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Historical Article

Nikolay Ivanovich Pirogov: a surgeon's contribution to military and civilian anaesthesia

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Summary

A key figure in the development of anaesthesia in Russia was the surgeon Nikolay Ivanovich Pirogov (1810–1881). He experimented with ether and chloroform and organised the general introduction of anaesthesia in Russia for patients undergoing surgery. He was the first to perform systematic research into anaesthesia-related morbidity and mortality. More specifically, he was one of the first to administer ether anaesthesia on the battlefield, where the principles of military medicine that he established remained virtually unchanged until the outbreak of the Second World War.

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Introduction

On the morning of Friday 16 October 1846, in the Bullfinch operating theatre of the Massachusetts General Hospital in Boston, William Morton carried out the first successful public demonstration of anaesthesia with ether in humans [1, 2]. News of this discovery was reported in the Russian press early in 1847 [3, 4]. Although B.F. Berenson, on the 15 January 1847 in Riga (at that time a region of Imperial Russia), and F.I. Inozemtsev, on 7 February 1847 in Moscow, were the first in Russia to use ether anaesthesia, it was the surgeon Nikolay Ivanovich Pirogov[1] (Fig. 1) who was to develop the widespread use of anaesthesia in that country and apply it on the battlefield [3, 5, 6].

Pirogov was born in Moscow on 13 November 1810.[2] He was a gifted child and by the age of six had taught himself to read Russian, and later was taught French and Latin by home tutors. When he was 11 years old, Pirogov entered a private boarding school; however within two years, financial difficulties befell the family and there was insufficient money to keep him at the school. A family friend, Efrem Osipovich Mukhin, Professor of Anatomy and Physiology at

[1] We have used common English transcription 'Pirogov' for the Russian surname 'Пирогов'. Other transcriptions such as 'Pirogoff' and 'Pirogow' also occur.

[2] There are uncertainties about the dates cited as it is not always known whether the Julian or the Gregorian calendar was used in the original source literature. We have used the old dates as far as we can determine.

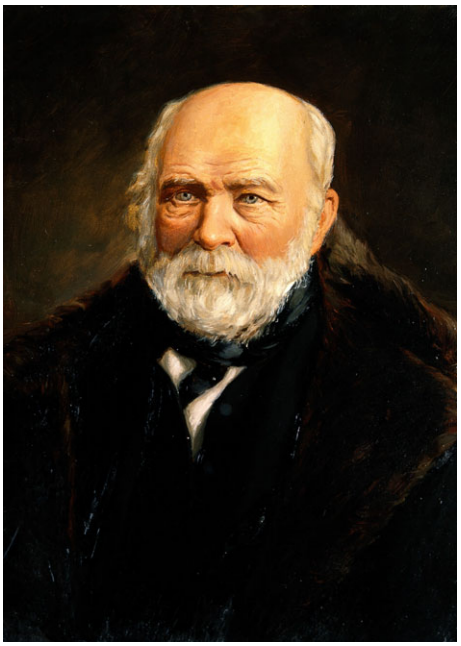

Figure 1 Portrait of Nikolay Ivanovich Pirogov. Oil on canvas, artist and date unknown. Wellcome Library, London (reproduced with permission).

Moscow University, arranged for the young Pirogov to be admitted to the Medical Faculty there, although he was three years younger than the usual entrance age of 16 [7]. The teaching of medicine in Moscow at that time was extremely poor, with lectures based on outdated textbooks. During his four years at university, Pirogov did not carry out a single anatomical dissection and was present at only two operations. Nevertheless, he qualified as a physician in May 1828, only 17 years old.

