carrying them in the dressing room, but treating them in their beds, even if an immobilizing device had been used” [3]. Pus drainage could occur spontaneously, especially in tears, in particular where the traumatic event had preserved the anatomical stratification and no obstacle prevented pus outflow from the infectious focus [4, 5]. In these cases, further attempts to remove pus could, in a situation of high infectious risk, cause additional traumatic events and favor a possible septic dissemination. In these cases physicians had only to promote the outflow of inflammatory products. Therefore, the wounds were placed in a position suitable to favor pus drainage by gravity. In the absence of radiological and ultrasonographic imaging, frequently, in the first days after the traumatic event, the differential diagnosis was not easy, and only a very careful clinical surveillance was a helpful approach. Whether, according to physician’s opinion, a severe sepsis was occurring, a surgical approach was considered necessary and the patient underwent a surgical debridement. Concerning the infectious foci (superficial, sub-aponeurotic and deep foci), debridements were performed with the respect of skin elastic fibers and folds direction [3]. Sub-aponeurotic foci were treated by military surgeons by a cross-sectional incision of aponeurosis or small side indentations. It was interesting the practice of the bites, which were performed by means of “thermocautery”, as this approach prevented the development of new paths to sepsis. The technique of multiple ignipunctures for drainage was commonly used, when a not particularly aggressive infectious lesion had to be treated. In general, these lesions remained open for 8-10 days and they were kept open by applications of silver nitrate, that were carried out, every 5-6 days. Figure 1 - reproduced from the original work of Lama shows a phlegmon in the foot and leg, which was drained through multiple ignipunctures [3]. In the experience of the military surgeons, multiple bites performed by means of the “thermocautery” were useful for exploring the wounds and for detecting the presence of pus. They were considered less invasive in comparison with the incisions, obtained by means of a scalpel. It is remarkable that this technique, especially in districts including tendons and joins (limbs), allowed pus draining reducing patients’ risk of tendons exposures. This approach prevented the development of adhesions and scar retractions, causing the impairment of the articulations, nerves or tendons functions in tissues, where these structures were present. This technique caused minimal scarring and safeguarded aesthetic aspects. The particularly rich casuistry, allowed the surgeons involved in the care of the wounded soldiers, during the First World War, to understand that it was meaningless to measure their skill - as the English Surgeon Treves reports - “by the smallness of the cut”. They had developed the awareness that the treatment of infected lesions, by means of too small incisions, especially in the presence of an incipient sepsis, could induce the risk of death in the wounded individuals. This technique often prevented an adequate pus drainage in these subjects and septic shock could develop. It has to be underlined that the surgeons, who

Figure 1 - Foot and leg phlegmon drained by means of ignipuncture.
worked in military hospitals during the Great War, had understood that the saprophytes pathogens, which were detectable on the skin, could be transferred into deep tissues. Concerning the need to maintain open surgical drainages, Captain Guide Lama reports as follows: “any foreign body has to be prevented from entering the hotbed of a wound, with the aim to avoid the main cause of secondary infections, saving the patient from the possible risk to bring surface germs, in the depth of the wound, causing a sepsis” [3]. In addition, Lama recommended that the drainage of tissue pus has not to be performed by means of a rubber tube, because pus might be easily obstructed in a few days, unless an adequate suction mode is maintained. A more reliable approach was represented by the lamellar drainage to evacuate the pus from the purulent wound. A “soft and harmless” gauze that was perfectly suited to the size of the wound and “that could not been impregnated” were introduced into the lesion. Then a virtually lamellar drainage, consisting of “inner tube pieces from bicycle or with sheets of gutta-percha” was connected. This approach allowed to drain the wound, avoiding in this way, “the repetition of unnecessary trauma, during each dressing”. The authors of that period attributed a greater effect of the draining power of the hydrophilic gauzes compared to all the other dressing materials, especially in relation “to the porosity, permeability, capillarity, hygroscopicity, absorption and evaporation”. In clinical practice, however, whether dense pus had to be drained from infected cavities, absorbent capacity was not as effective as that studied in experiments with colored liquids. In order to give strength to his clinical experiences, the Captain Lerda set out to assess different materials and determine which of them could better serve in the drainage of cavities, containing pus. As he wrote in his publication, he tested a lot of materials useful to perform his experiments. Therefore, this condition allowed him to evaluate adequately the different approaches. He noted that “we don't have to excessively rely on the capillarity action to evacuate the exudates from the wounds in a opposite direction to gravity, by means of a dry hydrophilic gauze”. According to Lama’s experiments, it was suggested that “the deposition of purulent corpuscles, the viscosity of the pus and its evaporation rather than gravity can hamper absorbent activity of gauze”. Pus viscosity and a narrow passage of wound lumen prevented the action of gravity, favoring the drainage of purulent material. Even a too tight bandage could prevent the evacuation of pus, while the continuous renewal of dressing prevented its drainage and favored the formation of a scab. Its consolidation caused the block of pus outflow. A damp gauze was an element, promoting pus drainage, in particular, damp status of the gauze favored it. In conclusion, in clinical practice “the use of a wet gauze increases conspicuously the absorbing activity of the dressing” [3].

