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# Blood transfusions for the wounded: promising method of battlefield surgery or utopia of the mid-1870s?

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**Abstract**

The first attempts to introduce blood transfusion into battlefield surgery were made in the 1860s and 1870s when the lack of coordination in the actions of army leaders and the unpreparedness of the military medical service meant that thousands of wounded soldiers died on the battlefield while awaiting medical assistance. The use of blood transfusion began with the Franco-Prussian War of 1870–1871. In the post-war period, military doctors had a wide choice of transfusion methods, and of tools and fluids (whole or defibrinated animal or human blood, normal saline, etc.) used for this purpose. The attempt to introduce blood transfusion into battlefield surgery in the mid-1870s was based not just on experimental and clinical data that gave hope of reviving and giving strength to the wounded, but also on the practical possibility of finding a suitable donor on the field of combat. The most promising methods appeared to be the transfusion of whole blood — human, obtained from fellow soldiers or assistants in the medical service (using a method pioneered by Joseph-Antoine Roussel) and animal (using a method pioneered by Franz Gesellius). For advocates of interspecies transfusion, the practical convenience of using animals as a living blood bank for transfusions for multiple patients outweighed the physiological data on the advantages of intraspecies transfusions. Even so, whole blood transfusions were not common in military medicine in the last quarter of the nineteenth century, mainly because not enough was known about blood physiology.

**Keywords**

military medicine, blood transfusion, loss of blood, battle wounds, animal blood, defibrinated blood

## Introduction

Traumatic injury is one of the leading causes of death among both civilians and the military today. The main threat to life from such injuries is profuse loss of blood. Today, acute blood loss is the cause of death on the battlefield for over 50% of those wounded, of death soon after the evacuation for around 30% of those wounded, and of death soon after injury for at least 40% of civilians (Spinella et al. 2009; Spahn et al. 2007; Usov, Shmidt, Evseev 2021; Borgman et al. 2011). According to findings from modern retrospective and prospective studies, first aid procedures, including stopping the bleeding and preventing its recurrence, may prevent up to half of such deaths (Spinella et al. 2009; Spahn et al. 2007; Usov, Shmidt, Evseev 2021; Borgman

et al. 2011). The methods of introducing stored whole blood, blood components, fresh frozen plasma, cryoprecipitate, crystalloid solutions, or fresh whole blood in randomised trials hold the promise of a reduction in the proportion of early deaths (within six hours of the injury) and an increase in the proportion of patients with traumatic haemorrhagic shock surviving for 28–30 days (Spinella et al. 2009; Spahn et al. 2007). In the twentieth century, Russian medicine developed the practice of using blood components and blood substitutes. Since the start of the twenty-first, however, European and American researchers have increasingly been discussing the possibility of using fresh or stored whole blood in the prehospital phase if the loss of blood poses an urgent threat to life (Spinella et al. 2009; Usov, Shmidt, Evseev 2021; Berner 2020).

The first attempt to use whole blood in battlefield surgery was made in the second half of the nineteenth century. In the 1860s and 1870s, thousands of wounded soldiers died of loss of blood on the battlefield as a consequence of the numerous wars abroad and the rapid development of the tactics and equipment of European armies (Berner 2020). There was a need for a complete overhaul of the system of military medical administration, for medical personnel and supplies, for the wounded to be evacuated, and for dressing stations and mobile field hospitals. In the mid-1870s, practising military doctors saw the possibility of adding blood transfusion to the first aid methods during evacuation as one of the elements of this. The principles of modern transfusion medicine show that this idea was reasonable, but what we know today about the immunological characteristics and group compatibility of blood shows that the idea of large-scale blood transfusion in battlefield conditions in the last quarter of the nineteenth century was wishful thinking because people did not know enough about the physiology of blood (Spinella et al. 2009; Spahn et al. 2007; Usov, Shmidt, Evseev 2021; Borgman et al. 2011).

Our study aims to analyse the blood transfusion methods existing in the 1870s and to identify the factors affecting the prospects for the use of blood transfusion as a method of first aid in battlefield medicine, and why the practice fell out of favour at the start of the 1880s.