After graduating, Pirogov enrolled at the postgraduate institute of the German-Baltic University of Dorpat (now Tartu in Estonia) to continue his medical education. He completed his studies at Dorpat in August 1832, receiving a doctorate after defending his thesis *Num vinctura aortae abdominalis in aneurismate inhunali adhibitu facile ac tutum sit remedium* [Is the ligation of the ventral aorta an easy and effective therapy for inguinal aneurysm?]. Dorpat University kept in close contact with developments in Western Europe, and here Pirogov developed an international outlook in medicine. After graduation, he studied for two years in Berlin and Göttingen. In March 1836, still only 25 years old, he was appointed Professor of Surgery at Dorpat University and the successor to his former teacher Professor Moier. Then, in March 1841, he was appointed Professor of Hospital Surgery and Applied Anatomy at the Military Medical Academy and Chief Surgeon of the Second Military Land Force Hospital in St. Petersburg (until 1917 the capital of Imperial Russia) [7–9]. His time in St. Petersburg was not altogether a happy one. From the start, he met with hostile opposition from an incompetent administration and visiting medical staff jealous of his reputation, so that life for him became a ceaseless struggle. Nonetheless, this failed to deter him from his hospital and teaching duties, private practice and scientific pursuits. This situation continued after his return from the Crimean War, and he resigned his position in St. Petersburg in April 1856, and moved first to Odessa and later to Kiev [8].

Pirogov probably learnt about Morton's demonstration of ether anaesthesia in Russian newspapers and journals such as *Northern Bee*, the medical newspaper *Friend of Health*, *St. Petersburg Vedomosti* and others [4]. He was initially reluctant to use ether, as he was worried about the safety of the technique and concerned about possible excitatory effects during recovery from anaesthesia. However, the Russian government was interested in this new development and, in contrast to elsewhere in Europe and America, ordered and funded scientific research into ether. Pirogov began experimenting with ether in January 1847, and the results convinced him that his earlier misgivings were unfounded, and that ether anaesthesia was "*. . . . a remedy, that in one sense can transform the whole of surgery*" [10, 11]. He published his first monograph on the subject on 17 May 1847 [4, 11, 12]. Pirogov recommended that a test anaesthetic should always be administered because the response to ether anaesthesia could vary considerably between individuals. For the patient who did not want to inhale ether, or could not co-operate, he preferred rectal administration [11, 13].

Nikolay Pirogov investigated the clinical course of ether anaesthesia on himself and his assistants before using it on his patients. He carried out his first two operations under ether anaesthesia on 14 February, 1847 in the Second Military Land Force Hospital in St. Petersburg, using a simple green bottle with a rubber tube inserted into the patient's nose for inhalation of ether vapour [10, 11, 14]. On 16 February 1847, Piro-

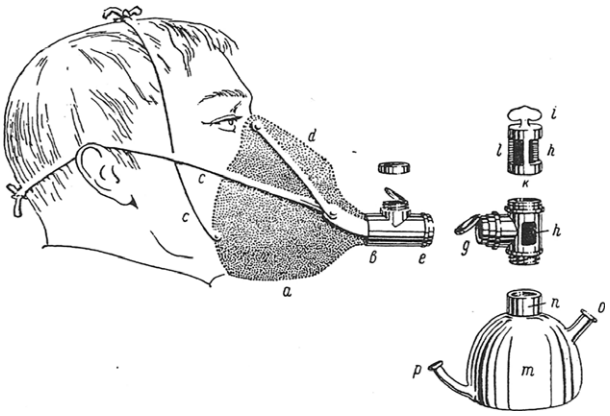

Figure 2 Device for inhalation of ether vapour developed by N.I. Pirogov [11]. Ether vapour from flask (m) enters the inhalation valve (h) where it mixes with air inhaled through openings in the valve. The amount of mixing, and thus the inspired concentration of ether, was controlled by the tap (i) on the upper half of the inhalation valve. The ether/air mixture was inhaled by the patient via the tight-fitting face mask connected to the inhalation valve by a length of tubing containing an exhalation valve. The face mask designed by Pirogov to fit snugly around the mouth and nose of the patient was an entirely new innovation at that time. This illustration is in the public domain in Russia and thus according to Russian law no specific permission is required for its reproduction.

