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ADOPTERs of Innovation in a Crisis

The History of Vera Gedroits, Kanehiro Takaki and the Russo-Japanese War of 1904–1905

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Abstract: The 1904–1905 Russo-Japanese War was the first "modern" conflict, using rapid-firing artillery and machine guns, fought over imperial ambitions in Korea and Manchuria. During the war, Princess Vera Gedroits pioneered early laparotomy for penetrating abdominal wounds with unprecedented success. Her techniques were then adopted by the Russian Society of Military Doctors. However, Allied forces took 10 years to adopt operative management of penetrating abdominal wounds over conservative management. Gedroits was later appointed in Kyiv as the world's first female Professor of Surgery. Kanehiro Takaki, a Japanese Naval surgeon, showed in 1884 a diet of barley, meat, milk, bread, and beans, rather than polished white rice, eliminated beriberi in the Japanese Navy. Despite this success, the Japanese Army failed to change the white rice rations until March 1905. During the 1904–1905 Russo-Japanese War, an estimated 250,000 Japanese soldiers developed beriberi, of whom 27,000 died. Japan's 1905 defeat of Russia sowed the seeds of discontent with Tsar Nicholas' rule, culminating in the 1917 Russian Revolution. Although the Russian Navy was destroyed, Japan ceded North Sakhalin Island to Russia in peace negotiations, and Russia seized Manchuria, South Sakhalin, and the Kuril Islands in 1945. We highlight the contributions of Gedroits and Takaki, 2 intellectual prodigies who respectively pioneered rapid triage and surgical management of trauma and a cure for beriberi. We aim to show how both these surgeons challenged entrenched dogma and the cultural and political zeitgeist, and risked their professional reputations and their lives in being ADOPTERs of innovation during a crisis.

INTRODUCTION

The Russo-Japanese (RJ) War of 1904–1905 represents a pivotal event in history. It had lasting repercussions for regional and worldwide geopolitics.[1] Vera Gedroits of Russia and Kanehiro Takaki of Japan played crucial roles in saving hundreds of lives on opposite sides of the conflict. Dr Gedroits pioneered rapid triage and operative management for penetrating abdominal wounds (PAWs) and treated injured soldiers from both sides.

Dr Takaki initiated a preventative intervention for beriberi based on traditional medicine and modern epidemiology, improving the health and operational capability of the Japanese Navy. Both Takaki and Gedroits had been rigorously trained by their respective surgical mentors. We aim to show that they were able to innovate in a crisis because they were ADOPTERs, showing Agility, Decisiveness, being Outcome-focused, Politically aware, Tolerant of risk, Empowered, and Rewarded.[2] During a crisis like a military conflict or an epidemic, ADOPTERs in innovation transformation within an organization also require good leadership and a receptive and responsive network.[2] Impediments to innovation translation included the zeitgeist of publication bias, pseudoscience and dogma, gender discrimination, vested interests, cognitive dissonance, political intrigue, professional rivalry, and cost, which are still relevant today.

The lives and achievements of both Gedroits and Takaki were intertwined with politics, economics, royalty, social revolution and war, and it is on this background that we describe the struggles each experienced in introducing and disseminating their innovations in patient care.

WORLD WAR ZERO

The RJ War centered around a clash of the imperial ambitions of the Japanese and Russian Empires in the Korean peninsula and Manchuria.[1,3,4] Japanese officials regarded Russian expansion to the Far East through the strategic ports of Vladivostok and Port Arthur as a threat to Japan's interests. The Anglo-Japanese Alliance was signed in 1902, an attempt to curtail Russian expansion in the region. Negotiations between Russia and Japan over territorial expansion, spheres of influence, and trade broke down between 1903 and 1904. Russia took the opportunity to invade Manchuria in 1900 during the Boxer Rebellion, but failed to withdraw its troops after the agreed date of October 1903 in the Russo-Qing Treaty of 1902. The Russian military also entered Northern Korea in pursuit of timber enterprises.[5]

The intelligence Japan received from London and Poland was that additional Russian naval forces were sailing from the Mediterranean toward the Far East in December 1903, and

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extra traffic on the Trans-Siberian Railway indicated a troop buildup in Manchuria in January 1904.[6] On February 8, 1904, Japan launched a nighttime naval attack on the heavily fortified Port Arthur, on the Liaodong Peninsula in Manchuria. This was followed by the prolonged Japanese naval blockade and army siege of Port Arthur, with the eventual sinking of the Russian 1st Pacific Squadron and Russian surrender of the warm-water naval base on January 2, 1905.[7,8] The deployment of huge armies and modern weaponry including high explosive shells, rapid firing howitzers and machine guns during the RJ land war led to mass casualties but minimal territorial gains.[9] This was described as World War Zero, a prelude to the trench warfare and stalemate of WWI.[1,3,4]

VERA GEDROITS

Vera Gedroits (1870–1932) (Fig. 1)[10] was born in Kyiv and grew up on her family's estate in Slobodishche in the Russian district of Bryansk. Descended from a line of Radziwiłł, one of the oldest Polish-Lithuanian nobilities, she was officially considered a princess. Her grandfather had been executed for his involvement in the 1863 Polish Insurrection, a failed attempt to restore the independence of the Polish-Lithuanian Commonwealth from Russia. Her father had fled to Russia and the Giedroyć noble title was stripped, and only officially restored in 1878. She completed her education at home and finishing school in St Petersburg.[11] Princess Gedroits then pursued a career in medicine, despite restricted access to medical studies for women in Russia.[12]

In 1892, whilst in St Petersburg attending courses of anatomy professor Peter Lesgaft, she became involved in a revolutionary group and was arrested by the Okhrana (Tsarist secret police). She was deported to her father's home to serve house arrest with ongoing police surveillance. She then arranged a marriage of convenience to a friend, Nikolai Belozerov, to change her name, obtain a passport, and escape to Switzerland to pursue medical studies.[14,15] She graduated from Lausanne University in 1898 with honors, achieving almost perfect marks.[11]

Following her graduation, Gedroits was supervised by Professor César Roux as senior assistant. He then appointed her Privatdozentin (academic surgeon) in Lausanne.[11,16] She honed her surgical skills and worked on repair of herniae of the abdominal wall. Her father recalled her in 1900 after the death of her sister from tuberculosis and her mother becoming unwell. Gedroits reluctantly left her Swiss post and began work as an industrial doctor in the Maltsov cement factory in Russia. Concerned about poor occupational health and safety, she made nutrition, drinking water and hygiene improvements and provided surgical services for workers, their families and local communities.[17]

She presented her work at the 1902 Third Congress of Surgeons which was well received by surgical colleagues, and obtained further qualifications to practice medicine throughout Russia in 1903, despite the existing institutional barriers to female emancipation in Russia. Perhaps due to increasing attention from the Okhrana, or her provincial life, in 1904 she volunteered as a Red Cross surgeon as part of its aid program for the RJ War.[11] The Russian Red Cross was funded by Russian nobility. Selection for this role came from a central committee in St Petersburg under the Tsarina's patronage, validating the ability of selected surgeons.[14] The use of modern military weapons and mass casualties provided the landscape on which Dr Gedroits pioneered lifesaving trauma laparotomies.

