Irradiated Trajectories: Medical Radiology in Modern Japan

Irradiated Trajectories: Medical Radiology in Modern Japan

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Abstract

This dissertation examines the history of modern Japan via a study of *rentogen*, or X-rays, in medical practice. Conventional milestones in Japan's encounters with nuclear science all date from 1945: the atomic bombings of Hiroshima and Nagasaki that same year, the Bikini Atoll fallout incident in 1954, the construction of nuclear power plants from the late 1950s onwards, and most recently, the Fukushima Daiichi meltdown in 2011. All these events produced *hibakusha* – the Japanese term for survivors of nuclear-related accidents, or people suffering the effects of exposure to ionising radiation.

In contrast, this project locates the first *hibakusha* in an earlier period, revealing a history of radiation exposure in Japan before the atomic bombings. It reaches into the late nineteenth and early twentieth centuries to find Japanese bodies exposed through the development of radiology. In modern Japan, as in Western Europe and America, X-rays constituted the first source of ionizing radiation that produced victims of burns, cancers, and deaths. This study highlights the political, social and cultural impact of modern Western medicine on Japanese society from the Meiji period onwards, showing how electric-powered machines and Western expertise came to define medical practice in the emergent field of radiology.

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List of Abbreviations Used

ABCC – Atomic Bomb Casualty Committee 原爆傷害調査委員会

AHS – Adult Health Study

ICR – International Congress of Radiology

ICRU – International Commission on Radiation Units and Measurements

IXRPC – International X-ray and Radium Protection Committee

JIRA – Japan Medical Imaging and Radiological Systems Industries Association 日本画像医療システム工業会

JRS – Japan Radiological Society 日本放射線医学学会

JSRT – Japanese Society of Radiological Technology 日本放射線技術学会

LNT – Linear No-Threshold (model)

LSS – Life Span Study

NIRS – National Institute for Radiological Sciences 放射線医学総合研究所

RERF – Radiation Effects Research Foundation 放射線影響研究所

UNSCEAR – United Nations Scientific Committee on the Effects of Atomic Radiation

Note on Japanese Transliteration

The Hepburn system is used for romanizing all Japanese words in this text. The East Asian order for Japanese names (surname followed by first name) is used for all figures and authors that appear in this study, except where the reverse order is used in a publication. *Kanji* or Chinese characters, as well as other Japanese writing, are used when necessary to aid with recognition of proper nouns in romanization.

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To my mother and father
origin and process
first guides and final givers

Introduction

X Marks the Start: The "Scatter Rays" in Japan

Japan bears a special relationship to the epoch commonly termed the "atomic age". The only country to date to be hit by atomic bombs in warfare, its relationship to this period is frequently understood in terms of the impact caused by nuclear weapons and the nuclear energy industry. Its sites struck by those technological feats mark milestones of disaster, stark and self-apparent in their metonymy: Hiroshima, Nagasaki, and now Fukushima. The damage they suffered included vast physical damage: the destruction of urban infrastructure by explosions, earthquakes and tsunami. But in all three places, exposure to radiation and its effects of human health emerged as enduring flashpoints of public concern, whether through fears over lingering radiation in atomic-bomb survivors being somehow contagious, or anxieties about the continued release of radiation from an uncontained power plant meltdown. This refers to ionizing radiation, which may be very generally defined as particles, X-rays, or gamma rays that are energetic enough to impact the cellular makeup of the medium through which they pass. In large doses it can cause injury and eventually kill living beings.[1] Throughout this introduction and the following chapters, unless otherwise stated, "radiation" always indicates ionizing radiation, and specifically, *manmade* ionizing radiation.[2]

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[1] For a useful introduction to radiation in the history of science see Sungook Hong, "Theories and Experiments on Radiation from Thomas Young to X Rays", in Mary Jo Nye, ed., *The Cambridge History of Science, Vol. 5: The Modern Physical and Mathematical Sciences (*Cambridge, UK: Cambridge University Press, 2002), 272-288.

[2] In scientific terminology, "radiation" is an umbrella term applicable to any part of the electromagnetic spectrum, including visible light and heat. Ionizing radiation, more specifically, refers to radiation with sufficient energy to ionize the medium through which they pass – that is, when interacting with atoms in that medium, it can induce changes in the atoms by freeing electrons from their orbits, and changing an atom from a neutral state to an electrically charged one. Radiation 1) comes from unstable atoms that undergo radioactive decay, or 2) is produced by machines. Ionizing radiation is so called as it produces ionization i.e. carries enough energy to knock electrons out of atoms. It can come from radioactive elements, cosmic particles from outer space and x-ray machines. Non-ionizing radiation is energetic enough to move atoms in a molecule around, but not enough to remove electrons - for instance, radio waves, visible light, and microwaves. For a detailed technical explanation see the introduction to Nicolas Tsoulfandis and Sheldon Landsberger, *Measurement and Detection of Radiation*, 3rd ed. (Florida: CRC

Hiroshima is often designated the alpha of Japan's entry into the atomic age. Hence, the Japanese public's negative image of radiation exposure is assumed to stem from that catastrophe. Contrary to widely held assumptions, however, the atomic bombings are not Japan's first encounter with radiation. Decades before the United States dropped the Fat Man and Little Boy bombs on Hiroshima and Nagasaki, X-rays provided the earliest avenue by which Japanese bodies and minds were exposed to radiation. Japan was no different from other countries in this respect. X-rays, discovered in Germany at the end of the 19th century, also formed the first instance of radiation harnessed for human purposes in the United States and Western Europe. In those regions, the rays quickly garnered interest and adoption, eventually becoming fixtures of medical practice, cosmetic and entertainment commodities, and the popular imagination.[3] In Japanese, the rays more commonly went by the term *rentogen*, a phoneticization of "roentgen rays", as X-rays were often alternately called in America and Europe, after their discoverer, Wilhelm Roentgen; in this study both terms are used interchangeably, with a preference for using *rentogen* to refer to the rays in Japanese context.

In Japanese, those who undergo diagnostic screenings are termed *hikensha* 被検者. The survivors of Hiroshima and Nagasaki are called *hibakusha* – another compound term that literally means "explosion-affected person" 被爆者 or "exposed (to radiation) person" 被曝者, depending on the middle character used. As there is a pre-history of radiation before the atomic bombings, so there were *hibakusha* in Japan before the survivors of Hiroshima and Nagasaki –

Press, 2011), 1-2. See also the official website of the United States Environmental Protection Agency (EPA), "Radiation Basics | Radiation Protection | US EPA," http://www2.epa.gov/radiation/radiation-basics (accessed September 22, 2015).

[3] Bettyann H. Kevles, *Naked to the bone: medical imaging in the twentieth century* (New Brunswick, N.J.: Rutgers University Press, 1997; R.F. Mould, *A Century of X-Rays and Radioactivity in Medicine: With Emphasis on Photographic Records of the Early Years* (Bristol, Philadelphia: Institute of Physics Publishers, 1993).

primarily those exposed, either as *hibakusha* professionals or as *hikensha* patients, to radiation used in medicine. *Hikensha* are the forerunners of later *hibakusha* who acquired that status through working in postwar Japan's nuclear power industry. Moreover, it is also necessary to consider another category of irradiated bodies that also goes by the term *hikensha* 被験者 – those whose bodies were experimented upon. This category includes both humans and animals. X-rays, produced a category of *hikensha* in the two senses mentioned above – a group consisting of all the patients who received X-ray screenings. The *hibakusha* of the bombings and the nuclear power industry were preceded by the *hibakusha* of medical and scientific research – humans, yes, but also an assortment of domesticated flora and fauna, whose well-being was compromised on the altar of research and progress. These activities, like the *hibakusha* casualties of medicine and industry, were trans-national phenomena as diffuse as radiation itself.

Ionizing radiation is a form of radiant energy. This energy was eventually harnessed as nuclear energy, in the forms of fissile, manmade uranium and plutonium, to produce electrical power on a commercial scale after World War II. Before the nuclear power industry appeared, X-rays, as the prominent form of man-made ionizing radiation, enabled medical treatment and scientific experiments in a wide range of fields, including radiology, public health, crystallography, applied physics and genetics. X-rays in this period constituted the world's most socially and politically prominent form of ionizing radiation. They have been studied extensively in the fields of medical and cultural history, two prominent works in this vein being Bettyann Kevles' *Naked to the Bone* and Matthew Levine's *The First Atomic Age,* both of which analyze the social and cultural histories of X-rays in the United States.[4] Following Wilhelm Conrad

[4] Kevles, *Naked to the bone*; Matthew Levine, *The first atomic age: scientists, radiations, and the American public, 1895-1945* (New York, NY: Palgrave Macmillan, 2013).

Roentgen's discovery of X-rays in 1895, the development of radiology in medicine has been studied extensively by scholars in America and Europe. Historians of medicine such as Adrian Thomas and Arpan Banerjee have traced the development of radiology as a medical specialty, while other scholars have shed light on the broader social and cultural waves in the use of medical imaging. Other research plumbs the domains of popular culture and public perceptions of the "unknown" rays and other kinds of radiations in the late 19th and early 20th century. Here the pioneering work of Spencer Weart clarifies this in great detail, as does Levine's analysis of what he evocatively terms the "First Atomic Age", or the period that transpired prior to the advent of nuclear energy and nuclear weapons.[5]

Drawing inspiration from such studies, this dissertation historicizes Japanese experiences of X-rays/*rentogen* to provide a deeper, broader analysis of modern Japan's relationship with radiation. Much previous historical scholarship on *rentogen* involves tracing the genesis of how X-ray technology entered Japan and which scientists or doctors first made use of it for their research and work. While acknowledging the value and necessity of this foregoing scholarship, this dissertation offers a supplemental perspective on the significance of incorporating *rentogen* for medical use into a consideration not only of modern Japanese history, but also on the ways in which radiology in Japan as a case study can contribute to the literature on socio-cultural analyses of radiation science and technology.[6] This introduction has several aims. It first positions the study in existing literature and scholarly approaches from Japanese history and science and technology studies. Next, in order to orient the reader in the meanings and processes

[5] Levine, *The First Atomic Age.*

[6] See e.g. Angela N.H. Creager, *Life atomic: a history of radioisotopes in science and medicine* (Chicago: University of Chicago Press, 2013).

of radiology and radiation, it provides brief, descriptive accounts of two things: i) the chronology of the process by which *rentogen* entered Japan from Germany and into scientific and medical practice, and ii) the integration of radiology into a system of medical practice labouring to modernize and Westernize itself to serve the ends of the newly created Japanese nation-state. Finally, it outlines the chapters that comprise the body of this work and explains the thematic structure of the overall project.