gov again operated using ether anaesthesia in the Obukhov Hospital, and his fourth operation with anaesthesia was on the 27 February in the Peter and Paul Hospital, St. Petersburg. The operation was a successful palliative procedure on a young girl who had developed a purulent stump following amputation of a leg. This time he replaced his earlier primitive equipment with the device invented by the Frenchman Charrière. However, not entirely satisfied with this inhaler, he constructed, together with master instrument maker L. Rookh, his own device with a mask for ether inhalation[3] (Fig. 2) [10, 11]. The mask enabled Pirogov to administer ether while he was operating without the help of an assistant. The valve allowed adjustment of the mixture of ether and room air, allowing him to regulate the depth of anaesthesia. Within one year of Morton's demonstration of ether anaesthesia, Pirogov had operated on more than 300 patients using ether in his own surgical practice and on the battlefield [10].

On the 30 March 1847, Pirogov submitted a paper to the Académie des Sciences in Paris describing his experiences with rectal ether; this was read on 5 May 1847 [12]. On 21 June 1847, he presented a second paper to the Académie describing the results of his animal experiments with rectal administration of ether [15]. This paper was intended to accompany his book in which he described his experience of administering ether to 40 animals and 50 patients [11]. The purpose of the manual was to provide physicians with information about the effects of ether anaesthesia and details about the construction and use of the inhalation device for its administration. This book deserves to be added to the list of early textbooks on anaesthesia compiled by Secher and Dinnick [15, 16].

The research Pirogov conducted with rectal administration of ether was on animals, mostly dogs, but also rats and rabbits. His idea was based on the work of the French physiologist François Magendie, who had performed experiments on animals using rectal ether [11, 17]. Ether, introduced as a vapour into the rectum by means of an elastic tube [10, 11], was rapidly absorbed into the blood, and could soon be detected in the exhaled air. Most patients lost consciousness within 2–3 min after the start of administration. Compared with the inhalation technique, the patients were more deeply anaesthetised, with better muscle relaxation. Anaesthesia also lasted longer (about 15–20 min) than inhalation anaesthesia, allowing more major operations to be carried out. Due to significant muscle relaxation, this type of anaesthesia was particularly suitable for strangulated hernias and chronic dislocations. The method had, however, several drawbacks. Hot water was always needed to heat the delivery system, which made the technique unsuitable for use on the battlefield; furthermore, the colon had to be cleansed by enemas, and patients often complained of colic and diarrhoea as the ether vapour cooled and liquefied. Pirogov was initially enthusiastic about this method, but later he only used it as an antispasmodic in the management of urinary tract stones [10, 11]. Indeed, rectal ether never achieved wide-

[3] *Pirogov* (in Russian: Пирогов) is a 1947 Soviet film directed by Grigori Kozintsev, based on the life of Nicolay Ivanovich Pirogov. Part of this film demonstrates the use of the Pirogov inhaler.

spread popularity, although it was used in London by Dr. Buxton at King's College Hospital for operations by Sir Joseph Lister and Sir Victor Horsley [18]. There is also one report from Canada of its use in obstetrics in the 1930s [19].

Pirogov also carried out animal experiments injecting ether both intravenously and into different areas of the nervous system. He demonstrated that anaesthesia only occurred if the ether could be detected in the exhaled air: "*Thus the arterial blood constitutes the transport medium of vapour, and thus the calming effect on the central nervous system is transmitted*" [10, 11]. He promptly gave up the concept of intravenous administration of ether as hazardous. Pirogov also experimented with the use of direct intra-tracheal administration through a rubber tube inserted into a tracheotomy opening [11].

The scientific work and inventiveness of Pirogov had an enormous impact on what was then in Russia called 'the etherisation process' [5]. Although he was convinced that the discovery of ether anaesthesia was one of the greatest achievements of science, he was also very much aware of its limitations and dangers: "*This kind of anaesthesia can be destructive, or can significantly weaken the reflective activity; it is only one step away from death*" [10, 11].