## Working conditions for military medical personnel in military conflicts in the 1860s and 1870s

The physicians involved in the military conflicts of the 1860s and 1870s all agreed that the Austro-Prussian (1866) and Franco-Prussian (1870–1871) wars were "incomparably more onerous, murderous and disastrous than previous ones" (Pirogov 1871, p. 10). The high manoeuvrability of the troops, the fleeting nature of the military operations, and the lack of coordination of the activities of the military authorities meant that the military medical services of the warring states were not ready for war. Medical detachments lagged behind their regiments and were unable to set up dressing stations by the start of the fighting (Höppner 1872, p. 53). New accurate, rapid-fire, and long-range weaponry turned the tactic of attacking in close formation, which had been effective in the first half of the nineteenth century, into mass execution. Many more soldiers were wounded in battle than the existing medical detachments could cope with (Höppner 1872, p. 54). Evacuating thousands of wounded soldiers from the battlefield required at least 500 stretcher bearers, whereas in the Prussian Army's medical company, for example, there were no more than 150 people (Pirogov 1871, p. 53). As a result, "few of the wounded, and even then, only those wounded lightly, could be taken quickly to a mobile field hospital or dressed at all faster than 5 or 6 hours after being wounded" (Höppner 1872, p. 54). Most of the wounded lay on the battlefield for days. Around 15% died before they could be given first aid (Pirogov 1871, p. 55; Hübbenet 1871, p. 68). The shortage of doctors at the dressing stations meant that it was not possible to provide timely medical assistance to all the evacuated wounded (Pirogov 1871, p. 50): at best, soldiers weakened by the loss of blood were given stimulants and tonics (wine, vodka or coffee) (Heyfelder 1879, p. 68). Complex operations, ligations of major vessels and blood transfusions were performed at dressing stations in exceptional circumstances (Pirogov 1871, p. 57; Heyfelder 1879, p. 53). Russian military doctor Karl Ludwig Höppner (1833–1874) observed that "three-fourths of deaths on the battlefield and the majority of deaths in the first two or three days after the fighting were due to loss of blood," (Höppner 1872, p. 173–174). Thus, the primary objective of military medicine

after the Franco-Prussian War was to find ways of reviving as quickly as possible the wounded who had been weakened by loss of blood, and the most promising of these seemed to be blood transfusion.

## Methods of blood transfusion

In 1874, Russian military surgeon Oscar Heyfelder (1828–1890) classified all the blood transfusion methods then known according to the surgical technique used, and the composition and type of the donor blood. He identified artery-to-vein, artery-to-artery, vein-to-vein and vein-to-artery blood transfusion techniques, and, depending on the composition of the blood, direct transfusion of whole unaltered blood or indirect introduction of defibrinated blood. The donors could be both animals and a person (Heyfelder 1879, p. 259). For doctors in the second half of the nineteenth century, the main difficulties of transfusion related to the formation of "fibrous clots" and "overfilling a weak patient with blood" as a result of introducing the donor blood too quickly or in too great a volume (Heyfelder 1879, p. 262).

Transfusing arterial blood into veins did not require complicated equipment: all that was required was to connect the vessels of the donor and the recipient with a glass or rubber tube with cannulas on the ends (Gori 1874, p. 104–105). The pressure gradient needed for the procedure was created by the donor's beating heart. In the 1870s, however, blood transfusion entailed full-scale surgery on the vessels. An arteriotomy presented an additional threat to the donor's life, so was rarely performed on a human donor. "Human arterial blood is very hard to obtain," wrote Austrian military surgeon Joseph Friedrich Eckert, "and even the boldest surgeons do not approach arterial trauma without qualms" (Eckert 1876, p. 117). Accordingly, "double arterial" transfusion of whole human blood, and artery-to-vein transfusion of human blood, were not common in clinical practice (Heyfelder 1875, p. 220).

