Kanehiro Takaki. National Museum of Health and Medicine

Rice, beriberi, and Meiji Japan

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Beriberi was widespread in Japan and the Orient in the 19th century because the consumption of white rice created a dietary deficiency of thiamin, the cause of the disease. The winnowing process to convert brown rice to white removed the thiamin-rich pericarp layer from the endosperm. With no other source of thiamin, a diet solely of white rice led to a clinical deficiency of the vitamin, that if uncorrected led to permanent disability or death.

In Japan, there were so many victims of beriberi that the Meiji government considered it a threat to the nation. From the many useless folk nostrums recommended by *Kampō*, Japanese traditional medicine, one remedy was effective: a diet of barley and red beans, foodstuffs that were later identified as good sources of thiamin.

Faced with decimation of the Imperial Navy from beriberi, in 1882 Kanehiro Takaki (1849–1920) instituted dietary reforms that added barley to the sailors' mess. By 1887, he had eliminated beriberi from the navy. Not so in the Imperial Army, where its medical leadership adhered to the modern concept of germ theory and rejected *Kampō* treatments as old-fashioned. Despite its victories in its first two major international wars, the First Sino-Japanese War (1894–1895) and the Russo-Japanese War (1904–1905), the army was nearly devastated by beriberi, with 250,000 falling ill and 27,000 dying in the latter conflict.

Gaishi Takegishi, a doctor with the army medical branch, wrote:

> [During] the Sino-Japanese and Russo-Japanese Wars, our army's most formidable enemy was not the unrestrained Qing army, nor was it the brave Russian Army, but a disease that we did not plan for—beriberi.[1]

Not until it began to provide barley and red beans in soldiers' rations would the disease be controlled. Until then hundreds of thousands of lives were needlessly lost in the two decades after it had been eliminated from the navy.

The conquest of beriberi is integral to the foundation stories of nutritional science, tropical medicine, and global health policy. Less known in the West is the story of the impact of the disease on the Japanese military and its threat to the nascent Japanese empire. It is also the story of the disastrous effects of groupthink among the medical decision-makers in the Imperial Army.

Thiamin deficiency and beriberi

As a coenzyme in key biochemical processes, a deficiency of thiamin has deleterious effects on the cardiovascular, neurological, and immune systems.[2] With limited stores in the body and a short half-life once absorbed, thiamin homeostasis requires a continuous dietary supply. Clinical thiamin deficiency may become manifest in a just a few days.[3]

Today, beriberi is seen in profound malnutrition states that complicate alcoholism, acquired immune deficiency syndrome, malignancy, prolonged critical care, bariatric surgery, and breast-fed infants.[2]

There are two classical syndromes, dry and wet beriberi. Beriberi is dry when polyneuritis dominates with peripheral dysesthesia and muscle wasting, especially of the lower extremities. The wet variety refers to the peripheral edema caused by high output cardiac failure because of the chronic deficiency of adenosine triphosphate required by cardiac myocytes, a late stage of the disease in which the victim is near death.[2,4-6]

Wet beriberi. Transactions of the Epidemiology Society of London, Public domain

Beriberi was an enormous burden to the economic viability of countries and colonial empires in the Far East. Sir Patrick Manson, the pioneering parasitologist and founder of the discipline of tropical medicine, wrote:

> Directly or indirectly, it is a serious tax on these communities, and a great drag on their progress. Not only does it lead to great loss of life, but it is an enormous drain on the labour market and on the industrial resources; for beriberi is a disease which, when not quickly fatal, usually runs a long course—probably of several months—during which the patient is, as a rule incapable of earning his living; and … of even cooking his food, or in other ways attending to his personal requirements. It hampers every industry.[7]

Rice and the national disease of Japan

"Rice," wrote historian Kenneth Carpenter, "is the heart of Japanese civilization."[8] Specifically, milled white rice.

David Arnold, a historian at the University of Warwick, wrote that mechanized milling "fueled a revolution in taste. …[White] rice was sought after as more palatable, more prestigious, and might even [have been] cheaper."[9]

White rice had a practical advantage over brown rice. The pericarp attracted pests and was prone to mold. When dried, white rice was resistant to rot and infestation, and simple to store and transport.[8] Mechanical processing near the rice fields made white rice available from the paddies to the cities, feeding all strata of society.