The Caucasian War and military anaesthesia

In the spring of 1847, mountain tribes in the Caucasus rebelled anew against the Russian government; thousands of Russian soldiers were killed and maimed in bloody battles with the rebels. Field hospitals were overflowing with young men with horrendous injuries. The Tsar insisted that ether should be used in surgical operations during this campaign, not only for humanitarian but also for tactical reasons. He reasoned that soldiers would be better motivated to fight if they knew that, should they be wounded, they could avoid the excruciating pain usually associated with surgery [10]. Therefore, in a meeting of the Conference of the Medical-Surgical Academy on 25 May 1847, Pirogov was told that the Tsar was pleased to send him, as the Ordinary Professor and State Councillor, to the Caucasus to instruct doctors of the Separate Caucasian Corps on the use of ether vapour during surgery. The Tsar appointed Dr Peter Y. Nemmert as his assistant, and also Ivan Kalashnikov, a senior paramedic of the Second Military Land Force Hospital. Their preparations for the journey took a week. They left Saint Petersburg in June by carriage to cross the country from the north to the war zone in the south. En route, Pirogov visited several towns and cities where he introduced ether anaesthesia to the local physicians [4]. From a factory producing surgical equipment (of which he was also director), he had brought 30 anaesthesia inhalers, and from the State Pharmacies of Stavropol and Tiflis, he obtained 32 kg of ether. He had misgivings about transporting ether because of the high temperature (30–33 °C) in the Caucasus region, fearing that the liquid would vaporise. To his relief, the entire volume of ether was transported without loss, despite the bumpy carriage journey, the narrow roads and the heat. When the ether arrived at its destination it was dispensed into individual bottles of thick glass, each holding about 800 g of liquid, and stored in specially designed boxes closed with matting and oil cloth [10]. In the city of Pyatigorsk, in a military hospital, Pirogov organised theoretical and practical sessions for local doctors and, together with Nemmert, he performed 14 operations of varying complexity [4].

In the city of Oglakh, the wounded were housed in tents. There was no separate room for operations, and because Pirogov wanted to convince other wounded soldiers of the analgesic effect of ether, he carried out operations in their presence. This visual propaganda had a profound effect on the wounded soldiers, who subsequently came for surgery without fear. In his Report on the journey to the Caucasus, he wrote:

> "*For the first time operations were carried out without the moans and screams of the wounded. . .the most consoling effect of etherisation was that the operations performed by us in the presence of other wounded men did not frighten them, but, on the contrary, reassured them of their own plight.*"

Finally, Pirogov arrived at the Samurtsky military detachment, which was located in the fortified village of Salta. Here, in a primitive 'field hospital' (a few huts made of tree branches with a roof of straw), he had to kneel to carry out operations on a table made of stones

and covered with straw. During the war, they anaesthetised 100 wounded soldiers on the battle field. Pirogov himself stated:

> "*From the number of surgical operations performed with ether, 47 were carried out by me, 35 by my assistant Nemmert, five under my supervision by the local physician Dukshinsky, and the remaining 13 under my supervision by regimental battalion doctors*" [4].

Of these patients, only two received rectal ether because of the primitive conditions and the presence of an open fire. This was the first time in military history that wounded soldiers underwent operations and amputations with general anaesthesia. Pirogov also found time to demonstrate to local surgeons the technical aspects of ether anaesthesia.

During the period February 1847–February 1848, with the help of his assistant Nemmert, Pirogov gathered data on operations performed under anaesthesia both on the battlefield and in military and civilian hospitals (Table 1). Of the 580 operations for which sufficient data were available, 108 patients died, a mortality rate of 1 per 5.4 operations. Of these, 11 died within 48 h of surgery, but a surgical cause was found in each patient. Pirogov described his Caucasian experiences and his statistical analysis in his book *Medical Report from a Trip to the Caucasus* [10, 11] in which he stated:

Table 1 Number of patients operated on by Nicolay Pirogov between February 1847 and February 1848, classified according to the types of anaesthesia and surgery [10].