A Conservative Doctrine

> "In this war [Boer War], a man wounded in the abdomen dies if he is operated upon and remains alive if he is left in peace"—Sir William MacCormac, c1900[14,18]

Despite the development of antiseptics and improved anesthetic methods, nonoperative management of PAWs dominated at the time of the RJ War.[14,18] One influential proponent of the conservative approach was Paul Reclus, a French surgeon, based on gunshot experiments in dogs.[14,18] This principle would be supported by results from the First Sino-Japanese War (1894–1895), the Spanish-American War (1868), and the Anglo-Boer War (1899–1902). It was widely believed a major laparotomy was not advised under the makeshift and unstable conditions of wartime.[19] Furthermore, the Boer War was the first war in which high-powered magazine-fed rifles (average muzzle velocity 2400 fps), automatic handguns and machine guns were used, which caused far more numerous and extensive injuries.[20] Sir William MacCormac, surgeon-in-chief of the Anglo-American Ambulance service, observed that during the Anglo-Boer War,

FIGURE 1. Baron Kanehiro Takaki (L) (Reproduced under creative commons license from Jikeikai Med J. 2002;49:85–90[13]) and Princess Vera Gedroits, (R), Tsarskoye Selo hospital, c1915. (Reproduced from Beinecke Library, Picryl, public domain[10]).

British military surgeons performed 26 laparotomies for PAWs with a 69% mortality rate.[14]

MacCormac famously documented the above aphorism, and was also appointed Honorary Member of the Russian Imperial Military Academy of Medicine in 1898, which influenced PAWs management in Western Europe and Russia.[14] Conservative management of PAWs involved placing patients in Fowler's position to facilitate abdominal drainage, bowel rest, and strong opioid analgesia.[14] The observation that conservative management of gunshot injuries was successful in up to 20% of patients persisted into WWI, influenced by the concept that the dry dust of the South African veldt was "sterile." This was very different from the manure-laden mud of the trenches of Western Europe during WWI.[21]

An Alternative Approach

Conditions for medical personnel during the RJ War were fraught with danger, hardly an optimal setting for meticulous surgical work. Russian Red Cross Noble Forward Hospitals were set up in medical train carriages which functioned as nursing quarters, dressing centers, and operating theaters (Fig. 2).[22] Japanese troops commonly fired upon these carriages, and during the first 13 months of the war 12 surgeons were lost, 21 wounded and 28 taken prisoner.[11]

Despite the risks, in October 1904 Gedroits and her team treated 1255 patients in the first month of Red Cross operations in Mukden, Manchuria, 61 with PAWs. Initially treatment was performed remotely from the battlefield in clay-lined tents.[14,18] Gedroits made recommendations to move operating centers closer to battlefronts, utilizing frontline triage in horse-drawn ambulances, and rapidly transporting casualties to train carriage hospitals.[23] In January 1905 she received an operating theatre carriage and was appointed as head surgeon for the hospital train. Among her patients was a Japanese prince, who subsequently sent a letter of thanks and exquisite gifts to the "princess with merciful hands" who saved his life. She also performed a successful laparotomy on Colonel Vasily Gurko (future commander-in-chief of the Russian Imperial Army), who had sustained a PAW with 2 intestinal perforations and hemorrhage from a mesenteric artery.[15,16] She continued to perform exploratory laparotomies on patients with PAWs, based on her experience in abdominal surgery, keeping a policy to only operate on patients within 3 hours of injury. In 1905, she performed 183 laparotomies for PAWs, and although official mortality figures were not available, it was accepted her techniques had unprecedented success.[14,24] She presented her innovations to, and they were immediately adopted by, the Russian Society of Military Doctors in July 1905.[14,15,25]

FIGURE 2. Red Cross train carriage hospital, Manchuria, RJ War, c1904. (Reproduced with permission from Sueddeutsche Zeitung Photo, Alamy[22]).

In her 57-page report, she stated that "the closer a hospital was to the battlefield the more productive was its work."[26] Gedroits did not invent the concept, but she was an adopter of its innovation, a precursor to modern Mobile Army Surgical Hospitals units and Early Management of Severe Trauma systems. In fact, the idea of the "flying ambulance" and immediate triage and surgical treatment by forward medical divisions was first introduced by the French military surgeon Jean Dominique Larrey during the Battle of the Rhine in 1792. He also reported his successful "enteroraphy" of a gunshot wound to the small intestine.[27,28] He personally designed and then tested the light, horse-drawn, 2-wheeled carriages with suspension (*ambulances volantes*) during a French campaign under crossfire in the snowy mountains of Oberursel, and found the evacuation time could be reduced from several days to approximately 1 hour. In doing so, many more soldiers survived their injuries and could even return to combat after treatment. The flying ambulance was so successful (and popular with the troops), that it was rapidly adopted as military policy by the Revolutionary Government of France, and disseminated across all 14 armies of the French Republic. Larrey's principle of surgical triage for wounded soldiers was based on the severity of their injuries, rather than their military rank or nationality. This saved him when he was wounded, left for dead and captured by the Prussian army at the Battle of Waterloo in 1815. He was recognized by a Prussian surgeon, spared from execution and released by Field Marshall Gebhard von Blücher, as Larrey had treated Blücher's injured son at the Battle of Dresden in 1813.[27,28] Trains were first used for evacuation of wounded soldiers in 1854, during the Crimean War.[20,29]

Gedroits' success stemmed from her recognition of the crucial relationship between time to operative management and survival for PAWs. Her advocacy of rapid triage, retrieval and early surgical intervention, despite surrounding dangers, allowed for successful innovation where others had failed. Russian Red Cross hospital trains were positioned in close proximity to the battlefield, while trench warfare created a frontline with unprecedented stability.[14,18,30] This meant that makeshift operating theaters could receive wounded patients soon after injury, whilst the extensive fortified trenches offered protection to the casualty bearers that facilitated rapid evacuation.[30] Previously, definitive treatment for PAWs was commonly delayed by 8–10 hours, well after the onset of widespread peritonitis, extensive hemorrhage, and inevitable patient deterioration.[11,14] She treated only a fraction of the injured soldiers in Mukden- there were 78 similar hospital trains deployed during the RJ War, each of which could accommodate 250 patients and typically consisted of 14 railcars. However, other Russian surgeons at Mukden, Liao Yang and Port Arthur did not have successful results of laparotomy for PAWs. During the RJ War, there were between 34,000 and 52,623 Russian soldiers killed and 146,032 wounded in action.[11,14,30,31]