White rice also made the entire population subject to beriberi. The Meiji Emperor had been afflicted. In the royal family, Princess Chikako succumbed to beriberi despite removing her to a spa at Tonosawa in the mistaken belief that a change in location would be curative. A study from the statistics bureau documented that between 1899 and 1901, 265,000 persons, or five to seven of every 1,000 population, fell ill from beriberi. The disease caused 8.2 percent of all deaths in the country.[1] With good reason it was considered "the national disease of Japan."[8]

Dry beriberi. Transactions of the Epidemiology Society of London, Public domain

Japan adopts German medicine

Commodore Matthew Perry's gunboat diplomacy of 1853 forcibly opened Japan markets to trade with the U.S. In part due to its weakness before the industrialized West, the ruling Tokugawa regime was deposed in the Boshin civil war (1868–1869) by an alliance of rebel warlords. To solidify

its legitimacy, the victorious junta restored Emperor Meiji as its titular ruler and used his name for its government.[10]

With the responsibility of building a modern state the Meiji government set the twin goals of "rich country, strong army."[10] Astounded by the "energies unleashed by industrial capitalism"[10] on their visits to the America and Europe, the Meiji concluded that to survive it had to adopt Western industries and institutions. In a crash program it chose the best countries to emulate: Britain for railways, harbors, and postal system; and Germany, for science, national organization, and bureaucratic structure. For its army the Meiji chose Germany and Britain for its navy. Militarily it made sense, but the decision had an enormous impact on how they approached beriberi among its troops.[10]

In 1858, a cholera epidemic devastated Japan, with an estimated 200,000 dead, of which more than 40,000 were in Edō alone. "How to contain public fear of disease was one of the first major challenges that the Meiji government found crucial to solve," wrote Hoi-eun Kim, a historian at Texas A&M University, and scholar of medical science in the Meiji era.[11]

In 1869, the Meiji took over a Tokugawa-era vaccination clinic in Tokyo and invited the German government to use it as a medical school. The Germans sent Leopold Müller and Theodor Hoffman, two of its best military doctors, to teach medical science in Japan. When they arrived for their first day in 1871, they found a dilapidated facility without anatomical models, microscopes, or osteology sets.[11]

Those were minor irritants compared with the "lack of intellectual capacity on the part of the Japanese medical students." Medicine was an occupation for "people who were physically and mentally useless for other jobs."[11] Müller complained that "not one of them could describe the circulation of the blood…Not one was able to distinguish the right thigh from the left and explain the reason for his choice."[11]

Neither of the professors spoke Japanese, and the sentence-by-sentence translation of lectures made effective instruction impossible. Teaching in German was therefore essential, so Japanese students were forced to become fluent in German.

Their lack of basic science training was an impediment to learning natural sciences, so a preparatory school was opened. Müller expanded his medical faculty to 11 German nationals and instituted an eight-year course of study.

Overcoming their initial frustrations Müller and Hoffman began to attract increasing numbers of motivated students, eager to learn Western medicine despite the German language requirement. When Wilhelm Schultze succeeded Müller as chair of the faculty in 1874, he had a different opinion than his predecessor's.

> The students are, without exception, easy to deal with, polite, industrious, eager to learn, and often highly gifted. …In terms of manual dexterity, operating skill, and charting, the average Japanese student exceeds the performance of our own students in Germany.[11]

The Japanese were ready to regain control of the Tokyo Medical School. In 1877, the first Japanese professor, Kenji Ozawa, was appointed to the faculty. By the end of academic year of 1893–1894 there were 19 Japanese on the Tokyo faculty, and only two Germans, both in lesser roles.

With sponsorship of the government newly-trained physicians furthered their training by traveling to Germany. More than 1,000 Japanese students traveled to Berlin to study medicine between 1868 and 1914, with nearly 300 officially enrolled at Berlin University for at least one semester.[11]

Shibasaburo Kitasato embodied the success of Meiji strategy. Educated in medicine in Japan, he studied with Robert Koch and Emil von Behring and became Japan's first world-class medical scientist.

Under Koch he was the first to isolate *Clostridium tetani* in pure culture. He worked with von Behring to develop neutralizing antibodies to diphtheria and tetanus toxin (1890). The latter won the inaugural Nobel Prize in Medicine for the achievement, an honor for which some say Kitasato was unjustly deprived.[12]

Kanehiro Takaki

Instead of the German-dominated system in Tokyo, Takaki received training in Western medicine in a British system where instruction was in English. His native Satsuma province on Kyushu was far from the educational and social reforms taking place in Tokyo. Takaki's parents, low-ranking samurai under the Tokugawa, held great ambitions for their son. They were impressed by simple privileges such as being allowed to wear white *tabi*, slotted ankle socks that under the previous regime they were by caste forbidden from wearing. A local physician took a liking to young Takaki and took him on as an apprentice, teaching him precepts that originated from Dutch merchant traders during the Tokugawa era and *Kampō* remedies. The mentor arranged a marriage for his protégé to the daughter of another physician, then set him up with a job in a government bureau.[13]