In 1873–1874, the technique of artery-to-vein transfusion lay behind the rapidly increasing popularity of the method of animal-to-human blood transfusion. In 1871, Giuseppe Albini (1827–1911) transfused whole lamb blood into a person in Naples (Gorini et al. 2019, p. 182). In 1873, Franz Gesellius (1840–1900) concluded from his own retrospective analysis of clinical cases of blood transfusion, published in European medical literature, that animal-to-human blood transfusion was safe (Gesellius 1873, p. 68). In 1873–1874, Oscar Hasse (1837–1898) conducted clinical trials of this method, personally performing 31 transfusions, and confirmed that Gesellius's theoretical conclusions were correct. Their proposed method involved transfusing blood from the carotid arteries of lambs 4–6 months old into a person's superficial veins (Gori 1874, pp. 104–105; Eckert 1876, p. 161). As accurate measurement of the volume of the blood introduced was not possible, it was recommended that the procedure continue until the onset of extreme clinical manifestations, when patients either could no longer tolerate the transfusion and insisted that it be stopped, or lost consciousness (Sergeeva and Panova 2021, p. 247). Albini recommended using a percutaneous puncture of the artery to collect the donor blood, rather than cutting it open (Gorini et al. 2019, p. 182).

It was most common in clinical practice in the 1870s for whole or defibrinated venous donor blood to be used. This required special instruments to pump the blood into the patients' veins. At the 1873 Vienna World's Fair, an apparatus invented by Joseph-Antoine Roussel (1837–1901), in which a lancet connected by rubber tubes to a manual pump was used to collect the venous blood, was recognised as the best device for transfusing whole venous human blood (Sergeeva and Panova 2020, p. 5). An advantage of this device check was that the rate and volume of the transfusion could be controlled, excess loss of blood avoided, and the likelihood of infection and phlebitis of the donor's veins reduced. In addition, when the lancet was replaced, its cannulas could be used for animal-to-human blood transfusion.

For vein-to-vein transfusion of defibrinated blood, devices that delivered the blood being transfused mechanically (syringes) or with the help of hydraulic pressure, were used (Heyfelder 1879, p. 260). The fibrin was removed by agitating the venous blood previously collected with metal rods in a glass cylinder and then filtering it. The obvious shortcomings of this method included the length of time need to prepare the donor blood and alter its composition: deformation of the structure of the blood corpuscles; reduction of its "life-giving activity"; and microbial con-

tamination. "Blood," wrote Louis Jullien (1850–1913), head of a surgical clinic in Lyon, "when in contact with the air, when in the vessels and when passed through flannel, manages to capture many of the germs that exist everywhere in the atmosphere and thereby may contaminate the whole mass of blood fluid" (Jullien 1875, p. 210).

The vein-to-artery technique formed the basis of the method developed by German professor Carl Hueter (1838–1882) of transfusing defibrinated venous human blood into the recipient's artery. Hueter stated that "the method of arterial transfusion, by delivering new blood to the heart more slowly and correctly than venous... does not entail such threatening symptoms" as a coronary of pulmonary embolism or kidney damage, the main causes of a fatal outcome (Heyfelder 1879, p. 261; Eckert 1876, p. 73).

Thus, the variety of methods of blood transfusion that existed in the 1870s were the result of the search for the best method, enabling effectiveness to be achieved in its clinical use, within the context of ideas of the functions and properties of blood at the time. Although there were many arguments between advocates of the transfusion of whole and defibrinate blood over "the physiological significance of fibrous material as an integral component of blood," scientists and practising physicians had no doubt that intraspecies transfusions was better than interspecies transfusion (Eckert 1876, p. 74). "Numerous experiments," argued advocates of blood transfusion, "have shown that the blood of one individual and the blood of another individual of the same species are completely harmless" (Eckert 1876, p. 72). Even so, between 1873 and 1876, a fundamental argument flared up between advocates of transfusing whole human venous blood (using Roussel's method) and those in favour of transfusing arterial animal blood (using Gesellius's method) over which of these methods should take priority in battlefield surgery.

## Blood transfusion in battlefield surgery in the 1860s and 1870s

Blood transfusion was first used in battlefield medicine during the Franco-Austrian War (1859) when Austrian military doctor Ignaz Josef Neudörfer (1825–1898) transfused defibrinated human blood into six soldiers with purulent fire-arm wounds (Berner 2020, p. 48). Albini first performed transfusions during the Austro-Prussian campaign, providing four wounded soldiers with animal blood. He wrote: "I firmly asked for one or more living lambs... so as to use their... blood in transfusions... saving soldiers life" (Gorini et al. 2019, p. 182). During the Franco-Prussian War, 37 transfusions of defibrinated human blood were performed at mobile and fixed field hospitals. Of the 33 patients involved in this clinical experiment, 14 survived (Köhler 1901, p. 93).