After the RJ War, Dr Gedroits was awarded the Gold Medal of Diligence from the Order of Saint Anna, Ribbon of Saint George and Silver Medal for Bravery, the 3 highest awards from the Russian Red Cross[32] for her treatment of the wounded and actions during the Battle of Mukden. The Red Cross trains were considered neutral unless they were defended by a military force. However, during the evacuation from the Fushun mining area near Mukden on February 22, 1905, Russian Army troops refused to retreat until all the injured soldiers on Gedroits' Red Cross train were safely evacuated. This made her train a target for enemy gunners during its nighttime withdrawal.[14]

Aftermath

Although Dr Gedroits' innovations were successful, and her work was reported by French, British, and American military observers of the RJ War, they were not internationally disseminated, and thus were not adopted by Western militaries.[7,30,33–37]

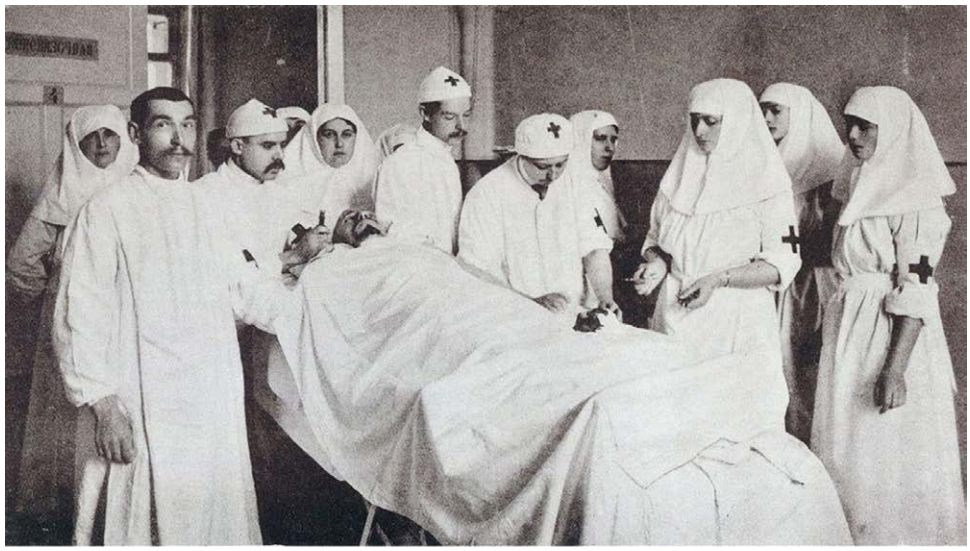

FIGURE 3. Tsarina Alexandra Romanov delivers instruments during surgery. Behind (R) are the Grand Duchesses Olga and Tatiana. Princess V. I. Gedroitz operates (Center). 4th left A. Vyrubova. Tsarskoye Selo hospital, c1915. (Reproduced from Beinecke Library, Picryl, public domain[44]).

This is despite her being the only surgeon who had successful outcomes from immediate exploratory laparotomy for PAWs during the RJ War.[31] Exploratory laparotomy for PAWs was in fact forbidden in forward facilities by the Surgeon General of the Japanese Army, due to the associated high mortality in patients.[18,33,37]

At the start of WWI, PAWs continued to be managed expectantly, with mortality rates of 70–84%.[14,18] It was the work of 2 British military surgeons, Owen Richards and Cuthbert Wallace, which caused a paradigm shift. In particular, Wallace's systematic works and postmortem analysis revealed peritoneal soiling and hemorrhage as major contributors to mortality, which could be prevented by early operative intervention.[18,38] Wallace's studies also suggested the poor outcomes of laparotomy for PAWs in the Spanish-American and Anglo-Boer Wars were due to delayed definitive management.[33] In June 1915 the Surgeon General of the British Expeditionary Force, based on Wallace's clinical and autopsy findings, mandated that soldiers with PAWs were to be immediately evacuated to a casualty clearance station for surgical evaluation and intervention. Richards' article on operative management of 9 cases of small intestinal injury from gunshot wounds was published in the British Medical Journal, and prompt evacuation of soldiers with PAWs for operative intervention was introduced as standard of care for Western militaries in August 2015, some 10 years after Gedroits' work.[34] In 1916, Wallace published a study in the British Journal of Surgery of 965 laparotomies in 1288 soldiers with abdominal gunshot injuries. He found that placement of field hospitals, rapid ambulance retrieval, and operative management resulted in operative mortality of 53.9% overall and 64.7% in hollow viscus injury from PAWs. Given that PAWs made up approximately 1.5% of all injuries, it can be presumed that a substantial number of the 2.5 million Allied deaths in WWI may have been prevented if operative management had been adopted as standard of care before 1914, as promulgated by Gedroits in 1905.[20,25] Indeed, in his 1917 publication on PAWs, Wallace grudgingly referred to Gedroits as a surgeon in the RJ War who had "met with some measure of success."[39]

Following the RJ War, Gedroits transformed the Maltsov facility into a multidisciplinary surgical hospital and introduced ether anesthesia, modern Tesla X-ray facilities and surgical equipment.[40] In 1909, she was appointed by Tsarina Alexandra Feodorovna Romanov as attending physician to the children of the Russian royal family, Department Head of Surgery and Gynecology/Obstetrics and second in charge at Tsarskoye Selo Summer Palace hospital near St Petersburg. Gedroits' appointment by the Tsarina was controversial, and background police intelligence checks ordered by the Chief physician Dr NM Schrader, revealed "the named Gedroyts... was acquainted with persons whose trustworthiness was compromised."[41] She joined the Guild of Poets in 1911, publishing under the pseudonym Sergei Gedroits (the name of her late brother) and became known in Russian literary and bohemian circles. Her friends included the famous poet Nikolai Gumilyov, who was shot by the Bolsheviks in 1921. In 1912 she was awarded a Doctorate of Medicine from Moscow University after defending her thesis "Long-term results of inguinal hernia operations using the protocol of Professor Roux based upon 268 operations."[11,14,42]