During the First World War surgeons used the “discontinuous intermittent irrigation” method (6-8). Infected wounds were treated by means of disinfectant solutions, containing hypochlorites, diluted in water. The advantage was not associated with the disinfecting power of such an irrigation, rather there was the evidence that physical conditions useful to wound care were created. Irrigation not only caused pus dilution, therefore with reduction of its toxicity, but also the constant humidification of material used for dressing prevented its drying. Pus evacuation was also facilitated and so deep tissues (tendons, cartilage, no nerves etc) were protected and at last the evacuation of necrotic tissue debris and wound cleansing were favored [3]. Hypochlorites were introduced in continuum maintaining a constant concentration of drug and persistent antibacterial lethal action on the microorganisms responsible for the infection. The intermittent irrigation was used by Captain Lerda in purulent knee infections. Such an intermittent irrigation was favorite, because the intermittent irrigation was favored over the continuous irrigation and over the so-called bath in permanence, as it was applicable at patient's bed and in any event, even when there were symptoms of infection, involving the trunk or the head, in particular, when plaster bandages had been used. The bathroom was not possible, when the infection arose in foci of bone fracture. Concerning the mentioned therapeutic solutions, there was the recommendation to use a concentration at 5%, especially in the acute phase, as microbiologists had observed that a concentration equal to 2% only decreased the development of germs, while a concentration equal to 5% blocked it. In the experience of military surgeon Dr. Lama, magnesium chloride had to be preferred, far and away. This product preserved the vitality of health tissues, improving the activity of the gran-
ulomatous tissue and decreasing the risk of tissue suppuration. Magnesium salts were considered able to stimulate phagocytosis, and, when they were used in hypertonic solution, they induced the inhibition of Streptococci and Escherichia coli growth. Therefore, they blocked the digestive action of these pathogens on the tissues. It has to be underlined that Captain Lama was a surgeon, who, 100 years ago, had a very remarkable microbiological culture in difficult contexts, where study and research resulted particularly complex. The severity of post traumatic infections, caused by fire-arms (grenades and gunshots) imposed to consider the prevention of infections as well as of septicemic risk. The soldiers were provided with a handbook by Italian health Authorities so that they adopted correct behavior, whether they were wounded [8-10]. The soldiers received the warning that they should not touch any wounds with hands or other objects, because of a further super-infection risk. In addition to the handbook, the soldiers were provided with a dressing kit, including sterile gauze, bandages and iodine tincture. The gradual introduction of new chemical weapons in the following war phases, caused the inclusion of further equipment in the soldiers’ kit, such as gas masks and goggles.