The Current Field of Radiation Studies

The growing use of X-rays in diagnosis and, to a lesser extent, therapy, are two key trajectories by which ionizing radiation became a part of medical practice in pre-war Japan. They weave together a thematic study in a span of time that covers the communication of X-rays' discovery in 1896 and follows their trail into the immediate aftermath of the atomic bombings in August 1945. A study of *rentogen* provides a broader, more nuanced understanding of Japan's relationship with the age of nuclear science. X-rays/*rentogen* manifested primarily in medicine, but also provided a conduit for circulating information and images about radiation long before nuclear weapons exploded into global public consciousness. Professional and popular discourses on "the scatter rays", as they were also known (in Japanese, *hōsansen* or, more frequently, *hōshasen*) informed expert and public conceptions of radiation across the entire 20th century. The rays also played a crucial role in the conceptualization, diagnosis, treatment and representation of radiation illness in the sphere of popular culture, where mass media publications furnishing positive images of radiologists as martyrs to science. Examining the impact of radiological medicine and radiation illness in this early period demonstrates that people in Japan confronted the specter of radiation exposure before the atomic bombings as an essentially *professional* hazard, a danger that accrued primarily to *individuals* who worked with powerful new machines. Before and during World War II, radiation exposures in Japan and elsewhere were a problem largely confined to communities in medicine and science. Within the former group, doctors, nurses, technicians, patients, and laboratory animals formed the chief categories of the irradiated. After the war, and especially during the era of atmospheric nuclear tests during the Cold War, the category of those exposed broadened to civilians across the globe, making radiation exposure into an issue for environmental and anti-nuclear war citizens' movements.[7] But the significance of this later shift cannot be truly appreciated without examining the earlier history of how professional doctors, scientists, bureaucrats and the general public understood – and normalized – the potential risks of radiation. In addition, tracing the trajectory of *rentogen* in medicine also allows us a more penetrating insight into the process of modernization - not only with respect to medical practice, but also Japan itself. The ways in which *rentogen* were gradually integrated into medical practice and medical institutions, as well as popular culture, reveal links between a wide array of groups: doctors, manufacturers, the military and the state, even journalists and educators. All of them played roles that served the development of modern culture and nation-statehood, themes that the following chapters explore.

This study provides a historical examination of both discursive and material developments around radiation in its Japanese context. It aligns itself with extant studies of the history of technology in East Asia, such as Aaron Moore's research on the impact of modernization projects in Japan that drew heavily on technological expertise, and Victor Seow's

[7] Soraya Boudia, "Global Regulation: Controlling and Accepting Radioactivity Risks", *History and Technology* 23:4 (2007), 389-406. See also Higuchi Toshi, "Radioactive fallout, the politics of risk, and the making of a global environmental crisis, 1954-1963", Ph.D. diss., Georgetown University, 2011.

work on the coal industry in China.[8] It is also allied with a growing body of work that historicizes radiation as a social and cultural phenomenon in Japan beyond Hiroshima and Nagasaki. To date, most existing research has produced a valuable cluster of studies on the atomic bombings and their impact on Japanese society, via analyses that tease out the tangled relationships between history, politics and memory.[9] Post-Fukushima, too, the history of nuclear energy for commercial and civilian use in Japan has also drawn the interest of scholars who publish in English.[10] However, far less has been written, either in English or Japanese, about the histories of radiation in other areas of science, technology and society that emerged in modern Japan. Besides the use of X-rays, other understudied domains that researchers have begun studying include genetics research, the commercial boom in radium as a commodity, the Atomic Bomb Casualty Commission, and the role of transnational scientific exchanges in researching radiation.[11] Beyond these lie the equally under-examined uses of radiation in the pure and

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[8] Aaron S. Moore, *Constructing East Asia: technology, ideology, and empire in Japan's wartime era, 1931-1945* (Stanford, California: Stanford University Press, 2013). Victor Kian Giap Seow, "Carbon Technocracy: East Asian Energy Regimes and the Industrial Modern, 1900-1957", Ph.D. diss., Harvard University, 2014. See also the four volumes of Shigeru Nakayama, Kunio Gotō and Hitoshi Yoshioka, eds., *A social history of science and technology in contemporary Japan* (Melbourne: Trans Pacific Press, 2001-2006).

[9] Key works on the history of the atomic bombings in Japan include Lisa Yoneyama, *Hiroshima traces: time, space, and the dialectics of memory* (Berkeley: University of California Press, 1999); James J. Orr, *The Victim as Hero: ideologies of peace and national identity in postwar Japan* (Honolulu: University of Hawa'ii Press, 2001); Laura Hein and Mark Selden, eds., *Living with the bomb: American and Japanese cultural conflicts in the Nuclear Age* (Armonk, N.Y.: M.E. Sharpe, 1997); John Dower, "The Bombed: Hiroshimas and Nagasakis in Japanese History", *Diplomatic History* 19:2 (Spring 1995), 27-48. For a more recent work see e.g. Ran Zwigenberg, *Hiroshima: The Origins of Global Memory Culture* (Cambridge, UK: Cambridge University Press, 2014).

[10] For English-language scholarship on Japan post-Fukushima or 3.11 see e.g. Richard J. Samuels, *3.11: disaster and change in Japan* (Ithaca, New York: Cornell University Press, 2013); Martin Dusinberre and Daniel P. Aldrich, "Hatoko Comes Home: Civil Society and Nuclear Power in Japan", *Journal of Asian Studies* 70:3 (August 2011), 683-705; Noriko Manabe, *The Revolution Will Not Be Televised: Protest Music After Fukushima* (Oxford: Oxford University Press, 2015).

[11] Lisa Onaga, "Toyama Kametaro and Vernon Kellogg: Silkworm Inheritance Experiments in Japan, Siam, and the United States, 1900–1912", *Journal of the History of Biology*, 43:2(2010), 215-264; Nakao Maika, "Kindaika wo hōyō suru onsen: Taishō ki no rajiumu onsen būmu ni okeru hōshasen igaku no yakuwari", *Kagakushi kenkyū*

applied sciences – physics, chemistry and biology, which all developed into distinct disciplines, and techniques of industrial manufacturing.

The present dissertation strives to connect the two fields of modern Japanese history and science and technology studies (STS), showing how perspectives from the latter realm can shed light on the former. Although science and technology are considered by some as objectively neutral phenomena, the cluster of approaches known as STS emphatically rebuts that idea by showing, from a variety of disciplines and methodologies, that science and technology are political agents that affect the expression and exercise of power. Scientific knowledge does not come into being independent of political thought and action; neither do social institutions passively reorder themselves to suit technology's requirements.[12] Social analyses of technology, for instance, reveal the biases and socio-cultural factors that shape the production of artefacts.[13] Writing about American public knowledge of radiation, Levine makes the case that "nuclear culture" is more than a convenient term for cultural historians, and should be viewed as a periodization that suggests the "continuous influence of an idea at work across a broad swath of a culture". It is important to place scientific and technological developments in broader contexts because their applications often have ramifications far beyond the laboratories and workshops that conceive them. It is crucial to gauge what broader audiences outside the confines of official

52:268 (2014), 187-199; M. Susan Lindee, *Suffering made real: American science and the survivors at Hiroshima* (Chicago: University of Chicago Press, 1994); Vassiliki B. Smocovitis, "The "Devil's Heritage": Masuo Kodani, the "Nisei Problem", and Social Stratification in the ABCC." Paper presented at the 4th Workshop on Historical Studies of Imperial Japanese Sciences and Networks, Kobe University, December 7, 2014.

[12] Sheila Jasanoff, ed., *States of knowledge: the co-production of science and social order* (London: Routledge, 2004), 27-28.