During WWI, she equipped the Tsarskoye Selo Palace hospital to rapidly receive wounded soldiers from the front, which included hospital trains and direct rail lines. She published a surgical manual and taught a formal surgical nursing diploma course to the Sisters of Mercy, including the Tsarina and her 2 eldest daughters, and they assisted her in surgical procedures.[15,43] (Fig. 3)[44]

After the Russian Revolution in February 1917 and Tsar Nicholas' abdication and the house arrest of the Romanovs on March 15, Gedroits' Tsarskoye Selo infirmary number 3 was closed and Dr Schrader stopped paying her salary. However, Gedroits escaped the future Yekaterinburg fate of the Romanovs (and other aristocrats).[41] She altered her birthdate from 1870 to 1876 so as to be eligible to join the 6th Siberian Rifle Regiment as a military surgeon in May 1917 at the Southwestern front in Galicia (now western Ukraine).[45] Her old patient, Vasily Gurko, was now the Russian Commander-in-Chief of the Western Front (from March 31, 1917 to May 23, 1917), until he was removed by the Russian Provisional Government for refusing to agree to the Kerensky Offensive against the Austro-Hungarian armies in Galicia, due to the inadequate state of the Russian Army.

After the Bolshevik Revolution in October 1917 and the demobilization of the Russian Army, the whereabouts of Gedroits was unclear. Returning to St Petersburg was too dangerous, due to her previous association with the Russian Royal Family.[15] Some sources suggest she spoke Ukrainian well and served as a surgeon in the armed forces of the Ukrainian People's Republic.[15] She was wounded in January 1918 and evacuated to a military hospital in Kyiv. On February 9, 1918, the Ukrainian nationalist delegation signed a peace treaty with the Central Powers in Brest-Litovsk, ending WWI hostilities. Both the Ukrainian and Soviet Brest-Litovsk treaties were

annulled on November 11, 1918, after the Allied defeat of Germany. However, Belarus, Ukraine, Finland, Estonia, Latvia, and Lithuania remained independent of Russia.[15] Gedroits recovered from her injuries and was appointed as a surgeon at Kyiv Medical Institute in 1920 and Professor of Medicine in 1923 by Professor Yevgeny Tcherniakhovsky. She became Professorial Chair of the Surgery Department in 1929 after the arrest of Tcherniakhovsky by Soviet secret police.[14,32] She was removed from her Kyiv post in 1930 in the Stalinist purge of Ukrainian academic intelligentsia and denied a pension. Before her death from metastatic uterine cancer in 1932, it emerged that Professor Roux had bequeathed the Chair of Surgery at the University of Geneva to Gedroits.[41]

KANEHIRO TAKAKI

Kanehiro Takaki (Fig. 1)[13] was a Japanese Naval surgeon, known for contributions to holistic medicine, medical education, and care for the underprivileged. He is particularly remembered for using epidemiology to identify white rice consumption as a risk factor for beriberi. Beriberi was common among sailors in the Japanese Navy in the late 19th century. His work[46] led to the eradication of beriberi, before the correct identification of the molecular structure of thiamin (vitamin B1) in 1934 by Robert Runnels Williams. This was the micronutrient in rice bran removed during mechanical milling of brown to white rice.[47]

Kanehiro Takaki (1849–1920) was born at Mukasa on Kyushu, the first-son of a lower-class samurai and carpenter in the Satsuma Daimyō.[48] His father, when sent to protect the Royal Palace in Kyoto, had learned of the association between beriberi in palace guards and the garrison diet.[49] Takaki was inspired to become a doctor by Ryosuke Kuroki, a respected local practitioner of Chinese medicine. In 1866 Takaki became apprentice to Ryosaku Ishigami, a surgeon who had trained in Dutch medicine in Nagasaki, and worked with him in Kyoto during the Boshin Civil War. Takaki observed the skill and principles of the British doctor William Willis (chief surgeon of the Satsuma Domain military hospital established in the temple of Shōkokuji in Kyoto) in treating wounded soldiers from both sides. Takaki recognized his own deficiencies and those of other Satsuma surgeons and traditional *Kampō* medicine, which required transformational change.[50]

After the Meiji Restoration of 1868, Takaki was trained by William Willis, in the new Kagoshima medical school established by the Satsuma clan, the only medical school in Japan with a British medical curriculum taught in English.[51] In 1872 Takaki was invited by Ishigami to become a surgeon in the Japanese Navy, where beriberi was endemic in sailors. Takaki was then sent to St Thomas's Hospital Medical School in London in 1875 and awarded the Cheselden Gold Medal and Fellowship of the Royal College of Surgeons in 1880.[48,51–53]

Beriberi Endemic

After the overthrow of the Tokugawa Shogunate and restoration of the Meiji Emperor by the Satsuma–Chōshū Alliance, Japanese medicine continued its transformation, from traditional practice during the Edo period (1603–1867) to a Western-based medical doctrine, known as "Meiji." Western medicine had originally been introduced by Dutch practitioners in Nagasaki after 1641, and was known as *rampo*.[52] Beriberi was described in traditional Edo texts as Japanese Kak'ke, or in Chinese *Jiao qi* ("leg spirit"), named after the associated leg weakness and swelling in afflicted patients. Edo teaching from the mid-18th century was based on traditional Chinese medicine and the balance of *qi*, a fundamental concept representing one's vital energy. Edo taught that imbalances within eating, drinking and engagement in sexual activity, and environmental factors, were involved in disease.[54] *Kak'ke* was historically treated with buckwheat, barley rice, or azuki beans (now known to all contain thiamin), and herbal medicines.[52,55] This is an important contextual point, as when Takaki eventually employed barley to treat beriberi, his work was criticized. It was felt his treatment belonged to the old world of traditional Chinese or *Kampō* medicine, which was trivialized and even considered shameful by Meiji medical physicians in Tokyo.[52]

Kak'ke was uncommon in rural Japan in the 1800s, where villagers grew and ate brown rice, beans, barley, and millet, but endemic in cities where white rice was popular such as Edo (renamed Tokyo in 1868), Kyoto, and Osaka. *Kak'ke* was recognized as "*Edo wazurai*"—the Tokyo illness. Since 1699 it was known that *Edo wazurai* would improve if the samurai returned from Edo to their provinces before winter snow blocked the mountain passes.[49,55] In 1877, the Meiji Emperor developed a personal interest in *Kak'ke* when his aunt Princess Chikako died of wet beriberi.[52] Beriberi was also common in soldiers, sailors, plantation laborers, prisoners, and asylum inmates and became worse during the wet season. Military and civil institutions believed beriberi to be a contagious disease related to contaminated water or the surrounding soil, prevented by adequate hygiene and relocation to higher and drier environments.[48,52,55]