	Type of surgery		Deaths per surgical type	
Type of anaesthesia	**Major**	**Minor**	**Major**	**Minor**
Ether by inhalation				
Adults	242	16	59	1
Children	29	4	4	0
Rectal ether				
Adults	58	14	13	1
Children	8	1	1	0
Chloroform				
Adults	104	74	25	1
Children	18	12	3	0

> "*Russia, ahead of Europe, shows the world by our actions in the siege of Salta not only the opportunity of the application, but the undeniable benefit of etherisation for the wounded on the battle field itself. We hope that from now on etherisation will be, just as the surgeon's knife, an indispensable attribute of each doctor during his action on the battle field*" [11].

This summarised his views about anaesthesia and its importance for surgery.

Pirogov and chloroform

After his return from the Caucasian War, Pirogov administered his first anaesthesia with chloroform on 21 December 1847 in Moscow; the subject was a large dog [20, 21]. He meticulously recorded every detail of his operations and animal experiments and, in addition to the publication of surgical outcomes, he described the influence of anaesthesia on the postoperative course. As well as surgical mortality rates, he reported anaesthesia-related side-effects, which he defined as prolonged loss of consciousness, vomiting, delirium, headache and abdominal discomfort. He spoke of 'anaesthesia-related mortality' if death occurred within 24–48 h and at autopsy no surgical or other explanations for the death were found.

On the basis of his observations and analyses, he was convinced that mortality was not increased by administration of ether or chloroform [10]. This was contrary to the observations of French and British doctors (influenced partly by the famous case of Hannah Greener) that the administration of chloroform could lead to sudden cardiac death, or as Glover suggested, of intense lung congestion from the toxic action of the anaesthetic [22]. Pirogov surmised that the deaths described by the French and British doctors were the result of too rapid and excessive administration of chloroform [10]. Acute cardiac death was certainly not due to the occurrence of gas bubbles in the blood, as some had speculated, but to acute right heart failure caused by an overdose of chloroform. Pirogov had himself demonstrated this in dogs and cats [10, 13]. John Snow reported similar findings in 1852 [23]. Chloroform had obvious advantages over ether for use in the field. The quantity needed for effective anaesthe-

sia was small; unlike ether it was not inflammable; and it did not require complicated equipment, as anaesthesia could easily be induced using a simple rag-and-bottle technique. Indeed, the French Army Medical Service used chloroform extensively during the Crimean War, and it was also used by some British Army surgeons [24–26].

None of the deaths among the patients to whom Pirogov gave chloroform during the Crimean conflict were related to anaesthesia, nor were there any reports of chloroform-related deaths in the Russian field hospitals. However, five of his patients developed 'deep shock' during anaesthesia. One patient died of severe blood loss; the other four made a full recovery within a few hours. One of these patients underwent a reduction in contracture of the knee under deep anaesthesia. After adding a small amount of chloroform to increase muscle relaxation, there was a sudden bradycardia. The patient was without a palpable pulse or respiration for 45 min despite all means of stimulation. There was marked dilatation of neck and arm veins. Pirogov performed a bloodletting of the median vein and observed a release of gas with an audible hiss but with little blood loss. Then, with rubbing of the neck and arm veins, more blood appeared initially with gas bubbles and finally pure blood. Although Pirogov was meticulous in recording all his observations, he was unable to provide an explanation for these extraordinary findings in this patient. Fortunately, the patient made a full recovery [13].