[13] The literature here is a broad one: a classic is Lynn White's *Medieval Technology and Social Change* (Oxford: Clarendon Press, 1962); for scholarship on the driving force of technology as an agent of social change see Langdon Winner, *Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1977); also Wiebe Bijker, Thomas Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, MA: MIT Press, 1987).

institutions knew or thought about science and technology, from sources of information that were publicly accessible. The same is true of examining how the daily lives of ordinary people intersected with the knowledge and artefacts produced in laboratories – in the case of X-rays, the fluoroscopy machines that were once a staple of shoe stores in America.[14]

At the same time, there remains much value in research that examines what the practitioners of science and technology themselves did and thought about their work – if only because they were, and continue to be, key sources of information that are released to the public. Moreover, in times of national emergencies, the scientific knowledge that eventually becomes part of public understanding and public discourse is often circumscribed in its circulation, whether through censorship or a shortage of attempts to publicise and transmit research findings to a broader audience. In that vein, this study probes the links between scientific research, state policy, popular discourse and technological developments surrounding radiation in Japan until just after WWII. It assesses the role of radiation in Japanese society during this period and finds continuities in images and ideas across the pre- and post-WWII periods. Ultimately, it argues for the importance of attending to how developments in medical practice contributed to the project known as modernization. Currently, the history of medicine, science and technology requires better integration into the broader fields of research into the modern history of East Asia, given

[14] Ibid., 153-4. From an STS perspective, the subfield of the public understanding of science has produced a literature examining the need to recognise the agency of laypersons in interacting with scientific knowledge, instead of clinging to a top-down model of knowledge dissemination that sees non-scientists as having deficient ability to understand science, and which fails to interrogate scientists and scientific institutions. Brian Wynne's study of the responses of Cumbrian sheep farmers to the Sellafield nuclear reprocessing complex in north-west England is a classic work in this field; see also his entry in Sheila Jasanoff, ed., *Handbook of Science and Technology Studies* (London: Sage Publications, 1995), 361-388.

that these areas of study present crucial perspectives on social, political and cultural histories.[15] Within the literature in English, there are illuminating works on early modern history of Japanese medicine, and there is a growing body of literature on medicine in modern Japan.[16] However, much remains to be studied from the late Meiji period into the contemporary world.[17]

In terms of modern Japanese history, this project shows that radiation is not confined to studies of the atomic bombings and the postwar period. Neither was it confined to a particular location. Japan possessed a network of sites where medical radiation was produced and utilized. Medical modernization occurred in multiple institutions and places within Japan, although Tokyo remained the political center of events. As Louise Young argues, it is important to pay attention to the intra-national politics and processes of development in "second cities" – that is, urban locales outside of the metropolis.[18] Other cities like Kyoto and Nagasaki, as well as the locales of the imperial medical colleges, including Okayama and Sendai, also figured in this process. This

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[15] A classic work that argued for the importance of seeing Japanese science in its own context and traditions is James Bartholomew, *The formation of science in Japan: building a research tradition* (New Haven: Yale University Press, 1989). This and other works, such as Yoshiyuki Kikuchi's *Anglo-American connections in Japanese chemistry: the lab as contact zone* (New York, NY: Palgrave Macmillan, 2013) are grouped more in the literature on the history of science instead of also being part of the literature on modern Japanese history.

[16] For the early modern history of Japanese medicine see Daniel Trambaiolo, "Writing, Authority and Practice in Tokugawa Medicine, 1650-1850", PhD. diss., Princeton University, 2014; also Ann Jannetta, *The vaccinators: smallpox, medical knowledge, and the "opening" of Japan* (Stanford, Calif.: Stanford University Press, 2007) and Ellen Nakamura, *Practical pursuits: Takano Chōei, Takahashi Keisaku, and western medicine in nineteenth-century Japan* (Cambridge, MA: Harvard University Press, 2005).

[17] Suzuki Akihito, "Illness Experience and Therapeutic Choice: Evidence from Modern Japan", *Social Science History*, 32(2008), 515-534.; Akihito Suzuki and Mika Suzuki, "Cholera, consumer and citizenship: Modernisations of medicine in Japan," in *The development of modern medicine in non-western countries: historical perspectives*, ed. Hormoz Ebrahimnejad (New York: Routledge: 2009), 184-203; Alexander Bay, *Beriberi in modern Japan: the making of a national disease* (Rochester, NY: University of Rochester Press, 2012) and Susan L. Burns, ""From 'Leper Villages' to Leprosariums: Public Health, Medicine, and the Culture of Exclusion in Modern Japan", in *Isolation: Policies and Practices of Exclusio*n, eds. Alison Bashford and Carolyn Strange (London: Routledge, 2003), 97-110.

[18] Louise Young, *Beyond the metropolis: second cities and modern life in interwar Japan* (Berkeley: University of California Press, 2013).

study, therefore, is not simply an effort to extend the timeline of Japanese nuclear-related history into a pre-Hiroshima past. It seeks to avoid a pure 'internalist' perspective on the use of *rentogen* in Japanese medicine and public health that only focuses on the activities of elite doctors and state agents. Instead, it argues that the early history of radiation science and technology shows less the evolution of technical prowess in machinery and theory than an array of different groups of agents who negotiated issues of use and meaning.

***Rentogen*: A Basic Chronology**

As this dissertation is thematically rather than chronologically arranged, this section provides an overview of the actual process by which *rentogen* first appeared in Japan, with information that will help to contextualize the following chapters. An abbreviated chronology of milestones in the Japanese use of *rentogen* appears in Table 1:

Table 1. Timeline of *rentogen* use and development[19]

Year	Agents [Organization]	Events
1895.12	Wilhelm Roentgen	Discovers X-rays in Germany
1896.5.31	Marumō Fumiyoshi [Saisei Gakusha (private medical school)]	Public demonstration of and lecture on X-rays at alumni gathering of Saisei Gakusha
1896.10	Muraoka Han'ichi [Professor, Third Higher School] Shimazu Genzō [Shimadzu Corporation]	Successful collaborative experiment to produce X-rays
1897.10	Konishiroku Company [later Konika]	Imports X-ray apparatus, successful generation of X-rays

19 Information for this table compiled from the records of the Japanese Society of Radiological Technology (JSRT). Nihon Hōshasen Gijutsu Gakkai, ed., *Nihon hōshasen gijutsu shi* (Tokyo: Nihon hōshasen gijutsu gakkai gijutsu shi hensan iinkai, 1989), 333-353. Entries also sourced from the chronology compiled by Tateno Yukio for the online museum exhibition of the Japan Medical Imaging and Radiological Systems Industries Association (JIRA). JIRA Virtual Museum, "Nenpyō", http://www.jira-net.or.jp/vm/various.html (accessed February 20, 2016).

Table 1. Timeline of *rentogen* use and development (cont'd)

1897.4	Tokyo Imperial University	Installs X-ray machine in surgical faculty of medical school
1897.9	Shimadzu Corporation	Manufactures X-ray apparatus for educational use, traveling display
1898.12	Haga Eijirō, M.D., Imperial Army Tokyo Army Medical School Imperial Japanese Army	Buys Siemens (Germany) X-ray apparatus , installs it in Tokyo Army Medical School. Imperial Arm buys two more machines and gives them to the 4th Division and Taiwan military detachment
1898.3.17	Julius Karl Scriba, M.D., surgical faculty of medical school, Tokyo Imperial University	Public demonstration of X-ray screening using Imperial University's X-ray machine at Tokyo Society of Medicine
1899.1	Faculty of internal medicine, Tokyo Imperial University	Installs X-ray apparatus
1899.2	Tanaka Mokujirō, proprietor of medical instruments store in Tokyo	Begins sale of imported X-ray apparatuses
1899.5	Tokyo First Army Garrison Hospital	Installs Siemens-made X-ray apparatus
1899.7	Imperial Japanese Navy	Installs X-ray apparatus in Yokosuka Naval Hospital
1899.8.10	Japanese Red Cross Society	Installs X-ray room on the Kōsaimaru, a hospital ship for maritime patients, available to public
1899.9	Sendai Second Higher School Medical College	Purchases 1000-yen imported X-ray machine from Gotō Fu'undō medical instrument emporium
1901.1	Anritsu Electrical Manufacturing Company, Tokyo	Begins sale of imported X-ray apparatuses

News of Wilhelm Roentgen's monumental discoveries had reached Japan in February of 1896 via letters from the physicist Nagaoka Hantarō, who was at the time studying in Germany, to his physicist colleagues back home.

The first X-rays in Japan were produced in 1896, just short of three decades after the restoration of the monarchy and the end of an era of government by the samurai class. These experimental successes stemmed from four research groups in the country: three in Tokyo and one in Kyoto. In the First School of Higher Education (currently Tokyo University's Graduate School of Arts and Sciences), a team of four professors successfully produced X-rays and published a report on their experimental outcomes in late March of the same year.[20] This included photographs of X-rays that they took of a human hand, a fish and a knife. Another group led by Muraoka Han'ichi, working in Kyoto University, began experimenting with making an X-ray generating apparatus in the summer of 1896. Muraoka secured the assistance of Shimazu Genzō, the Shimadzu company in Kyoto, which provided him and his assistants with equipment and technical advice. Outside this exclusive community, the Roentgen rays also received some public press, appearing in a series of reports published in the *Jiji Shinpō* from March 7, 1896 onwards.[21]

The entries in Table 1 are clustered around the new and old urban political centers of Tokyo and Kyoto. This strongly suggests that the main group of users who could access this emergent technology were elite actors based in prosperous urban locations. With the exceptions of a few enterprising private companies, those with the resources to import the expensive machines largely came from governmental organs like the army and the imperial universities, or

[20] The First School of Higher Education (*Dai-ichi Kōtō Gakkō*) was so called for being the first of a series of institutes of post-compulsory education started in 1894 that lasted until 1950. It was affectionately called "Ichikō" for short by its affiliates. See the official commemorative website run by the Komaba Museum, University of Tokyo, "Dai-ichi Kōtō Gakkō Hōmupēji", http://museum.c.u-tokyo.ac.jp/ICHIKOH/home.html (accessed March 18, 2016).