Using Epidemiology

In 1880 when Takaki returned from London and became chief of Tokyo Naval Hospital, beriberi affected 36% of naval staff and accounted for 27 deaths. Using British epidemiological methods, Takaki researched *Kak'ke* prevalence in naval personnel and found rates were highest amongst lower-class sailors and lowest among higher-ranking officers. He found the same pattern in civilians, as students and poorer citizens were disproportionately affected compared to wealthier classes. Over 2 years, across 18 ships and 4683 naval personnel, he examined living conditions, clothing, climate, and sanitation as possible beriberi causes. However, diet was the only variable consistently linked with mortality.[46,56] From nutritional surveys he deduced that in naval units where nitrogen (protein) consumption was lowest, beriberi incidence was highest and vice versa.[52,55] He recognized that Western navies did not usually experience beriberi. He hypothesized that the polished white rice rations of the Japanese Navy, representing a diet high in carbohydrates and low in protein, was the cause for beriberi. A protein-to-carbohydrate ratio of 1:15 was considered healthy.[52] Japanese sailors purchased their rations from the ship's galley. The exception was white rice, provided free of charge. Naval officers could afford to eat a more expensive, diverse, and nutritious diet. This resulted in the naval dietary ratio ranging from 1:17 to 1:32 of protein-to-carbohydrates.[48,56]

With the discoveries of Joseph Lister, Louis Pasteur, Emil von Behring, and Robert Koch and the emergence of germ theory, the prevailing belief was that beriberi had an infectious cause.[52] Nonetheless, Takaki pursued his hypothesis that beriberi was a nutritional disease. This was met with substantial resistance, with the Naval Ministry refusing grants required by Takaki to prove his hypothesis. Takaki's proposed reforms toward a more protein-rich diet represented a large financial commitment for naval officials.[52]

In December 1882, the Japanese Naval cadetship *Ryujo* sailed on a tour of the Pacific Ocean from Shinagawa in Japan through New Zealand, Chile, Peru, and Hawaii. Of 376 crew members, 169 (44.9%) developed beriberi, and 25 (6.7%) died. Beriberi was so severe that the *Ryujo* was forced to dock in Hawaii for further supplies and medical aid. Upon taking on more meat and vegetables, a large proportion of cases were resolved, and no new cases were recorded when the ship returned to Shinigawa in October 1883.[48] Takaki recognized the strategic importance of a functional navy, and requested the *Ryujo*

special investigation.[46] Takaki found that during the ship's early voyage, the protein-to-carbohydrate ratio of the sailors' diets was 1:28 and corresponded to the high incidence of beriberi. After resupply, the protein-to-carbohydrate ratio improved to 1:17, which correlated with the dramatic improvement in beriberi incidence.[48,50,52,55]

Takaki presented his report on the cause and prevention of beriberi to the Japanese Emperor on November 29, 1883. Takaki was then permitted to commission the naval ship *Tsukuba* for a large-scale experimental platform for dietary reform. Takaki's professional reputation (and life) depended on the outcome of his nutritional intervention, as he was prepared to commit seppuku if it failed.[50] Funding for the project (~¥60,000), was provided by a special Treasury allowance, with the assistance of Seigi Matsugata, Minister of Finance and Hakubun Ito, Councelor of the Imperial Household.[50,51,56] On a training exercise between February and November 1884, the *Tsukuba* followed the identical route of *Ryujo*. However, sailors were provided with a "Western-type" protein-rich diet comprising meat, bread, vegetables, and condensed milk. Of 287 men on board, only 14 (5%) developed beriberi. It was found these 14 men refused the new diet, and inadvertently served as a control group. Takaki (erroneously) concluded a dietary ratio of 1:15 of nitrogen to carbohydrates would prevent beriberi in his 1885 work "On the Cause and Prevention of Kak'ke."[48,50,52]

Although Takaki initially introduced a Western diet with meat and bread in February 1884, many Japanese sailors did not find this palatable or customary, often discarding rations.[56] The custom of meat avoidance originated from Buddhist beliefs of reincarnation and the prohibition of meat consumption by Emperor Tenmu in 675 AD.[57] Brown rice and barley were commonly consumed in rural areas and regarded as peasant or prison food, whilst polished white rice was considered prestigious and available in Tokyo.[49] In April 1885, Takaki fortified the existing rice-based rations with equal parts of barley to increase dietary protein content and compliance.[46] Subsequently, beriberi incidence in the Japanese Navy fell to 0.59% in 1885, 0.04% in 1886, and zero thereafter[52,55] supporting Takaki's hypothesis (Fig. 4).[52] Takaki tried to introduce an innovative form of medicine in the Meiji era, an amalgam of traditional Japanese holistic teaching and Western medical principles. In 1890, he presented evidence to the Meiji Emperor for the elimination of beriberi in the Japanese Imperial Navy by his dietary interventions and the associated cost-effectiveness, with savings of ¥1,232,416 (£123,242) between 1884 and 1889.[46]

Meiji Western medicine practitioners and the Japanese Army Medical Staff in Tokyo were still intransigent, despite Takaki's success. Many Japanese Army physicians had been trained in Germany or recruited from Tokyo Imperial University. Domestic medical education in Japan was dominated by German teaching, which emphasized infection-based disease, experimental rigor, and laboratory proof, rather than British principles of epidemiology and clinical-based experience.[49]

RJ War

Beriberi thus remained prevalent in the Japanese Army up to and during the RJ War. The Army Medical Bureau, including prominent members Ishiguro Tadanori (Army Surgeon-General 1888–1897) and Mori Rintarō, established an anti-barley faction, defending current practices and white rice rations.[52,54,55] They promulgated the work of Ogata Masanori, who in 1885 claimed to have isolated the "beriberi bacillus," supporting an infectious cause for beriberi. Although these results were not reproducible by Robert Koch, and famously questioned by his protégé Shibasaburo Kitasato, doctors at the (German-sponsored) Tokyo Imperial University and Army Medical Bureau continued to argue beriberi was an infectious disease.[55] This anti-barley stance persisted into the 20th century despite compelling evidence for white rice fortified with barley preventing beriberi reported by army surgeons Toki Yoritoku (2nd Army Surgeon-General) and Horiuchi Toshikuni (Osaka Army Hospital), and high rates of beriberi in the Japanese Army during the First Sino-Japanese War (1894–1895).[54,55] Toki Yoritoku was demoted and his military record in Taiwan expunged in 1896, and Horiuchi Toshikuni was publically reprimanded in 1888 (and later ordered to retire) by the Army Medical Bureau for ignoring Ishiguro Tadanori's orders about the use of barley in the army rations. In 1895, Ishiguro, using a pen name, wrote in Tokyo Medical Journal: "the army does not need Chinese medicine, statistical speculation, or 1860-year-old theories to solve its beriberi problems; it needs scientific knowledge based on experimental medicine".[55]