The high mortality rate among the wounded before they could be treated on the battlefield drove the attempt to perform transfusions sooner after the injury was received – as part of first aid provision on the battlefield. In the post-war period (1873–1876), this issue was addressed in many statistical, experimental and clinical studies, the results of which were covered most fully in Neudörfer's findings (Sergeeva and Panova 2021, p. 248; Roussel 1876, p. 159). He regarded transfusing whole venous human blood into patients as the safest and most effective method. Where the supply of such blood was insufficient, defibrinated human blood previously prepared and stored at a low temperature (0 °C) needed to be used. However, the limitations of the existing medical support system and the specific requirements for storing defibrinated blood meant that it could not be used at dressing stations. Accordingly, it was necessary to find a source of donor blood, available in battlefield conditions – a so-called "walking blood bank". Advocates of intraspecies transfusion (Roussel, Heyfelder, etc.) proposed that those wounded on the battlefield be given whole blood from their fellow soldiers or personnel from medical detachments. However, an obstacle to this was the risk of further wounding and the exhausted state of the potential donors (Jullien 1875, p. 45). As a result, the idea proposed by advocates of interspecies transfusion (Gesellius, Eckert, Jullien, etc.) of using lambs from the regimental supply service as donors, came to the forefront. "An animal will always show superiority over a human in that its blood is inexhaustible and always ready," claimed Jullien (Jullien 1875, p. 217). Gesellius suggested that soldiers in the medical service carry animals "prepared" for transfusion in special leather bags on their back, so as to be able, via a blood transfusion, to maintain the strength of the wounded awaiting evacuation from the battlefield (Gesellius 1874, p. 11). Further-

more, Neudörfer suggested that if cannulas were inserted into the carotid arteries of ten sheep before the fighting, 40 wounded soldiers might be given transfusions on the battlefield in two hours. By his estimates, one sheep could be used as a donor for 24 hours before it began to suffer from "fever". To avoid overexciting the animals and stop their sensations of pain, which provoked a high temperature, the lambs needed to be given chloroform (Neudörfer 1875, p. 563).

Thus, the main condition for the use of animal blood in battlefield conditions was a lack of suitable human donor blood. Opponents of the use of animal blood claimed that in practice it was not possible to perform blood transfusions at dressing stations and mobile field hospitals because of the need for a large number of assistants, time, and space for the lambs near the wounded (Tabure 1873, p. 85). Nikolai Pirogov (1810–1881) said: "Blood transfusion is hardly going to figure at any time among the operations that can be performed at dressing stations" (Pirogov 1941, p. 241).

## Wishful thinking or reality?

The practical experience of European and Russian military surgeons showed that how quickly the wounded recovered and the extent of any "serous" wound complications ("purulent infiltration"; "hospital gangrene") directly depended on the quality and quantity of the blood. Consequently, as Nikolai Tabure (1838–?) stated in 1873, blood transfusion was useful in battlefield surgery as supportive therapy (Tabure 1873, p. 85). Experiments performed by him on dogs showed that whatever type of blood (whole or defibrinated) was transfused into the animals a day prior to an amputation or two days after an operation, it "visibly improved the wound's condition and helped it to heel faster" (Tabure 1873, p. 94). Defibrinated blood, said Tabure, was significantly lighter than whole blood and was assimilated by the recipient's body more quickly. Consequently, "in its inconveniences and dangers, the transfusion of whole heterogeneous blood... is much inferior to the transfusion of defibrinated" (Tabure 1873, p. 94).