Pirogov formulated the following guidelines for the use of chloroform [10, 13]:

1 Chloroform must always be administered in divided doses, especially when used for major trauma. He ordered chloroform in small bottles containing 1 dram (~3.9 g).
2 Patients should where possible be anaesthetised in the prone position.
3 Patients should not undergo surgery immediately after a meal, or after prolonged fasting.
4 Anaesthesia should be gradually induced by applying a handkerchief or sponge soaked in chloroform from a distance, gradually approaching the patient. In this way, laryngospasm or coughing could be avoided.
5 An experienced assistant, or the surgeon himself, should constantly monitor the pulse to guide anaesthesia. If bradycardia occurred, then the chloroform sponge should immediately be completely removed.
6 The greatest caution should be exercised in anaemic patients, as they are especially prone to go suddenly into shock if chloroform is administered too rapidly.

Pirogov also made several recommendations about resuscitation, including compression of the thorax and lower body, opening the mouth, removal of accumulated mucus and blood from the throat, and full forward displacement of the tongue. Although now considered standard practice, these ideas were quite new in Pirogov's time. He also insisted that during surgery, the surgeon should observe the colour and the amount of blood loss. If the arterial blood was black and the blood stream was weak, the administration of chloroform must be stopped. Pirogov suggested that the quantity of chloroform should be limited and usually 3 drams would be enough, although in some patients larger doses must be used. Even when significant quantities of chloroform were used, shock never occurred in these cases, but was more likely in those patients where an insufficient amount was used, or when the chloroform was administered too rapidly. Pirogov also used chloroform, during strabismus operations in children, for childbirth, and for diagnostic procedures such as diagnosis of latent fractures [10, 13].

The Crimean War (1853–1856)

Pirogov served as an army surgeon during the Crimean War, arriving in Simferopol on 11 December 1854, and was appointed the chief surgeon of the besieged city of Sevastopol [13, 27]. Shortly after his arrival in Sevastopol he initiated (with the assistance of Grand Duchess Elena Pavlovna Romanova-von Württemberg, sister-in-law of Tsar Nicholas I), the deployment of female nursing sisters, who became known as 'The Sisters of Mercy'. Pirogov trained them to assist during operations and in the administration of anaesthesia, among other duties. This group of women became the foundation for what later became the Russian Red Cross. Unlike the British nurses of

Florence Nightingale, the Russian nurses worked not only in small field medical units but also in the battlefield, often directly under shellfire [28, 29]. Seventeen Russian nurses died on duty during the Crimean War, six in the town of Simferopol alone [30].

During the defence of Sevastopol, Pirogov introduced the widespread use of anaesthesia and gained considerable experience in its use during many thousands of operations. He built on his experiences during the Caucasian campaign of 1847, though now the Russian medical service performed every operation under chloroform, rather than ether, anaesthesia. Over the course of nine months, he personally performed 5000 amputations, i.e. 30 a day. But, probably as a result of overwork, he fell ill with typhoid fever and was close to death for three weeks. Fortunately, he made a complete recovery. He described his experiences in field surgery, including a chapter on anaesthesia, in the book *Grundzüge der allgemeinen Kriegschirurgie usw* [13], published in 1864, which became the standard reference for field surgery. The principles of battlefield medicine established by Pirogov were soon followed by surgeons of other countries and remained virtually unchanged until the outbreak of the Second World War. Pirogov's work during the Crimean War is of such importance that he may be considered the founder of field surgery.

At the Crimean front, Russian soldiers were convinced that Pirogov possessed almost supernatural abilities as a surgeon. Soldiers would bring severely injured comrades, many with already fatal wounds, to his field hospital, in the expectation that he could restore them to health. On one occasion, a group of soldiers brought a wounded comrade to a medical post. Seeing that the man had no head, the doctor on duty exclaimed: "*What are you doing? Where are you taking him, can't you see he's got no head?*" "*The head is coming behind us*", the men responded, "*Dr Pirogov is here; he'll put it back on somehow*" [31].