The schism between the English-trained Japanese Naval Surgeons and the Japanese Army Bureau in the etiology and management of beriberi was highlighted in 1901 by Shigemichi

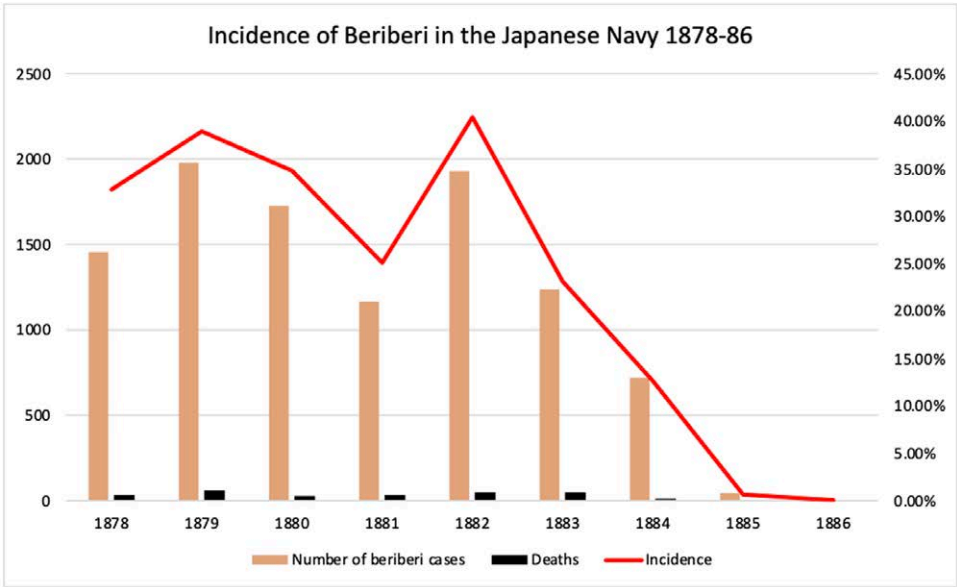

FIGURE 4. Japanese Navy beriberi cases 1878–1886.[52]

Suzuki, M.R.C.S.Eng., L.R.C.P.Lond., Surgeon General of the Navy. He concluded that during the First Sino-Japanese War, "the circumstances… show that Kak'ke cannot be regarded as an infectious disease."[49,58]

Despite the mounting evidence for beriberi being a nutritional disease, the primary ration supplied to the Japanese Army during the RJ War remained white rice.[55] While efforts were made to improve hygiene and living conditions, there were 97,572 beriberi cases recorded in official Japanese War records.[46] Published estimates were much higher: an estimated 250,000 Japanese soldiers developed beriberi, with 27,000 Japanese soldiers dying of beriberi and 47,000 from combat.[52] The Siege of Port Arthur (August 1, 1904–January 2, 1905) was particularly costly for the Japanese Army, with official casualties of 57,780 soldiers, of whom 14,000 were killed.[59] During this strategically vital battle, 25,000 soldiers from the 80,000-strong Japanese Third Army were evacuated due to beriberi.[49]

However, it was only after the Japanese victory at the Battle of Mukden (February 20–March 10, 1905), that the Army Minister Masatake Terauchi sidestepped the Army Medical Bureau and made the general order that four gō of polished rice and two gō of split barley be provided daily to all Japanese Imperial army troops in the field (one gō = 180 ml). Terauchi had suffered from beriberi in his youth and was successfully treated with barley by Tota Chōan, the master of Kampō medicine.[52] These changes came too late for the Japanese Army. Japan's external funding for the RJ War came from a syndicate of British and American bankers led by Jacob H. Schiff. Schiff was motivated to finance Japan's war effort due to Tsarist government oppression of Russian Jews, and floated almost half (£36M) of Japan's total foreign RJ War debt of £82M/US$410M.[60,61] However, when it became known Japan had effectively run out of able-bodied soldiers after the pyrrhic Battle of Mukden, loan procurement was more difficult and Japan's ability to continue the Manchurian land war and capture strategic Harbin and Vladivostok was effectively ended.[3,4]

This set the stage for the Japanese Navy to engage and defeat the Russian Baltic Fleet at the decisive Battle of Tsushima Straits on May 27–29, 1905. The Baltic fleet had initially sailed from Liepāja and Tallinn on the Baltic Coast in October 1904, aiming to relieve the 1st Pacific Squadron in Port Arthur, and then reinforce the remaining Russian ships in Vladivostok, a voyage of 29,000 km.[3] (Fig. 5) During the Battle of Tsushima, facing a healthy and modern Japanese Navy which possessed *pre-Dreadnought* steel battleships and armour-piercing artillery, the Russian Baltic Fleet (renamed 2nd and 3rd Pacific Squadrons) lost all of its battleships and most of its cruisers and destroyers.[3]

The Special Beriberi Research Council (BRC) was eventually established in 1908, but headed by Mori Rintaro (Army Surgeon-General 1907–16), and conspicuously rejected dietary science.[52] Shortly after, the Japanese Emperor warned the Army Medical Bureau that "the army's beriberi problem can be effectively prevented if the army provides a staple of *mugimeshi* (barley and rice)."[62] In 1910, Umetaro Suzuki, a professor of agricultural science at Tokyo Imperial University, isolated a water-soluble extract from rice bran which could cure beriberi in humans and polyneuritis in birds. He called this extract "aberic acid" and patented it as "oryzanine" after *Oryza sativa*, but did not correctly identify its chemical composition.[63] This was based on earlier observations by Christiaan Eijkman in Batavia (1889) that avian polyneuritis was caused by consumption of polished white rice and cured by the "antineuritic principle" contained in the kernels of unpolished rice.[64] Suzuki's discovery was ridiculed until the Polish biochemist Casimir Funk crystallized a compound from rice bran (without acknowledging Suzuki's published method) in 1911 and called it *vitamine* (vital amine).[65–67] This explained the reason for Takaki's successful naval dietary reforms in preventing beriberi some 25 years earlier.[67]