Like many young physicians in Japan, Takaki sought training in Western practices. Rather than attending the German facility in Tokyo, he attended a medical school and hospital established by the British Navy in Osaka. Becoming fluent in English, in 1872 Takaki entered service as a medical officer in the Japanese Imperial Navy, then studied anatomy and clinical medicine from 1875 to 1880 in London.[14]

Upon his return to Japan in 1880, he was appointed director of the Tokyo Naval Hospital. Beriberi victims comprised as many as three-fourths of the caseload and overflowed into nearby temples commandeered during outbreaks.[15] That year, the attack rate of beriberi in the navy was 349 per 1,000 sailors, of which eight died and an average of 2.5 became invalids. "If such a state of health continued without the cause and treatment of *kakke* [the Japanese word for beriberi] being discovered, our navy would be of no use in time of need," Takaki wrote.[16]

The strength of the Naval fighting force was tested in 1882 when rebellion in Korea nearly brought China and Japan to armed conflict, a prelude to the First Sino-Japanese War a decade later. Japan sent four warships to protect its interests. While the mission took only 40 days, beriberi nearly incapacitated the ships. Of 330 sailors on board one vessel, the *Hiyei*, 195 suffered from beriberi. While Japanese forces did not engage the Chinese, in Takaki's opinion, "the ships would have been unable to cope with the North China squadron."[16] Beriberi threatened to make a grim joke of the "rich country, strong army" Meiji strategy.[10]

A Kampō cure

Takaki was promoted to director of the Naval Medical Bureau in 1883. Now in charge of the well-being of the entire Imperial Navy, he focused on beriberi.

English medical training stressed bedside observation and clinical treatment, in contrast to the German emphasis on laboratory research and germ theory. Takaki suspected that something about the sailors' diets might be responsible for the disease. Steeped in English medical heritage, he knew of James Lind's *Treatise of the Scurvy* (1753) and the British maritime tradition of treating the disease as a nutritional deficiency curable by eating citrus fruits.[17] It was logical to compare sailors' diets in the Japanese Navy with those in their counterparts in the Italian and British navies where beriberi was unknown.

The obvious difference was that white rice dominated Japanese sailors' rations, which included some spices, pickled vegetables, and a bit of dried fish. Western navies provided regular portions of meat, vegetables, and, of course, citrus fruit. Takaki hypothesized that the cause of beriberi lay in the difference in diet, specifically the amount of dietary protein.[8]

His hypothesis that a deficiency in dietary protein was the cause of beriberi was wrong, but he was on the right track. He proposed a change in dietary orders that followed those of the West. His opponents in the admiralty failed to see why a sailor's diet should be any different than what the rest of country consumed. They balked at having to purchase food on the basis of variety—buying rice in bulk was simpler and cheaper.[15]

The admiralty learned a hard lesson in 1883 when the training ship *Ryujo* returned to port after a nine-month trans-Pacific voyage with 169 cases of beriberi and 25 deaths, a disaster that demanded an inquest.[1] After studying every detail of the trip that might explain the outbreak, no identifiable pattern of contagion could be found that would indicate an infectious etiology.

Almost exactly one year after the *Ryujo* incident another training ship, the *Tsukuba*, was to embark on a long voyage similar to that of the *Ryujo*. At Takaki's request, the itinerary was changed to the one taken by the *Ryujo*, and the food changed to provide more protein. The *Tsukuba* returned to port in 1884 with only 14 cases of beriberi among its crew of 287. On closer review, all who came down with the disease had chosen not to follow the new diet, unintentionally serving as a control group.[1]

The effect of Takaki's changes was undeniable. In February 1884, he convinced the minister of the navy to issue a general order that liberalized the daily rations of all sailors to include regular portions of meat, vegetables, bread, beans, and wheat flour. The incidence of beriberi fell by more than one-half to 127 per 1,000 sailors (from 349), and the death rate dropped to 1.42 (from 8).[15]

However, the incidence of beriberi was still too high for Takaki. He drew from his training in *Kampō* medicine. The 19th century *Kampō* authority Tōta Chōan directly stated that white rice was the cause of the disease and prescribed the centuries-old regimen of barley and red beans.[1]