The beneficial effect of defibrinated blood on the treatment of wounds was noted by Russian doctor Sergei Kolomnin (1842–1886), who performed blood transfusions in military hospitals during the Russo-Serbian (1876) and Russo-Turkish (1877–1878) wars. He combined "amputation of the upper leg or arm with the transfusion into the radial artery of defibrinated blood taken from a person," in order to "maintain the fading life of the patient, who had sometimes been operated on earlier, or to strengthen a weak patient who would need to be operated on later" (Kolomnin 1878, p. 145). In wartime, Kolomnin performed 12 arterial transfusions of defibrinated human blood using Hueter's method and concluded that "transfusion is always useful, completely safe, and if it rarely leads to the patient's recovery, this is only because it is used in extremely serious cases"(Kolomnin 1878, p. 146). In his view, the effect of the transfused blood was that it improved the composition of the blood, increased the strength of the body and the mass of blood in the major vessels, and provided mechanical compensation for the work of the heart.

The physiological studies carried out between 1873 and 1885 were aimed at a qualitative and quantitative analysis of how the blood altered in interspecies transfusions. The change in the makeup of the recipient's blood in the post-transfusion period was evidence of the destructive effect of foreign blood and the progressive reduction in the number of the recipient's blood corpuscles in the first 2–6 days after the transfusion, whatever kind of blood (whole or defibrinated) was used (Landois 1875). Restoring the original makeup of the recipient's blood took from two to eight weeks (Ott 1884, p. 91). Consequently, even the early positive effect of blood transfusion (within six hours) resulted in a decrease in the number of erythrocytes in patients' blood in the long term (over 7–28 days), which made their already poor condition even worse, and was actual cause of death. As a result, Professor Ernst von Bergmann (1836–1907), of the University of Berlin, who took part in military campaigns in the 1860s and 1870s, observed that "transfusion of the blood of animals, direct or indirect, both whole and defibrinated" never brought the expected beneficial impact (von Bergmann 1883, p. 25).

The effort to mitigate the negative effects of the potentially promising procedure encouraged physiologists to study the effects of donor blood in more detail. Their findings showed that where no more than a third of the total mass of blood was lost, the "life-saving effect" of blood transfusion was linked mainly to the volume of fluid introduced (Ott 1884,

p. 64). Thus, whatever the type of donor blood, its effect consisted of increasing the "water content of the blood" – a volemic effect maintaining the volume of blood in the vessels and preventing the heart from beating "dry". "We have done nothing," wrote von Bergmann, "except to restore the work of the heart in cases of acute anaemia, by filling an elastic tube" (von Bergmann 1883, p. 22). In 1877, the first attempts were made to use 0.6% saline rather than transfusing blood (Köhler 1901, p. 92; von Bergmann 1883, p. 22). In the first half of the 1880s, the use of saline was shown by experiment to be safer than intraspecies blood transfusion (Köhler 1901; Ott 1884; von Bergmann 1883). Experimental research by Russian physician Dmitry Ott (1855–1929) showed that "the full restoration of the number of blood corpuscles to the initial former norm takes place much more slowly in blood transfusion than when saline or serum is infused" (Ott 1884, p. 91). From a practical point of view, using saline in battlefield conditions saved the doctor completely from having to find donors. "Nothing is simpler," wrote Ott, "than to prepare an appropriate saline solution in a sufficient quantity and to disinfect it completely by boiling" (Ott 1884, p. 128). Thus, the hypothetical idea of giving blood transfusions to the wounded on the battlefield, which arose as military medical activities were being examined during the Franco-Prussian War, gave way to saline infusion in practice (Köhler 1901, p. 79).

## Conclusion

At the turn of the 1870s and 1980s, blood transfusion, seen by military doctors as the simplest and most effective method of first aid on the battlefield, turned out in practice to be impracticable. "In medicine," lamented Russian military surgeon Karl Ludwig Höppner, "more than anywhere else, the difference between theory and practice is extremely great... the idea may undoubtedly be good, but its application in practice encounters insurmountable obstacles," (Höppner 1872, p. 52). The main obstacles to the use of blood transfusion in battlefield surgery were, on one hand, the problems associated with the search for healthy donors, the preparation, transportation and procurement of donor blood by physicians at frontline medical detachments and dressing stations and, on the other, the data obtained by physiologists on the properties of blood and the adverse changes in the makeup of the recipient's blood as a result of the transfusion. Consequently, blood transfusion was not among the first aid methods used in battlefield surgery in the last quarter of the nineteenth century.

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