[21] Honda Ichiji, "Fukuzawa Yukichi to 'Jiji Shinpō' no kagaku hōdō", in *Fukuzawa Yukichi nenkan*, vol. 5, ed. Fukuzawa Yukichi Kyōkai (Tokyo: Fukuzawa Yukichi Kyōkai, 1979), 154-155. With thanks to Hansun Hsiung for providing this reference.

government-linked institutions like the Red Cross.[22] X-ray machines were mobilized by the Japanese state to serve the ends of military medicine in the imperial Army and Navy. They facilitated, for instance, the treatment of wounded soldiers in the Russo-Japanese war of 1904-1905.[23] Although American manufacturers like General Electric also became instrumental to the X-ray industry after WWI, in Japan their domestic manufacture was dominated by a Kyoto-based firm called the Shimadzu Corporation (*Shimazu seisakujo*), whose activities are explored in Chapter 3.[24] Due to their high cost and relative inaccessibility outside of specialist clinics and large university hospitals, a time lag existed from the introduction of X-ray machines and their spread as a medical technology used on even those of modest means. From the late 1930s on, *rentogen* became a staple of Western medicine in Japan, when mobile vans outfitted with portable X-ray machines became tools of public health, conducting mass screenings for tuberculosis around the entire country.[25]

The earliest recorded instance of research into the medical use of X-rays in Japan also occurred in 1896. In that year the physicist and surgeon Marumō Fumiyoshi, an employee of the Saisei Gakusha, a private medical school (later the Nippon Medical School) succeeded in generating X-rays. Marumō, like his physicist colleagues in the imperial universities of Tokyo

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[22] For a concise summary of the Japanese Red Cross's history see their official webpage, "History | About Us | JAPANESE RED CROSS SOCIETY," Japanese Red Cross Society, http://www.jrc.or.jp/english/about/history/ (accessed September 29, 2015). See also Nihon Sekijūjisha, *Jindō sono ayumi: Nihon sekijūjisha hyakunen shi* (Tokyo: Kyōdō Tsūshinsha, 1979).

[23] Kimura Masuo, "Dōnyū shoki no rinshō ni okeru X sen no unyō dai ippō", *Nihon hōshasen gishikai zasshi* 48:8 (2001), 1034-1049.

[24] Pierre-Yves Donzé, "Making medicine a business in Japan: Shimadzu Co. and the diffusion of radiology (1900–1960)," *Gesnerus* 67:2 (2010), 241–262.

[25] For the *rentogen* vans see Chapter 6 of Fukuda Mahito, *Kekkaku no bunkashi* (Tokyo: Nagoya Daigaku Shuppankai, 1995), 301-324.

and Kyoto, assembled a team to build an X-ray apparatus from scratch. Following this, he managed to develop radiographs of miscellaneous objects: the chain of his pocket watch, cigarettes, coins; he also took on the duties of lecturing about X-rays to the school's students.[26] Summed up, early interest in and research on *rentogen* in Japan took place within two main groups of people: scientists and doctors. The former group's main constituents were researchers in physics, chemistry and biology. Both groups experimented with building apparatuses to generate X-rays, and then applied them to their own fields of research.

The Significance of Medical Radiology

In November 1895 Roentgen, a German physicist, published a landmark paper about a new form of radiation that later acquired two names: an eponymous moniker after his own surname, and the alphabet "X", denoting mystery and the unknown. Roentgen took the first x-ray image on Jan. 12, 1896, a radiograph of his wife's hand that displayed her bones as well as a silhouette of her wedding ring. His report of his discovery eventually earned him the first Nobel Prize for Physics in 1901. Today, the term "radiology" encompasses multiple subfields which span basic scientific research to forensics and conservation. In the present day, it incorporates a wide range of imaging technologies which make use not only of X-rays, but also magnetic fields and radioisotopes. Medicine, however, was the first domain to which the term applied.[27]

The early 20th-century use of *rentogen* by Japanese medical practitioners – an umbrella

[26] Karasawa Nobuyuki, "Wagakuni igakukai hatsu no X sen jikken rinshō kōgisha Marumō Fumiyoshi," *Nihon ishigaku zasshi* 41:3, 437-438.

[27] The earliest recorded instance of radiology in reference to medical practice in Europe, according to the Oxford English Dictionary, occurred in 1900. "radiology, n.". OED Online. June 2014. Oxford University Press. http://www.oed.com/view/Entry/157319?redirectedFrom=radiology& (accessed June 14, 2014).

term that includes nurses and technicians as well as doctors – embodies the sea change in the system of medical practice drafted on paper and implemented gradually across the late 19th and 20th centuries, where the meanings of "medicine" and "doctor" were in flux. In the early modern era of the Edo period, medicine had by and large entailed Chinese medicine (*kanpō*) practiced by physicians who ran their own private practice (*kaigyōi*). The closing of Japan to the West had confined Western medicine to the port of Nagasaki, the only place that remained open to trade with the Dutch, and which provided a window into *rangaku* ("Dutch learning"). In this period Western medical learning was confined to the self-taught in the urban centers of Nagasaki and Edo, where autodidacts like Sugita Genpaku translated Dutch-language versions of German and English writings into Japanese.[28] After the Meiji Restoration of 1868, though, German medicine became the state-sanctioned form of medicine, taught in the newly established imperial universities. Thus began a process of standardizing and homogenizing medical training according to German standards; from 1883, state-granted medical licenses were restricted to those who had studied Western medicine, which dealt a severe blow to the status of *kanpō* medicine.[29] The promulgation of the first Physicians' Law (*Ishihō*) in 1906 further restricted medical licenses to physicians trained in Western-style medicine at national, public, or state-approved private schools of medicine, confirmed the prominence of these practitioners as doctors for the modern age.[30] In fact, the Japanese population remained predominantly rural, which suggests a continued reliance on traditional medical methods, and even in the Tokyo area some

[28] See Chapter 10 of Grant K. Goodman, *Japan and the Dutch, 1600-1853* (Richmond, Surrey: Curzon, 2000), 74-86.

[29] Kawakami Takeshi, *Gendai Nihon iryōshi* (Tokyo: Keisō Shobō, 1965), 123.

[30] Full text of the 1906 Physicians' Law available from the Digital Archive of the National Archives of Japan. "Ishi hō - Gōshomei genpon – Meiji sanjūkyū-nen – hōritsu dai yonjūshichi gō", http://www.digital.archives.go.jp/DAS/meta/Detail_F0000000000000020623 (accessed February 22, 2016).

urbanites continued to see *kanpō* trained doctors.[31] But the new breed of doctors enjoyed institutional prestige and access to emergent medical technologies and research from their Western colleagues.

Before *rentogen*, bodily examinations relied on physicians' observations of the external body to gauge the condition of the organs on the inside.[32] Western-trained doctors eventually acquired the use of stethoscopes, but those with access to *rentogen* acquired a completely different view of their patients' interiors. *Rentogen* enabled penetrative sight, as well as the production of a visual record of the body's interior that left its exterior intact. In the same way, X-ray technology facilitated the progress of several industries, including forensics and construction, by enabling the ability to see inside of objects without damaging their exteriors. But their impact featured most prominently in the field of professional medicine. Being able to render the internal structures of the body visible without surgery revolutionized medical diagnosis by allowing more accurate surgeries to be performed, and new methods of treatment to be developed for abnormal growths and lesions.

At this juncture, it is worth saying a few words about what this study does not cover. As it is first and foremost concerned with analysing the significance of early Japanese encounters with radiation, it does not deal with the philosophical issue of radiology's objectivity, or rather, the contingency of that objectivity on visual interpretation – an epistemological issue taken up by

[31] For a detailed analysis of the social preference, by some individuals, for traditional or 'folk' medicine over Western medicine, see Suzuki Akihito, "Senzen ki Tōkyō ni okeru byōki to shintai keiken – 'Takinogawa-ku kenkō chōsa (Shōwa jū-san nen) wo tegakari ni", in *Kindai Nihon no shintai kankaku*, eds. Kuriyama Shigehisa and Kitazawa Kazutoshi (Tokyo: Seikyūsha, 2004), 21-51.

[32] For a history of medical views of the body in Japan from ancient to early modern times, see Sakai Shizu, "Jū-shichi, jū-hachi seiki no Nihonjin no shintaikan", in *Rekishi no naka no yamai to igaku* , eds. Yamada Keiji, Kuriyama Shigehisa (Kyoto: Shibunkaku, 1997), 431-455.

scholars in the history and philosophy of science.[33] Although X-rays rendered the interior of the body visible, the *quality* of the vision they provided was highly contingent on many variables, particularly in the first few decades of radiological practice. Technical factors including the calibration of the machine and the skill of the operator could cause great differences in the images produced.[34]

Next, as this study focuses on the ways which *rentogen* encompassed actors in both state and society, it only mentions in passing radium – another key source of radiation from the early to mid-twentieth century. Radium generated intense popular interest and developing into a mode of radiation therapy that, in due course, also engendered concerns about the potential hazards it posed to its users. However, its high cost and relative scarcity made it far less common than *rentogen* in radiological medicine as practiced in Japan, and, even with a rise in popularity of radium hot springs during the Taisho period, did not generate an intense cultural ferment as seen in Europe and America.[35] Radium is thus mentioned in chapters of this work where it is relevant, but the primary discussion concentrates on *rentogen* to give its complexities deeper focus.

Chapter Outlines

The body of this study consists of a thematic analysis of X-rays/*rentogen* in radiology,

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[33] For a classic and concise analysis of visual objectivity in the late 19th and early 20th centuries see Lorraine Daston and Peter Galison, "The Image of Objectivity", *Representations* 0:40 (1992), 81-128.

[34] As two American roentgenologists wrote in a 1919 textbook: "It cannot be emphasized too strongly in the beginning that roentgen images are shadowgraphs; that they are the record of the varying opacities through which a bundle of rays pass; and that they are subject to the possibility of erroneous deductions consequent upon the fact that they are shadows. ...Another source of possible error lies in the fact that we commonly employ divergent rays. ...the images of objects in their path will be distorted according to their position with reference to the plate." George Holmes and Laurence Robbins, *Roentgen Interpretation* (Philadelphia: Lea & Febiger, 1919), 2.