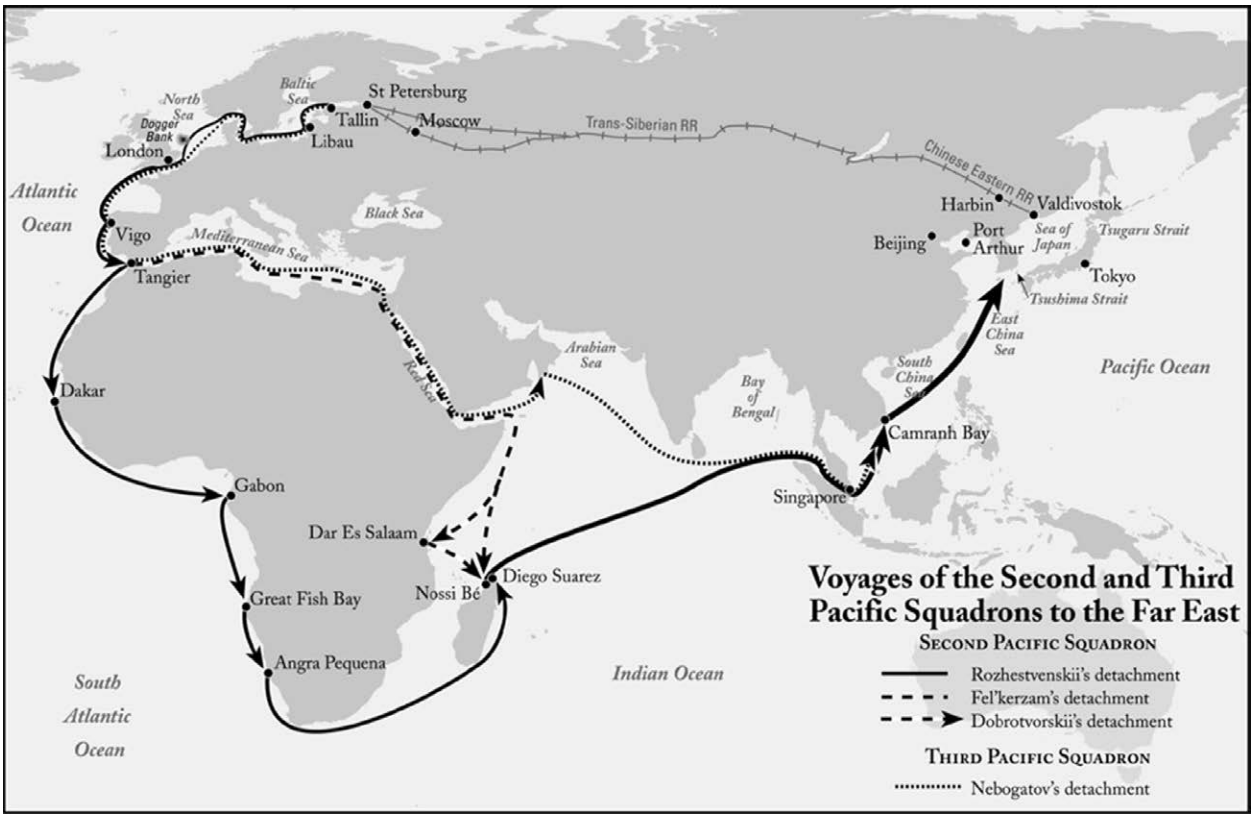

FIGURE 5. Voyage of the Russian Baltic Fleet from the Baltic Sea to the Tsushima Straits, October 1914–May 1915.[3] (Reproduced with permission from Brill Academic Publishers, Inc.).

Tokyo Imperial University professors and BRC members continued to actively discredit research that showed rice bran cured beriberi. This failure of innovation translation demonstrated their vested interest in supporting the unproven dogma of beriberi being a contagious disease. For Mori Rintarō and his colleagues to accept the rice bran research would mean admitting responsibility for the deaths of thousands of Japanese Army soldiers from beriberi, and risk the institutional reputation and prestige of Tokyo Imperial University. From translated primary sources, Bay (2012) reported use of systematic intimidation, career demotion, public humiliation, written and verbal abuse, publication bias, media propaganda, and pseudoscience for their objectives.[52] The BRC was only disbanded in 1925 when it became clear that beriberi was caused by a vitamin deficiency. The last BRC director Junjirō Shimazono finally conceded in 1927 that "beriberi develops from the vitamin B-deficient food that the Japanese eat daily. Enough vitamin B cures it and including enough vitamin B-rich foods in the diet, or administering vitamin B pharmaceutical, prevents it."[52]

Aftermath

Although the existence of thiamin and its role in beriberi pathogenesis was unknown at the time, Takaki employed epidemiological principles to identify causative factors and implement empirical treatment that would save many lives. He also aimed to introduce patient-centered care in Japan, and established the Tokyo Charity Hospital in 1884 with the help of Prince Takehito Arisugawa.[50] Takaki was awarded the title of Naval Surgeon General in 1885, Doctor of Medical Science in 1888 and a peerage of danshaku (baron) in 1905.[48,51] He was affectionately known as the "Barley Baron." In 1959, Takaki Promontory in Antarctica was named to honor his achievements.[48]

RUSSO-JAPANESE CONFLICT AND WORLD GEOPOLITICS

The RJ War represents a pivotal event in military medicine and modern history. After a yearlong battle with mass casualties on both sides, Russia and Japan signed a peace treaty at the US Portsmouth naval base in New Hampshire on September 5, 1905. This was brokered by US President Theodore Roosevelt. That an Asian power could defeat a major European power was unprecedented in modern warfare, and also a prelude to WWI.[1] The Russian Naval fleets lay destroyed or captured by Japan's modern British, Italian and locally built navy,[7,8] and the defeat undermined the power, stability and influence of Tsar Nicholas II's Imperial government.