The Organization for the evacuation and treatment of the wounded soldiers
At the head of the largest Italian military medical health system, the general Della Valle was appointed. In 41 months of war he had to manage the transport, hospitalization and treatment of a large number of wounded and sick soldiers, suffering from non-traumatic diseases (according to some estimates over two million of subjects)3. Protagonists of this huge work were represented by the soldiers of the Corps of Military Health and by the apparatus of the Italian Red Cross (staff and “Ladies of the Red Cross”, ie voluntary Red

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3 The most common diseases in the years of the war included cholera and dysentery, drinking water in the trenches was scarce and often polluted. The typhus was an important preoccupation, because it caused health epidemics. During the First World War, Psychiatry acquired for the first time the idea that the stress, during the war, could make the soldiers crazy, they presented a wide series of symptoms: palpitations, tremors, catatonic paralysis, nightmares, insomnia, they sometimes stopped talking, some of them seemed to lose their mind forever, while others recovered after a period of rest. There were many soldiers with severe mental illness who were taken for simulators, in some cases they were sentenced to firing squad, this practice after the defeat of Caporetto was summarily practiced.
Cross nurses), supported by volunteer nurses, belonging to different support committees such as the Knights from Malta as well as those of the Order of SS. Maurice and Lazarus and the Jesuits [11]. The wounded soldiers, who were retrieved by the stretcher bearers (Figure 2 and 3), were transported to the first aid stations, in the close proximity of the front lines, later they were transferred to the field infirmaries that were generally protected from enemy’s attack. Military hospitals were located further away from the front, and the wounded individuals were sent there, after they underwent immediate treatment to save their lives.

Since the beginning of the conflict the C.R.I. immediately militarized its staff, including 9,500 local nurses and 1,200 doctors; in addition, this Organization had 209 logistical equipment (territorial hospitals, camps and hospital trains. Later there was a sharp increase in military doctors: in 1916 they were 8,000 (in addition 6,000 physicians worked in the rear of the front), and in 1918 they reached the remarkable figure of 18,000.

The basic unit of Military Health at the front was the Healthcare Section, that was commanded by a physician with the rank of Captain. Each regiment was subdivided into two battalions. Each of them included one Health Team. Both Health Teams were headed by a doctor with the rank of Lieutenant. In each Healthcare Section one or two Medical Assistants as Cadets and a military chaplain were enrolled and about 30 nurses and stretcher bearers were also included. They were subdivided into teams of 10 men commanded by sergeants or corporals. There were also army units equipped with horses and mules, that were used to evacuate the wounded soldiers from the front lines. In Figure 4 a wagon ambulance is shown. In Friuli-Venezia Giulia, from the beginning of the war until 27 October 1917 (Caporetto retreat) a large series of Hospitals were available. The city of Udine was the centerpiece of a wide system of hospitals. They were located in the second lines of war zones and they served as contumacy and convalescence facilities [12, 13]. Close to the front lines there were the dressing places. Whether it was possible, they were out of the range of enemy fire. In these places the wounded soldiers were bandaged and medicated in an imperfect way, as far as possible and then, they were sent to small field hospitals, either by

Figure 4 - Ambulance Wagon pulled by mules (Museo Civico del Risorgimento, Bologna).

Figure 5 - Field hospital in the Italian-Austrian front (Museo Civico del Risorgimento, Bologna).

Figure 6 - Cableway used for the evacuation of wounded soldiers in advanced mountain position. (Museo Civico del Risorgimento, Bologna).
walking, either by riding on mules, either on shoulders or on stretchers (Figure 5). In isolated mountain locations, cableways were also used for the evacuation of wounded soldiers (Figure 6). The small field hospitals included tents, that were equipped for medical interventions. These procedures were performed in patients with more serious clinical conditions, who could be still surgically treated. On the other hand, inoperable individuals (when it was possible) were cared for until they died. At the beginning of the war, the morphine use for suffering patients was possible, unfortunately stocks of this drug soon ended and so the treatment of pain became difficult, and this type of therapy depended on the morphine availability.

The wounded individuals, who survived, were transferred to bigger field hospitals. Here they were admitted to shacks or wider tents. In these hospitals both the more seriously wounded soldiers and the soldiers with less than 30 days of convalescence were accommodated. At military hospitals (Divisional or Corp) or Territorial Hospitals of C.R.I. - that were located throughout the rear of the front - the convalescent maimed patients and the soldiers who were no longer able to return to the front were treated for prolonged periods. As the number of injured people increased during the war, these hospitals were overflowing with chronic patients, and they were no longer able to meet the requirements [8].