[35] On this see Nakao, "Kindaika wo hōyō suru onsen".

divided into five chapters and a concluding essay. It starts in the immediate aftermath of WWII and works backwards in time to explore various avenues in the use and development of radiology in Japan. The chapters, therefore, do not follow a chronological order, although within each chapter the material is chronologically dealt with. Each chapter explores the activities and motivations of a crucial group that enabled the production and integration of radiology.

Chapter 1 zooms in on the career of a man who is arguably Japan's most famous radiological martyr and *hibakusha* survivor. Nagai Takashi, a practicing radiologist in the 1920s and 1930s, had his life entangled with radiation again after becoming a *hibakusha* of the Nagasaki bombing. Despite the injuries he suffered to life and health, his post-war writings propagated a staunchly positive image of radiology and nuclear science and technology. Nagai's prolific output of memoirs and essays provided a bright counter-narrative to fears of nuclear war and weaponry and fears of radiation exposure. By analyzing Nagai's representations of radiology and radiation in his textual oeuvre, this chapter also introduces themes and groups of agents that form the foci of subsequent chapters, and which are woven together in Nagai's individual story: the military medical use of *rentogen*, the role of the machines themselves and those who operated them, the contingent nature of scientific expertise and the importance of popular culture in disseminating ideas and images about *rentogen*.

Chapter 2 examines the use of *rentogen* by agents of the state, mainly the Japanese military and the Welfare Ministry, for the purposes of screening and diagnosing two main groups of citizens: soldiers and the civilian population that provided those soldiers. It traces two broad developments: the late-19th century origins of how *rentogen* first entered medical practice in the imperial army and navy, and the introduction of a mass screening system of public health coordinated by the Welfare Ministry as part of an anti-tuberculosis campaign in the late 1930s. In doing so it makes the point that, although medical radiation is today classified as a "civilian" use, it took a decidedly military and state-driven trajectory in becoming a standard part of medical practice in Japan. It also raises the question of why, although state agents had an idea of the potentially deleterious effect of radiation on human health, they made such few provisions for protecting those who worked with radiation and those who received it.

Chapter 3 looks at two more vital groups implicated in the development of radiological science and technology: those who manufactured and managed machines that produced X-rays. It focuses on the commercial enterprise conducted by the Shimadzu Corporation (*Shimazu seisakusho*) from the 1910s to the 1940s, the first company to domestically manufacture *rentogen* machines, and also the first company to develop a training program for *rentogen* technicians. Although this group initially worked in the shadow of medical doctors trained in elite institutions, they eventually grew into a specialized profession that worked to gain recognition as an independent association of specialists. By focusing on the making and managing of *rentogen* machines, this chapter underscores the importance of attending to the material realities of the physical and human infrastructures that enabled medical radiology to exist; it also highlights the role of a key set of actors in the practice of radiology that are as important as the doctors and state officials discussed in previous chapters.

Chapter 4 zooms out to take a more comparative perspective. Through looking at literature published for specialists, it delves into the activities of professional scientists and medical researchers who experimented with *rentogen* in the first four decades of the 20th century. It juxtaposes the work of Japanese researchers alongside the efforts of their counterparts in Western Europe and the United States. A crucial issue that needed solving was that of how to measure and devise an internationally functioning system of measurements for a phenomenon invisible to the human eye, and one potentially toxic to human health. The plethora of problems that faced those who would implement such a system ranged from the calibrating of instruments to accurately record physical phenomena to the danger that they themselves, in the process of experimentation, would develop radiation injuries or illness. This chapter positions Japanese researchers as part of international efforts to understand and control the biological effects of radiation in pursuit of harnessing radiation for human ends.

Chapter 5 then turns to survey the images and ideas of radiation that appeared in the mass print media of the late 1890s to the 1940s. Research into the pre-WWII history of radiation in America and Western Europe shows a widespread range of popular fears and fantasies about X-radiation and radium pervaded an array of texts ranging from science fiction stories to advertisements; the same phenomenon also occurred in Japan. Through sampling four major publications consisting of two national dailies and two popular magazines, as well as novels and illustrations, it shows that those who produced and circulation information about radiation in this time period were more concerned with the cultural and progressive perspectives that could be read into *rentogen* – notably, in how it could be used to police the reproductive and moral fitness of female bodies – than on its possible harms. Although there were reports and news on the potential dangers that *rentogen* use might engender, the doctors, scientists and technicians who became casualties of X-radiation were viewed as heroes of science, and the benefits generally were presented as outweighing the demerits.

Finally, the conclusion briefly considers the post-war development of radiological medicine and how it reflects themes that the preceding chapters on the pre- and wartime use of radiology have explored. It further tries to apply some theoretical perspectives to illustrate the significance of historicizing the trajectories of radiation in modern Japan.

Chapter 1

Nagai Takashi: The A-Bombed Radiologist

> The first cases of atomic illness occurred in the laboratories that used X-rays and radium, and kept occurring amongst the doctors and nurses who used these in medical care, but at the time this passed unnoticed by the general public.[36]

August 9, 1945. Three days after Hiroshima, radioactive fallout from the world's second atomic bomb used in war spread over Nagasaki City. Thick clouds and drifting smoke had caused the United States B-29 bomber aircraft named *Bockscar*, laden with the rotund explosive christened *Fat Man*, to bypass its initial target of Kokura City. Instead it headed for the secondary target of Nagasaki, and took out its designated target of the Mitsubishi Steel and Arms Works. *Bockscar* dropped *Fat Man* into the Urakami Valley, a stretch of land ringed with mountains. This geography sheltered most of the city outside from the blast of *Fat Man*'s explosion. Most structures inside the valley, however, shattered. These included Urakami Cathedral, then the largest Catholic cathedral in Asia, and the Nagasaki Medical University. The tens of thousands of lives the *Fat Man* bomb claimed included close to 85 percent of Nagasaki's Catholic population.[37] But it left one survivor who became an iconic figure of the city's experience of nuclear war – and whose life embodied key aspects of modern Japan's relationship with radiation.

[36] Nagai Takashi, *Hana saku oka*, 321. Nine texts written by Nagai are referenced here as they appear in the collected volume titled *Nagai Takashi zenshū* (Tokyo: Kōdansha, 1971), with corresponding pagination. The texts are *Nagasaki no kane*, *Rozario no kusari*, *Kono ko wo nokoshite*, *Itoshigo yo*, *Hana saku oka*, *Horobinu mono wo*, *Son'i*, *Seimei no kawa* and *Genshi bakudan kyūgo hōkoku*. Where necessary, *Nagasaki no kane* and *Genshi bakudan kyūgo hōkoku* may be compared with their English translations: *The Bells of Nagasaki*, trans. William Johnston (New York: Kodansha International: 1994) and Nagai Takashi, *Atomic Bomb Rescue and Relief Report*, trans. Aloysius F. Kuo (Nagasaki: Nagasaki Association for Hibakushas' Medical Care, 2000).

[37] For an analysis of Catholicism in Nagasaki's handling of the bombing, see Okuyama Michiaki, "Religious Responses to the Atomic Bombing in Nagasaki", *Nanzan Institute for Religion and Culture* 37 (2013), 64-76.

Nagai Takashi (baptized Paul) is arguably Nagasaki's most famous *hibakusha* (被爆者), or survivor of the atomic bombings. He was also a radiologist by profession. His story is a unique instance of how medical and military radiation combined to produce a life both shaped and severed by the same phenomenon. His career and his very body furnish evidence of how the dark and bright sides of radiation harnessed for human ends coexisted long before the advent of atomic weapons. Above all, Nagai constitutes a compelling case of his own observations in the epigraph to this chapter: the roots of "atomic illness" – i.e. sickness induced by over-exposure to radiation, and a concept explored in subsequent pages – lie in the laboratory and clinical spaces inhabited by practitioners who worked with medical radiation.

In his native land and overseas, Nagai Takashi is celebrated for the virtues of his Catholicism and his accounts of surviving and overcoming the atomic bombing. When illness severed him from his former career as a doctor and scientist, he turned to writing, and produced a prodigious literary output: thirteen volumes of essays and fiction, two book-length translations, and two compilations of atomic bombing testimonies which he edited. As prolific as Nagai was, his best known work is an eyewitness account of the Nagasaki bombing called *The Bells of Nagasaki* (*Nagasaki no kane*; hereafter *Bells*). Published in January 1949, *Bells* tells the story of Nagasaki's devastation alongside Nagai's own immense personal losses: the death of his beloved wife, the worsening of his radiation sickness, and the knowledge he too would soon die, leaving his two young children orphaned. *Bells* swiftly climbed to the top of sales charts and acquired a score of foreign-language translations, along with eponymous adaptations in film and song.[38] William Johnston, its English translator, reports hearing its musical version all around him when he first arrived in Japan in 1951.

Even today Nagai continues to be commemorated as one of Japan's most famous *hibakusha*. Sometimes he is also called the "saint of Urakami", and invoked as a figure that links tragedy with hope via the melding of science, religion, literature and humanism. The author and dramatist Inoue Hisashi, who read Nagai's works during his childhood in a Sendai orphanage, recalled in a 1987 essay that, though younger readers of his time might find it hard to imagine, Nagai Takashi had been a "shining cultural hero, an enlightened man of religion who had transcended life and death".[39] Nagai's voice became one of the earliest and most prominent ones to reach a broad audience in Japan – and overseas, eventually – about what it meant to survive an atomic bombing. As historian Chad Diehl notes, "Nagai's point of view as a witness of the bombing, combined with the postwar benefits of his religious position, propelled him to the top of the literary world when the nation thirsted for information regarding the atomic bomb."[40]

Much less attention has been paid, however, to Nagai's life and work before his conversion to a martyr of the Nagasaki bomb. An examination of those aspects sketches a portrait of Nagai as a man of many identities and roles. He was a stalwart of the radiological department of the Nagasaki medical college and also in the Catholic community of Urakami Village; he was also a scientist, doctor, father and husband. The entirety of Nagai's relationship to medicine, science, empire and human relations cannot be unpacked in this limited space. But

[38] Satō Hachirō, *Nagasaki no kane*, performed by Fujiyama Ichirō (1949; Japan: Columbia Records); *Nagasaki no kane*, dir. Ōba Hideo (1950; Japan: Shōchiku).