Civilian anaesthesiology as a medical speciality

From personal experience, Pirogov warned against the administration of anaesthesia by untrained assistants. Based on his military medical experience at Salta during the Caucasian conflict, he became convinced of the effectiveness of physicians dedicated to administering anaesthesia, assisted by trained helpers [5, 10]. His main argument was that operations under anaesthesia were often more complicated, and tended to last much longer, than those without anaesthesia, so that the surgeon could not concentrate on the surgery and at the same time provide adequate care for the anaesthetised patient. His experience of the use of anaesthesia had increased immeasurably during the Crimean War, where he administered about 10 000 anaesthetics. Again, after observing the work of health services during the Franco-Prussian War of 1870 and in Bulgaria in 1877–78, Pirogov spoke forcibly about the importance of anaesthesia not only during surgery but also to enable painful procedures such as wound dressings [5, 10, 11, 13]. It took more than a century before his suggestion of professional anaesthetists was finally achieved in practice in Russia. In December 1938, the 24th All-Union Congress of Surgeons in the Soviet Union came to a special decision on the training of anaesthetists. This theme was a returning issue in subsequent congresses and finally, in 1955, at the 26th Congress of Surgeons in the USSR, it became a reality [5].

The impact of military anaesthesia on civilian practice

The contribution made by Pirogov to the advancement of medical care of military personnel during war, including his extensive use of anaesthesia, has correctly earned him the title of founder of field medicine [32]. He was able to apply the knowledge and experience he had gained with ether anaesthesia in his civilian practice to the very different, and difficult, circumstances with which he was confronted during the Caucasian and Crimean conflicts. And we know from his writings, his experiences during these conflicts confirmed his belief in the utility of anaesthesia. It is also true that widespread use of anaesthesia in war surgery by Pirogov and his colleagues in the Russian army medical service was to have a most significant influence on the subsequent advancement of anaesthesia for the general population in Russia [25]. Nikolay Ivanovich Pirogov played a crucial and central role in this development.

During his travels from St. Petersburg to the different war zones, Pirogov made frequent stops at cities

and towns along the routes, during which he took every opportunity to demonstrate the use of ether and to educate local surgeons and physicians in the technique and skills needed for the safe application of this new form of 'painless surgery'. In the hospitals he visited, he left anaesthetic masks and devices for rectal anaesthesia to enable the continued application of anaesthesia during surgery. This undoubtedly would have stimulated interest in the use of anaesthesia in these regions. Further, the reports of the successes of emergency anaesthesia in the Russian newspapers contributed much to the development of anaesthesia in the period immediately after the Caucasian and Crimean conflicts. Army surgeons returned to civilian practice armed with the skill to use anaesthesia, and returning soldiers would have spread the news of this new and miraculous medical advance.

In conclusion, Nikolay Ivanovich Pirogov was the greatest of all Russian military surgeons and the most important figure in Russians medical history, who played a key role in the development of anaesthesia in Russia [33]. He was that rare combination of scientist, skilled surgeon and excellent teacher, and taught his fellow doctors how to administer anaesthesia not only in hospitals but also on the battlefield, where he was one of the first to administer ether anaesthesia. He developed an alternative technique for administering ether, the rectal method, and investigated the use of chloroform in animals and then in humans. Pirogov was also the first to perform systematic research into anaesthesia-related morbidity and mortality. Although convinced that the discovery of anaesthesia was one of the greatest achievements of science, he was well aware of its limitations and dangers.

Pirogov died on 5 December 1881 in the village of Vishnya (now Vinnytsia, Ukraine). His body is preserved using embalming techniques he himself developed shortly before his death and rests in the village church in Vinnytsia. Many acknowledgements of his achievements have followed, including the naming in his honour of the Pirogov Glacier in Antarctica, the large Pirogov Hospital in Sofia, Bulgaria, and the 2506 Pirogov asteroid, discovered in August 1976 by Russian astronomer Nikolai Chernykh. Stamps with his portrait were issued in the Soviet Union in 1949 and on his 150th anniversary in 1960. Further, the highest humanitarian prize in the Soviet Union was the Pirogov Gold Medal. However, we believe that Nikolay Ivanovich Pirogov deserves to be more widely recognised outside his native Russia for his contributions to the advancement of anaesthesia.

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Competing interest

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