With the summer beriberi season approaching in February 1885, Takaki phased in barley so that by April it would be in an equal proportion to rice. The effect was dramatic. In 1886, the incidence of beriberi was 0.35 per 1,000, and no deaths. By the following year, beriberi had completely disappeared from the Imperial Navy.[15]

Search for the beriberi bacillus

In 1885, Takaki made a formal presentation on his work on beriberi. His counterparts from the university and the

army, educated under the German system, were unable to believe that a simple diet modification would have such a profound effect. Compared with the rigor demanded by German science, Takaki's experiment using the *Ryujo* and *Tsukuba* voyages was simplistic. Alexander Bay, a historian of Meiji-era Japan at Chapman University in California, summarized their objections with a quote from Tadanori Ishiguro, inspector general of the Japanese Army:

> Rice had been a staple of our people for thousands of years,…why is only a small percentage of the Japanese people, and not the majority, inflicted with beriberi? Why more men, fewer women? Why men between twenty and thirty, not those over forty? Why only those students and soldiers around the age of twenty who live in dormitories and barracks? [1]

Dominated by German medical science and germ theory, the Tokyo professors and their allies in the army medical bureau were stubborn in their belief that discovery of the cause of beriberi, and thereby its treatment, would only come from the laboratory and finding the disease-causing bacillus.[1] Shortly after Takaki's lecture, Masanori Ogata, working at the Tokyo Hygiene Laboratory and a member of the Tokyo faculty, announced in April 1885 that he had found the beriberi bacillus before an audience of nearly 1,000 that included all the luminaries of the Japanese medical world. "Ogata seemed to confirm that the government money spent on sending medical students to Germany was paying off handsomely for the country,"[11] Kim wrote.

In 1888, Kitasato, in Berlin with Koch, refuted Ogata's claim in publications in Japanese and German. In so doing, he violated the near-sacred Japanese taboo of criticizing a former teacher. Kitasato had worked in Ogata's lab for a few months in 1885 before leaving for Germany, a brief association that still demanded veneration of one's *sensei*. Upon his return to Japan in 1892, he found himself blackballed from a position at the Tokyo Imperial University, despite his worldwide fame in bacteriology. Instead, he established his own private research facility and in 1917 became the inaugural dean of the school of medicine at Keio University.[11,14]

Human cost of intransigence

The army rejected Takaki's work and made the tragic decision to not convert the soldiers' rations to the one proven in the navy to effectively prevent beriberi.[1]

During the First Sino-Japanese War (1894–1895), Japan's first major modern conflict, combat casualties were light, with 826 deaths and 3,693 wounded. The numbers were overshadowed by beriberi. In the 10 months of the war there were 66,956 cases of the disease, and 10,436 fatalities, a death rate of nearly 16 percent.

Some in the army medical corps knew of Takaki's success in the navy and asked to be supplied with barley. Rintarō Mori, in command of medical supplies as head of the Second Army Medical Bureau with the responsibility for overall logistics for the entire command, rejected their requests. One of the medical officers, Yoritoku Toki, ignored Mori's restrictions and commandeered local stores of barley and red beans for his troops.

After the war, beriberi continued to ravage Japanese troops occupying Taiwan. Of the estimated 23,338 soldiers in Taiwan in 1895, 21,087 were hospitalized with beriberi, nearly 90 percent of the force, with a mortality of 10 percent. During the epidemic Toki was assigned chief medical officer to Taiwan. Once again, he added barley and red beans to soldiers' rations. The incidence of beriberi immediately fell. By 1902, there were no deaths from beriberi among the occupying forces in Taiwan.

Despite the disasters during the First Sino-Japanese War and the occupation of Taiwan, the army still had not changed its rations when the Russo-Japanese War broke out in 1904. Over the 20-month duration of the conflict, official records documented that about one-fifth of the wounded and sick in army infirmaries (457,035) were soldiers suffering from beriberi (97,572), of whom 3,956 died.[15,18] Estimates published in the press were much higher: 250,000 suffering from beriberi alone, with 27,000 deaths.[1]

The effect of beriberi on the fighting strength of the army could no longer be ignored. The decisive Battle of Mukden had already been won by the Japanese forces in early March 1905, and the end of the conflict was within sight when Minister of War Masatake Terauchi ordered barley to be sent to the front. Terauchi made sure to include barley in his own diet since he contracted beriberi as a young man and was given the vital foodstuff by Chōan, the master of *Kampō* medicine. Now in command of all branches of the Imperial Army, including its medical corps, Terauchi made a general order that barley be distributed to all troops.[1]