[39] Inoue Hisashi, "Besutoserā no sengoshi Nagai Takashi 'Kono ko wo nokoshite' genbaku tōka wa "kami no onchō" datta?", *Bungei shunju* 65:7 (1987), 367.

[40] Chad Diehl, *Resurrecting Nagasaki: Reconstruction, the Urakami Catholics, and Atomic Memory, 1945-1970.* Ph.D. diss., Columbia University (2011), 112.

his attitudes towards science, medicine and humanity's progress are linked to his radiological career before the atomic bombings. Nagai's writings provide several fascinating insights into radiology as a medical practice within the institution of a medical school in imperial Japan. Moreover, unpacking his career allows us to make important trans-war connections about the relationship of radiation science and medicine to Japanese society.

A Doctor's Youth and Career

Nagai Takashi was born in 1908, three years after Japan's victory in the Russo-Japanese war. His birthplace was Matsue, the capital city of Shimane Prefecture in southwestern Japan, part of Izumo Province – described by Nagai's biographer, Kataoka Yakichi, as the ancient "land of Japan's foundation" (*Nihon kenkoku no chi*). The young Takashi proved himself an outstanding student from elementary school, where he received a prize from the local government for his academic achievements. On graduating from high school he claimed a monetary award bestowed by the imperial family.

Nagai descended from a patrilineage of doctors. His father Noburu had opened his own rural medical practice in the town of Iishi, which partly account for Nagai's own interest in taking up the mantle of medicine. In 1928, at the age of 21, he moved to Nagasaki Prefecture, where he enrolled as a student at the Nagasaki Medical University. He remained at the same institution as a research assistant in the physical therapy section from 1932 onwards, with two periods of absence when ordered to serve as a military medic: during the breakout of the Manchurian Incident in 1933 and the Shanghai Incident in 1937. In 1940 he was promoted to the position of assistant professor of radiology at Nagasaki Medical University, and later that same year, following the transfer of a senior colleague to Kyoto Imperial University, became the dean of the radiology department. His young son and daughter survived the atomic bombing, although his wife perished, and he subsequently moved with his children into a small hut called Nyokodō, the "dwelling of loving others as one loves oneself", built with the assistance of the local Catholic society of St. Vincent de Paul.[41]

Nagai's life-work began and ended with radiation science and technology. By the 1940s he manifested chronic symptoms of radiation illness induced by his heavy work with X-rays. These worsened after his exposure to the Nagasaki bombing, exacerbated by fatigue due to malnutrition and severe overwork. But by the time he died at the young age of forty-three, he left behind a young son and a daughter, as well as an iron-cast reputation both domestically and internationally as the "saint of Nagasaki". However, Nagai's popular influence internationally and locally was contingent on his situation being made to serve the interests of the American occupation in Japan. The occupation lasted almost seven years, from September 1945 to April 1952. *Bells* came into circulation during this period only because of a modification imposed by its officers.[42] The censorship department of the occupation's General Headquarters (GHQ) allowed *Bells* to be printed on condition that its publishers attach an account about the Japanese invasion of Manila, thus equating – and relativizing – the United States's atomic bomb with Japan's attack on the Philippines.[43] In addition to this appendix of comparative warfare, Nagai's Catholic identity, together with his emphasis on fostering peace and science, proved amenable to GHQ. *Bells* emphasized the importance of scientific progress and an understanding of the bomb as "divine Providence" (*kami no setsuri*).

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[41] A detailed chronology of Nagai's life can be found as an appendix to the *Nagai Takashi zenshū*, 1008-1013.

[42] Monica Braw, *The Atomic Bomb Suppressed: American Censorship in Occupied Japan* (Armonk, New York: M.E. Sharpe, 1991).

[43] Nagai, *Bells*, preface.

Nagai's relatively brief life is often understood in terms of martyrdom. Here was a man from whom the atomic bomb had taken everything – beloved wife, home, health – yet who still asserted, in the spirit of Christian forgiveness, that this same weapon of mass destruction be understood as the will of God. Even confined to his sickbed, he continued to write in support of peace, a faith-based humanism, and scientific progress. His work as a doctor and a scientist is often mentioned in this context, but far less has been said about what it actually entailed and what else it can tell us about the history of medical radiology in Japan during his lifetime.

Radiology as Medical Practice

Although he achieved some local fame for his work at Nagasaki Medical University, Nagai is not recognized as a key figure in the history of Japanese radiology. His name is absent from lists of pioneers in that field, and his scientific publications were mostly confined to the Nagasaki Medical University's in-house journal.[44] His twinned identities as *hibakusha* survivor and author won him far more fame than his research as a medical radiologist ever did. In part this stemmed from his relatively junior status in the world of medical research. His later fame outside medical circles resulted from his decision to write for a popular audience: in order to support his children, he needed to sell his writing to appeal to a broad range of readers.

In addition to economic necessity, Nagai wrote for a general audience out of a professed desire for ordinary people to understand the basic principles of atomic physics and radiology. He believed both that they could, and also that they *should* – the public, he felt, needed to educate themselves on the importance and potential of science. Perhaps driven by these motivations, his

[44] See e.g. Nagai Takashi, "Hai fuku shitaba no rentogen zo," *Nagasaki igakkai zasshi* 13(9), 1345-1357. Also see Kataoka Yakichi, *Nagai Takashi no shōgai* (Tokyo: San Paulo, 1961), 64-65, for further mentions of other articles Nagai published singly or with co-authors in the same journal.

works are for the most part highly readable, filled with humor and succinct yet evocative descriptions. On a visit to RIKEN, during the last stages of the battles at Saipan, he beheld a group of his scientific colleagues working in the cyclotron building. Observing their thinned ranks around the large machine, together with a dearth in experimental supplies, he drew the memorable comparison of them resembling "a tiny group of two or three ants hesitating over a large sandwich of chocolate bread".[45] He also provided lively sketches of interpersonal interactions between affiliates of the radiology department, including faculty, technicians, nurses, patients, and their relatives in his anecdotes.

According to Nagai, in Nagasaki Medical College, during the first few decades of the twentieth century, radiology was a fledgling discipline whose coming importance and utility to its fellow specialties went severely unrecognized. Nagai himself recalls how he, like many of his fellow students, had little interest in the discipline, paying scant attention to the material on atomic physics and radiology that was part of his medical curriculum. Only after an acute attack of tympanitis, or middle-ear infection, which left him partially deaf in his right ear, did he turn to radiology for his specialization. His impaired hearing had made it impossible for him to work in internal medicine, as he had originally planned. By his own account, he only chose radiology because a senior student who was a technician in the section encouraged him to do so.

Radiology's importance to the practice of twentieth-century medicine, in Japan as in Europe and America, can be seen from how X-rays became integrated into multiple medical specialties by the 1930s. X-ray technicians staffed not only their own department; they were also

[45] Nagai, *Nyokodō zuihitsu*, 181.

present in departments of gynecology, dermatology and surgery.[46] But in Nagai's professional home, the Nagasaki Medical University, it remained a minor specialty for most of his time as a student and an assistant professor.[47] One Mukai Matakichi, a radiologist who ran his own clinic in Tokyo, even reports that he was contacted by the police department on suspicion of fraud because "radiology" (*rentogen ka*) did not constitute a valid medical specialty according to the Physicians' Act (*Ishi hō*) passed in 1906. Mukai also notes the lack of autonomous departments of radiology at medical schools and institutions in Japan, which was also the case at Nagasaki Medical University when Nagai first entered as a student.[48] Radiologists could not admit their own patients; instead, they depended on referrals from the other departments of patients who needed X-ray screenings or treatment. Nagai relates his department's marginalized status in several anecdotes, a memorable one being his frustration and bewilderment on making the discovery that his new specialty had no lavatory of its own, which forced its practitioners to have to try and use the lavatories of other departments (which sometimes barred them from doing so, out of spite).[49]

Radiology occupied a prominent position on the frontlines of the mechanization of twentieth-century medicine – a phrase which, in this context, refers to the growing use of equipment powered by electricity in medical diagnosis and treatment.[50] Nagai's works vividly

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[46] See e.g. European Society of Radiology's *The Story of Radiology*, Vol. 1 (2012) and Vol. 2 (2013). Available as e-books from the British Society for the History of Radiology, http://www.bshr.org.uk/The_Story_of_Radiology_Vol1.pdf (accessed January 03, 2015) and http://www.bshr.org.uk/The_Story_of_Radiology_Volume_2_LR.pdf respectively (accessed January 03, 2015).

[47] Nagai, *Bells*, 34.

[48] Mukai Matakichi, *Rentogen hōshasen (X kōsen) no hanashi*, unpublished pamphlet, 1921, 3.

[49] Details for this paragraph taken from Nagai, *Horobinu mono wo*, 434-439.

sketch how the complexity of radiology made it a representative specialty of modern medicine. Its practice integrated a wide array of complex electrical machines, while performing its basic services required multiple specialists trained in particular skills, who worked in modern, electrified facilities. This world was far removed from the image of the general medical practitioner who presided over the needs of small communities in a Japan that was still, at this time, predominantly rural. In Nagai's novella *The Village Doctor* (*Son'i*), the protagonist Nakae Noboru goes to a small, remote island to set up his own clinic; he grows accustomed to paying house calls with his bag of medical supplies. Nagai had based this story on the experiences of his own father's rural practice in Shimane, and the contrast between his own radiological work and his predecessor's is striking.[51] Even during the shortage of material and human resources at the height of the Pacific War, radiological practice comprised a multitude of sub-departments whose operations had to be coordinated, and a complicated array of machinery.