A large series of battles was fought in a short period of time and they were characterized by a strong increase of thousands of wounded soldiers. These subjects bled until to death or they were neglected by the health staff, who was unable to meet the strong demand for assistance, they lacked bandages and disinfectants. Since 1916 British doctors were employed in Italian front. From this point of view, there was also an important contribution of the British and US medical personnel, working as stretcher-bearers and nurses or in ambulances [11].

In Friuli, except Udine, the Hospitals, where Italian Red Cross nurses also worked (Figure 7), were

78. They included 36 field Hospitals, 20 were defined war hospitals and 20 were defined Health Hospitals. In addition, two lazarettos were available: one at Manzano and one at Russiz. At San Giorgio di Nogaro hospital school of C.R.I. was installed. It included one field Hospital and also one laboratory of bacteriology. At San Vito, one ambulance for soldiers’ dressing was available. The town of Palmanova included: one Hospital field, one Health Hospital, one Hospital for con-

![Figure 7](image1) - Group of Italian Red Cross nurses who served in the Red Cross Hospitals. (Museo Civico del Risorgimento, Bologna).

![Figure 8](image2) - Train hospital used to transport the wounded soldiers far from the front to the city hospitals, such as Bologna, Padua, Milan, Turin. (Museo Civico del Risorgimento, Bologna).

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4 The meaningful participation of Ernest Hemingway to the First World War has to be underlined. He was excluded from combat units because of a vision defect, however, it was enlisted in the ambulance services as a driver ARC (American Red Cross) and he was assigned to the Italian front in the town of Schio at the foot of Mount Pasubio. Hemingway described his experience in his novel Farewell to Arms.
The treatment of wounds during World War I

tumacy. In addition, at the local station, one hospital train was on duty (Figure 8) [12, 14]. The Organization to treat health problems of wounded soldiers was rather complex and intricate, in figure 9 the evacuation scheme of wounded soldiers is proposed. In conclusion: in Italy 5,903,000 were enrolled between 1915 and 1918, 437,000 soldiers were exempted and 282,000 soldiers were dispensed. About 680,000 (estimate) soldiers died, because of war: 48.59% of deaths were caused by wounds, 33.05% by diseases, 1,85% by unknown or different causes and 16.51% represented missed soldiers. It is more difficult to establish the number of wounded soldiers. The soldiers transported to hospitals and very small hospitals, in particular subjects suffering from serious diseases (many returned from the dressing and places health care sections directly to their Military Units) are calculated in number of 1,050,000; the most serious among the survivors, invalids and mutilated by war with a physical impairment equal to at least 10% of working capacity, were estimated to be equal to 463,000.

The activity of Italian war surgeons reduced the devastating impact that had the great war on millions of wounded soldiers. Probably, as Cosmacini reports, there was an improvement of scientific knowledge of physicians, who worked for 4 years under these very difficult conditions, due to this tragic experience. The First World War taught doctors, who were engaged in all fronts worldwide, to focus on infection and to create a great effort, that led, in the next decades, to the discovery of sulfonamides and, later, of antibiotics.

The activity of Italian war surgeons reduced the devastating impact that had the great war on millions of conscripts wounded. Probably, Cosmacini says, eventually, due to this tragic experience, there was an improvement in the knowledge of who for 4 years did his best, valiantly, under working conditions very difficult. It was the first world war to teach doctors engaged in all fronts worldwide, focusing on infections, creating that great effort that led in the next decades to the discovery of sulfonamides at first and of antibiotics later.

**Conflict of interest.** The authors have no conflicts of interest to disclose.

**ACKNOWLEDGEMENTS**

The authors thank Dr. Otello Sangiorgi, Dr Mirtide Gavelli, the Museo Civico del Risorgimento in Bologna and Walter Marchetto. http://cadutivigevano.it/
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