Final acceptance

The Meiji government belatedly made beriberi a national research priority in 1908 with the establishment of the Special Beriberi Research Council (BRC). The Tokyo faculty and the army medical bureau dominated the council and its research agenda: germ theory, chemistry,

pathology, clinical studies, and history and statistics. Inexplicably nutrition science was excluded despite the demonstrated success of adding barley and red beans to dietary regimens.[1]

In 1889, Christiaan Eijkman, a Dutch physician working in Batavia (present day Jakarta), discovered that polyneuritis in fowl, a condition closely resembling dry beriberi, was caused by the animals being fed leftover white rice. He found that the missing dietary element lay in the pericarp discarded in the winnowing process, research that won him the Nobel Prize in 1929.[8] In 1913 Edward Vedder of the United States Army Medical Corps in the Philippines reported his use of an extract of rice polishings to cure infantile beriberi.[19] Despite claims by Casimir Funk, a Polish chemist working at the Lister Institute in London, that he had isolated the "vitamine" responsible for beriberi in 1912,[20] credit for the isolation (1933) and synthesis of thiamin (1935) went to Roger Williams, an American chemist at Bell Telephone Laboratories.[19]

The beriberi debate in Japan finally ended in 1925 when the BRC was disbanded. In 1927, Junjirō Shimazono, the final director of the BRC, wrote a concession:

> [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 pharmaceuticals, prevents it.[1]

References

1. Bay AR. Beriberi in Modern Japan: The Making of a National Disease. Rochester (NY): University of Rochester Press. 2012.
2. DiNicolantonio JJ, Liu J, O'Keefe JH. Thiamine and cardiovascular disease: a literature review. Prog Cardiovasc Dis. 2018; 61(1): 27–32.
3. Kumar N. Neurologic presentations of nutritional deficiencies. Neurol Clin. 2010; 28(1): 107–70.
4. Attaluri P, Castillo A, Edriss H, Nugent K. Thiamine Deficiency: An Important Consideration in Critically Ill Patients. Am J Med Sci. 2018; 356(4): 382–90.
5. Stroh C, Meyer F, Manger T. Beriberi, a severe complication after metabolic surgery – review of the literature. Obes Facts. 2014; 7(4): 246–52.
6. Reid DHS. Acute infantile beriberi. J Pediatr. 1961; 58(6): 858–63.
7. Manson P. The Etiology of Beri-Beri. Inaugural address of session 1901-1902. Trans Epidemiol Soc Lond. 1902; 21: 1–17.
8. Carpenter KJ. Beriberi, White Rice, and Vitamin B: A Disease, a Cause, and a Cure. Berkeley (CA): University of California Press. 2000.
9. Arnold D. British India and the "beriberi problem," 1798-1942. Med Hist. 2010; 54(3): 295–314.
10. Gordon A. A Modern History of Japan: From Tokugawa Times to the Present, 2nd Ed. New York: Oxford University Press. 2009.
11. Kim H-E. Doctors of empire. Medical and Cultural Encounters Between Imperial Germany and Meiji Japan. Toronto: University of Toronto Press. 2014.
12. Kantha SS. A Centennial Review; the 1890 Tetanus Antitoxin Paper of von Behring and Kitasato and the Related Developments. Historical Profile. Keio J Med. 1991; 40(1): 35–9.
13. Bartholomew JR. The Formation of Science in Japan: Building a Research Tradition. New Haven (CT): Yale University Press. 1989.
14. Bowers JZ. When the Twain Meet: The Rise of Western Medicine in Japan. Baltimore (MD): Johns Hopkins University Press. 1980.
15. Takaki B. Three Lectures on the Preservation of Health amongst the Personnel of the Japanese Navy and Army. Lancet. 1906; 167(4317): 1451–5.
16. Takaki K. Japanese Navy and Army Sanitation with a Statistical Report of the Medical Department during the Japanese-Russian War, and a history of the eradication of Kakke from the Japanese Navy. Surg Gynecol Obstet. 1906; 2(4): 421–41.
17. Carter KC. The germ theory, beriberi, and the deficiency theory of disease. Med Hist. 1977; 21: 119–36.
18. Suzuki S. Note on the sanitary condition of the Imperial Japanese Army during the late Russo-Japanese war. J Assoc Mil Surg US. 1906; 19(5): 431–6.
19. Williams RR. Toward the Conquest of Beriberi. Cambridge (MA): Harvard University Press. 1961.
20. Griminger P. Casimir Funk: a biographical sketch (1884-1967). J Nutr. 1972; 102(9): 1105–13.

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