This complexity is reflected in the narrative framework of *Bells*. Nagai's eyewitness account of the destruction wrought on the university by the Fat Man atomic bombing takes the reader on a trip through the various rooms of the radiology department. Moving from place to place, Nagai describes the casualties incurred to humans, architecture and materials as he tries to ascertain the safety of his colleagues. He himself, around 11AM, is "in my room on the second floor above the dispensary for outpatients…choosing X-ray films to teach the students the art of

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[50] The "mechanization" of medicine is also used in reference to the seventeenth-century shift to viewing the universe in mechanical rather than Aristotelian turns. See e.g. Chapter 6 of Renato Dicati, *Stamping Through Astronomy* (Milano: Springer Milan, 2013), 139-170.

[51] Nagai, *Son'i*, 555-664; see in particular 600-601, 648 for descriptions of Noboru's work. For another discussion of *Son'i* in the context of religion and medical practice see the essay by Okamoto Hiroyuki, "Nagai Takashi wa naze genbakushi ga kami no setsuri da to kyōchō shita no ka? - 'kegare' kara kangaeru kokoromi", *Kyōiku kagaku seminarī* 42 (2011), 4-5.

diagnosis." There then comes a "flash of blinding light…like a thunderbolt in a clear sky", promptly followed by intense blast winds. A nurse called Hashimoto, who is next door in the X-ray photography room, gets her legs tangled up in the electric wires of the X-ray camera with the impact of the blast. Eventually she extricates herself and makes her way to the X-ray examination room. The narrative then moves to a parallel story of Nagai's colleagues in the X-ray screening room just before the bomb falls. A nurse called Tsubakiyama and two technicians, Shiro and Choro, are "in the process of putting together the apparatus for examining X-rays." The havoc caused by the blast force of the bombings leaves a mess of "the powdered glass, the fragmented machinery, the smashed chairs, the tangled electric wires." Then there is Professor Fusé in the developing room, who is "about to remove an X-ray picture from the developing tank" when the explosion hits.[52]

Other works that recount Nagai's earlier times with the radiology team illustrate the many ways in which the X-ray apparatus and its various components constituted crucial parts of their lives. In *Horobinu mono wo*, for instance, Nagai describes the steps necessary to operate the department's large X-ray cannon that was used for radiotherapy, emphasizing the acute need for the technicians to be precise with generating the amount of electric current needed to produce the required amount of X-rays that the chief radiologist had calculated as necessary; any errors would not only skew the treatment but also endanger their lives, since radiotherapy utilized voltages around 80,000 volts.[53] In another anecdote, Nagai details the difficulty and joy involved in repairing a small hole in a vacuum tube, and contrasts the men and women of his department with their pleasure-seeking counterparts in society at large, declaring that his group of colleagues,

[52] Nagai, *Bells*, 11-19.

[53] Nagai, *Horobinu mono wo*, p.447.

"who lived amidst vacuum tubes, high-voltage cables, [X-ray] films and pencils, had no connection with the perfumed gentlemen and ladies downtown."[54]

Nagai's depictions of his fellow radiological workers reveal that they felt emotionally attached to their instruments. In *Bells*, for instance, the technician Shiro's first instinct is to save the machines, even before helping the wounded people around him. Professor Fusé, meanwhile, gets knocked unconscious when the bomb explodes because of a decision not to throw himself on the ground for safety. Instead he first rushes to tend to his X-ray films, prioritizing their preservation over his own safety: "Reflecting that his pictures might be destroyed, he washed them and placed them gently in the fixing tank" – and, of course, his first priority when he regains consciousness is to check the state of the films in the fixing tank. Nagai himself, receiving reports on the state of the X-ray instruments, laments that the news he hears of their state is "harsh and cruel": valves destroyed, electric wires cut, machine parts unsalvageable through being obstructed by debris; specimen films missing. Nagai finally makes the decision to focus on tending to the wounded instead of attempting to rescue the machines.[55] However, he experiences a final, heart-wrenching episode with the radiology department's materials:

> "Smoke is pouring out of the specimen room!" It was the voice of young Nagai [a third-year medical student].
>
> Ah! Those specimens, the fruit of more than ten years of sweat and toil! The irreplaceable and precious photographs! All these were turned into a cloud of smoke.
>
> "The photography room is burning! It's good-bye to our medical instruments!"
>
> Giving all our time to the care of the patients, we had been unable to save the specimens and the instruments. The documents and records that had been our daily food, the specimens that were tokens like our own hands, our own children – were not changed into red flames shooting up into the heavens. Before our very eyes, countless memories were being turned into black smoke and were vanishing from sight.

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[54] Ibid., 525.

[55] Nagai, *Bells*, 19-20, 32, 35.

> We stood silent and stupefied, staring at the awful scene. The fire became even more violent. It entered the cellar where our films were stored and blacking out black smoke and red flames it exploded with a deafening roar. My knees trembled and I felt all my strength ebbing away. "It's the end," I murmured and collapsed in the field where I stood. The chief nurse and the others around her broke out weeping and sobbing.[56]

In another memoir, Nagai expounds on what the X-ray machine, as the prime embodiment of his profession, meant to him. The machine that destroyed his life was also the same machine that built a large part of it:

> Ryūkichi [a name Nagai uses to speak from a third-person perspective in this work] gazed at the *rentogen* machine which had shortened his life. *The radiation it emits is killing me*. He tried to pursue this thought, but strangely enough he felt not a particle of hatred. – For this machine had, for a long time, been Ryūkichi's friend. Without it, Ryūkichi might not have done any work. It had birthed the many papers he had presented to the academy. It deserved thanks for the many students, Ryūkichi included, who had studied and accumulated fruitful experiences through using it. Even more crucially, it had given thousands of patients accurate courses of treatment, allowing them to survive in precarious situations.
>
> The machine's rack was coming apart in places; its cables were repaired with wrappings of electrical tape, and the growl of its transformer had acquired a staticky noise. It, too, was already aged and fatigued, nearing the end of its life. Ryūkichi was the one who had used it to such a state. If this machine had a soul, it would doubtless share Ryūkichi's sentiments.[57]

Nagai here draws an analogy between the wear and tear of the X-ray machine and the deterioration of his own body. In doing so he evokes the themes of sacrifice and service, the value of which transcended the erosion of its material subjects. This literary choice dovetailed neatly with Nagai's Catholic faith and his wartime support of the Japanese empire. True to his medical training, though, Nagai did not stop at mere analogies, but provided detailed descriptions of the symptoms and causes of radiation sickness, both in himself and in general.

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[56] Nagai, *Bells*, 42.

[57] Ibid., *Horobinu mono wo*, 538.

Depicting Radiation Sickness

> Atomic illness is a malaise caused by the radiation that is released when the atom is destroyed. It is a disease of civilization, the black thorn that lurks in the shadows of science's riotous blossoming.[58]

Nagai passed on after 43 years of life. His death was untimely but not unexpected; he had known a few years before the atomic bombings and Japan's defeat that he was terminally ill. In 1940 he had returned from two years and six months of medical service in China during the second Sino-Japanese war, for which he had received the Order of the Rising Sun. He resumed his radiological work at Nagasaki Medical University, but a wartime scarcity of materials straitened the supply of X-ray camera film. He could no longer take radiographs of patients via the indirect exposure method, which had been faster and easier a way to examine multiple patients in a limited span of time. Instead, he had to conduct radiographic examinations via the direct exposure method, which, coupled with poor protection – Nagai and his colleagues worked in a time of unshielded X-ray tubes and inadequate protective gear – ultimately exposed him to larger amounts of radiation.[59]

Nagai, while being fully aware of the increased health risk, could not reduce his workload due to a dire shortage of radiologists and the need to perform mass screenings in Japan's protracted battle with tuberculosis – a relatively new part of public health policy that the next chapter examines. Many male medical practitioners had been conscripted into the war effort, and tuberculosis continued to ravage the population on the home front. Nagai

[58] Nagai, *Hana saku oka*, 321.

[59] It should be noted that indirect exposure actually produces a higher exposure dose than the direct exposure method in radiography. See the essay by the chief of the radiology section of the Japan Anti-Tuberculosis Association, Nakano Shizuo, "Kyōbu chokusetsu, kansetsu satsuei no chigai to tokuchō", http://www.jata.or.jp/rit/rj/nakap.htm (accessed March 09, 2016). The relatively quicker time it took to radiograph patients, though, may have compensated for this, such that, in mass screenings done with the direct method instead of the indirect, the radiologist's cumulative exposure ended up being higher.

instituted a program of mass screening for Nagasaki locals, which only increased his workload, especially as younger male staff members were sent to the war. In the next few years he continued accumulating exposure to X-radiation, until finally in May 1945 he began feeling very ill. Pressed into receiving medical examination, the next month, he received a diagnosis of chronic leukemia. His white blood cell count had swelled to fifteen times above normal, while his red blood cell count had dropped to half that of a healthy adult's. He received a prognosis of three more years to live. Despite this, he continued to teach and treat patients, skimping severely on his own rest, and in full knowledge that his radiation sickness would worsen. He says in *Bells*, for instance:

> A good deal of research concerning the effects of radiation from nuclear fission on living things had already been done in clinical tests and experiments with different kinds of animals before the atomic bomb exploded. Although the reaction is different between a large amount of radiation released over a short period of time and a small amount over a long period, radiation always has a destructive effect on tissue cells.[60]

As Nagai describes above, at the time of the atomic bombings, the biological effects of ionizing radiation were already common knowledge amongst scientific and medical communities in Europe and America as well as in Japan. By the early twentieth century, animal studies showed that X-rays could induce cancer, kill living tissue and injure viscera, especially the skin, the blood-forming organs, and the reproductive organs.[61] As Chapter 4 discusses in greater detail, concerns over the hazards of overexposure to radiation in workers, doctors and patients had led the British Roentgen Society to adopt a resolution, in 1915, on the need to protect people from overexposure to X-rays, in one of the earliest organized efforts at radiation protection. These efforts gained a global institutional home in 1928, with the formation of the International

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[60] Nagai, *Bells*, 87.