Through Colonel Akashi Motojirō's extensive espionage network in Europe, the Japanese government also provided secret financial support to Russian revolutionaries including Vladimir Lenin and the Assembly of Russian Factory Workers' leader Georgy Gapon during the RJ War.[68] On January 22, 1905, protesters led by Georgy Gapon and discontented industrial workers marched to the Tsar's Winter Palace in St Petersburg. Their aim was to present a petition signed by 150,000 people to the Tsar requesting democratic, social, and economic reforms and an end to the RJ War.[69] The Palace Guard were ordered by Tsar Nicholas's uncle, Grand Duke Vladimir to open fire on the unarmed crowd and it was charged by the Cossack cavalry, resulting in the Bloody Sunday massacre. This was followed by the Potemkin Mutiny in June 1905, which was also brutally suppressed by Tsar Nicholas' autocracy.[70] The Revolution of 1905 was later described by Lenin as "The Great Dress Rehearsal," and contributed to the Russian Revolution of 1917, the murder of the Romanov Royal family by the Bolsheviks in July 1918 and the abolition of the Russian monarchy.[1,71]

Having made great sacrifices during the RJ War, the Japanese people anticipated substantial territory and reparations for their victory. However, unbeknown to the people, the extraordinary war costs almost bankrupted Japan. The marginal Manchurian land victory was also threatened by a massive buildup of fresh Russian reinforcements and supplies via the (now completed) Trans-Siberian Railway. These factors prompted Japanese Foreign Minister Komura Jutarō to sue for peace.[72] Jutarō initially requested the complete withdrawal of Russian forces from Manchuria, Japanese retention of the entire island of Sakhalin (reseized by Japan in July 1905) and their Korean interests, and payment of substantial war reparations by Russia. The Russian chief negotiator Sergei Witte stalled for time during the Portsmouth peace negotiations in August 1905, knowing Japan lacked the requisite manpower, resources, or finances to resume the conflict. Witte also diverted attention away from Russian treaty violations before the RJ War, which the Japanese tabled to demand reparations, and attempted to manipulate his American hosts and media to pressure Komura Jutarō.[70,73]

Whilst Japan maintained its sphere of influence over the Korean peninsula in the Portsmouth Treaty, it gained only the southern part of Sakhalin Island and the Liaodong Peninsula (including Port Arthur).[71] Japan ceded North Sakhalin Island to Russia (Fig. 6),[74] and Japanese negotiators withdrew their demands for Russia to pay war reparations. The Treaty of Portsmouth was regarded by the Japanese people as an international humiliation. Together with higher taxes from the war costs, it precipitated the September 5–7, 1905 Tokyo Hibiya riots, and the subsequent fall of the cabinet of Japanese Prime Minister Katsura Tarō.[70] The USSR declared war on Japan on August 8, 1945, 2 days after the United States dropped an atomic bomb on Hiroshima, and recaptured Manchuria, South Sakhalin, and Kuril Islands during the Japanese defeat in WWII. This remains an important part of current regional and world geopolitics. In March 2022, Russia withdrew from treaty negotiations with Japan over the disputed sovereignty of South Kuril Islands, after Japan joined international sanctions against the Russian invasion of Ukraine.[71,75]

DIFFUSION AND TRANSLATION OF INNOVATION

Major General Hodgetts, the Surgeon General for the UK Defence Medical Services, has identified the Russian targeting of hospitals during the current Russo-Ukraine War as a violation of the Geneva Conventions; and a danger to healthcare workers and their patients.[2] He promotes innovation translation learned from historical and ongoing conflicts, including protecting, hiding, defending, disguising, and mobilizing Red Cross or other medical facilities in war zones. This includes the use of protected medical evacuation, mobile forward field hospitals, and hospital trains for "damage control" surgery for injured soldiers, just as Gedroits did in the RJ War of 1904–1905.[2] Although the concept of early adopters and diffusion of innovation is originally founded in rural sociology, it similarly applies to the dissemination of innovations in healthcare.[76] This includes the introduction of new medicines, medical techniques, and health communications in both military and civilian medical organizations.[77]

The Japanese Army Medical Bureau adopted the policy of barley rice in troop food rations only after it became scientifically and politically untenable to continue with polished white rice- the innovation did not match the entrenched dogma and practices in the preexisting system.[77] Takaki succeeded in integrating barley rice into the diet of sailors and eliminating beriberi in the Japanese Navy because he was an early ADOPTER. He had the intellectual capacity, adaptability, and motivation to train in Japan and England and synthesize ancient *Kampō* medicine with modern epidemiology (Agility). He was from the Satsuma Daimyō and trained as a military surgeon (Decisive). He proved the utility and cost-effectiveness of barley rice in preventing beriberi (Outcome-focused). He gained support from

FIGURE 6. Russo-Japanese War and Peace 1904–1905, Treaty of Portsmouth. (Map commissioned by Japan-America Society of New Hampshire for Portsmouth Peace Treaty website at portsmouthpeacetreaty.org Map DesignMapWorks 2005, MAPSatWORK@aol.com[74]).

Satsuma members of the Japanese Government (Politically aware). He risked his professional reputation and his life to prove his hypothesis (Tolerant of risk). He became the head of Tokyo Naval Hospital and later Surgeon General for the Japanese Navy (Empowered), and was ennobled by the Japanese Emperor (Rewarded).[46]

Takaki recognized the military strategic importance of finding a cure for beriberi, just as Sir Gilbert Blane and the British Navy did in the 1795 policy of mandating daily lemon juice provision to its sailors to prevent scurvy, the history of which Takaki was undoubtedly familiar.[50,78] The Japanese defeat of the Russian Navy in 1905,[46] and the outcome of the Battle of Trafalgar in 1805 during the Napoleonic Wars[78] were both related to the successful adoption and diffusion of a nutritional innovation by surgeons in a military organization. The failure of translation of Takaki's naval nutritional reforms by the Japanese Army Bureau during the RJ War was highlighted by Shigemichi Suzuki's summary in 1906: "If the Army authorities had tried to prevent the occurrence of Kak'ke among the soldiers as the Japanese Naval authorities did many years ago (*in the Navy there was practically no Kak'ke during the whole war*) (author's italics), the sanitary record of the Army would have been better than that shown above."[79]

This principle of translation of innovation and its future application by surgeons is epitomized by Theodor Billroth in his 1859 treatise on the nature and treatment of wartime gunshot injuries.[80] In it, he described the teachings of prominent military surgeons including John Hennen, George James Guthrie,[81] Jean Domenique Larrey and Georg Stromeyer, and concluded with: "Only the (medical) man who is familiar with the art and science of the past is competent to aid in its progress in the future."[80] Gedroits adopted strikingly similar principles to Larrey in the wartime management of PAWs,[27,28] but also showed that familiarity with the "art and science of the past" could and should apply to surgeons regardless of gender, as championed by her Swiss mentor César Roux.[41]

CONCLUSIONS

We remember Doctors Takaki and Gedroits for their contributions to modern medicine and perseverance in an environment of medical dogma, gender discrimination, professional rivalry, and military conflict. Both risked their professional reputations and lives in being innovation ADOPTERs, implementing evidence-based care of patients. Their accomplishments demonstrate the requirement of transformational leadership in an organization for successful innovation to occur. It was the failure of innovation translation in military organizations that led to the beriberi epidemic in the Japanese Army during the 1904–1905 RJ War, and the continued conservative management of PAWs during

WWI, contributing to the unnecessary deaths of thousands of soldiers.

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