[61] Mario E. Schillaci, "Radiation and Risk - A Hard Look at the Data," *Los Alamos Science* 23 (1995), 117.

Commission on Radiation Protection (ICRP). In Japan, too, medical and scientific publications on the biological hazards posed by working with X-rays had been published as early as 1910, and by the 1920s research into the biological effects of X-rays was in full swing. The 1930s saw a mushrooming of work by scientists and doctors on the dangers of radiation overexposure and the need for protection regulations.[62]

Medical literature of the early twentieth century, in Japan and the West, used functional terms to describe radiation sickness, including "X-ray damage" (レントゲン障害 *rentogen shōgai*) and "radiation damage" (放射線障害 *hōshasen shōgai*). After Hiroshima and Nagasaki, "atomic explosion syndrome" (原爆症 *genbakushō*) became the preferred name for medical professionals referring to atom bomb sickness, or the devastation wrought on survivors' bodies. In contrast to these relatively utilitarian terms, Nagai in his post-bombing writings invokes "atomic illness" (*genshibyō*) as his preferred name to describe radiation sickness. Chapter Nine of *Bells* is an exposition on atomic illness that summarizes previous research on its effects and gives a medical report on the injuries to human bodies the Nagasaki bomb inflicted. Here Nagai draws comparisons between the symptoms of atom bomb sickness with the radiation sickness suffered by radium and X-ray workers, predicting the possibility that victims of radiation injury who developed edemas – swelling of organs, skin or limbs by a buildup of fluid in body tissue – would also suffer skin ulcers and cancer.

Like his colleagues who had earlier published on the subject, Nagai was also deeply concerned with injuries that radiation induced in the generative organs.[63] Commenting on the

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[62] Nihon Hōshasen Gijutsu Gakkai, *Nihon hoshasen gijutsu shi*, 219-223.

[63] Nagai, *Bells*, 94.

symptoms of this malaise, Nagai wrote that they manifested as "more or less similar to what radiotherapeutics has taught us until now". Indeed, he went so far as to say that some of these physical signs "were exactly as we had expected from former laboratory experiments. Indeed, we almost felt proud that they confirmed our theories so well."[64]

Nagai's memoirs, written after the war on his sickbed, reveal little trace of distress about his own deteriorating physical condition. Yet he understood the emotional dimensions of learning about one's imminent death, as seen in his anecdotes about conducting X-ray screenings. In 1950, for instance, he wrote a column for the *Tokyo Times* mourning the death of his old mentor, Suetsugu Itsuma, a casualty of leukemia, and whose limbs showed signs of severe radiation erythema.[65] And Nagai's memoirs, which provide a rare glimpse into a patient's experience of being X-rayed, contain a poignantly-described encounter with an old Shinto shrine priest. Accompanied by his wife, the priest had come up to Nagasaki city from his village on a referral from the local doctor. Nagai screened both of them, and wrote the following account of the priest's condition:

> The light disappeared. The screening room grew pitch dark. I turned on the switch of the X-ray machine. Its fluorescent board flickered into a pale glow. On its surface, in an instant, the human body's secrets would be recorded. One look told the observer it was stomach cancer. The diagnosis showed exactly according to the village doctor's prognosis. ---The screening was soon over and the light turned on. The emaciated body of the priest, bones visible, standing on the screening deck, made one think of an elderly pine tree clinging precariously to a precipice, or a clump of lichens dangling from the branches of a tree, and the barium which had spilled onto his white beard upon drinking presented an equally lonesome sight. The elderly pine descended the precipice and stood upon the linoleum, and his wife, who had been hugging his coat close to her chest to warm it, lovingly put it on him from behind. On seeing that, I understood how the wife felt, looking at her husband whose future was so foreshortened.[66]

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[64] Ibid., 88, 83.

[65] Nagai Takashi, "Suetsugu-sensei," *Nagasaki no hana*, Vol. 2 (Nagasaki: Seibo no Kishisha, 1988), 24-25.

His own equally foreshortened life, however, cast no cloud over Nagai's faith in scientific progress. The Nagasaki bombing caused Nagai to link radiation sickness and the scientific knowledge around it to life itself. In *The River of Life: The Story of Atomic Illness* (*Seimei no kawa: genshibyō no hanashi*), published in 1948, he penned a two-part treatise on the progress of radiology and of nuclear science. In the first part he tells stories about the early victims of atomic illness acquired through working with X-rays and radium, of heroic figures who, in the name of science or medicine, willingly lost fingers and limbs and developed horrific ulcers that sometimes necessitated amputation in order to preserve the rest of their body. *River of Life* was one of the earliest histories of radiology aimed at popular audiences in Japan, and one of the earliest texts that analyzed radiation sickness as *shokugyōbyō*, or a phenomenon linked to *professional work* in science and medicine. Nagai was not alone in addressing radiation sickness from this perspective. In 1950, for instance, Gotō Gorō, a senior professor of radiology, gave a presentation on chronic X-ray damage caused in the course of working with radiation.[67]

The notion that "atomic illness" constituted an occupational hazard showed that – like nuclear science itself – it was a phenomenon that did not manifest only with nuclear weapons, and that could also signal sacrifice for a higher cause, not just mass slaughter and devastation. The commingling of atomic illness as a product *not* uniquely tied to atomic bombs is a motif of the literature surrounding Nagai's life and career. He was not alone in this opinion – even one of his former colleagues, who remained dubious about asserting a clear relationship between radiation and exposure and leukemia (despite Nagai's own linkage of the two), remarked a few months after Nagai's death that the popular understanding of the atomic bomb being the cause of

[66] Nagai, *Rosario no kane*, 80.

[67] Nagai, "Genshibyō," *Nagasaki no hana*, 26-27.

Nagai's leukemia was mistaken, and emphasized that Nagai's illness had been diagnosed *before* the bombing of Nagasaki.[68] And a 1949 reviewer of *River of Life* commended the book for "its detailed explanations of how atomic illness may be classified," and went on to say that the prevention and treatment of atomic illness as a professional disease was necessary to enable the peaceful use of atomic energy, and by extension, the *true* age of nuclear energy to arrive. "To link atomic illness solely with the atomic bomb is heterodoxy," concluded the reviewer, adding that "the value of this book is how it makes a popular audience aware of this very point."[69]

Nagai concluded *River of Life* with the following thoughts on the visceral nature of the sacrifice made by radiological practitioners. Life for life: in Nagai's view, the untimely deaths of researchers paved the way for extending the lives of their brethren.

> Why is knowledge of things atomic increasing at such a dizzying rate, and acquiring such a beautiful shape? --- Because it grows on fresh blood! On the blood of its atomic disciples…
>
> The atomic illness stole away their lives on the road of truth-seeking. --- But though medical texts have catalogued atomic illness as a new category of malaise, at the same time many illnesses have been shifted from the ranks of the incurable to the curable.
>
> As protective measures have been fully enacted for atomic illness, may we not soon see the last of it? Like the dinosaurs which once revealed themselves for some time on the earth and then went extinct.
>
> Have no care about atomic illness; the age of using atomic energy for man's purposes has arrived at last. Bright, bright is the light of this atomic age! Brimming with hope, this atomic age![70]

Martyrdom and Science

Nagai's enthusiasm over the progress of science is amply expressed in the quotation above. Such a response, in the face of such vast personal loss and devastation, may seem

[68] Hasegawa Taketoshi, "Nagai-kun no hakketsubyō," *Koe* 884 (1951), 4.

[69] Tanaka Shin'jirō, "Seimei no kawa", *Asahi hyōron* 4:1(1949), 91-92.

[70] Nagai, *Seimei no kawa*, 787.

counter-intuitive. How could he have felt so positively about a phenomenon that had taken so much from him? Brightness and hope, as the previous quote from *River of Life* shows, suffuse his post-bombing writings; his memoirs frame his suffering for the war effort and the treatment of his patients in the name of higher causes – divine providence and scientific truth.

Given Nagai's Catholicism, there are clear parallels here with the notion of Christian sacrifice.[71] His references to the deaths suffered by pioneers of radiological research and medicine as "martyr-like" underscore this point.[72] This framing further resonates with a time-honored tradition of scientific martyrdom, as he wrote about in the first part of *River of Life*, where researchers sacrificed health, limbs, and often lives in the pursuit of discoveries, for no reward other than the hope of uncovering truth. Here it is useful to locate Nagai's suffering for the war effort and the treatment of his patients in the context of a phenomenon that Rebecca Herzig terms "scientific martyrdom".[73] His reaction becomes legible when read as part of a transnational tradition where scientific researchers sacrificed health, limbs, and often lives in the pursuit of discoveries, for no reward other than the hope of uncovering truth. A July 1936 review of a book on victims claimed by working with X-rays in America praised it for vivifying its subjects – "those earnest, faithful scientists who, by every sacrifice, including that of life itself, made the advance of roentgenology possible. …They gave their lives to the cause of science, and if ever the term Martyr should be applied, it belongs to them."[74] And the Journal of the American

[71] Okamoto, "Nagai Takashi wa naze genbakushi ga kami no setsuri da to kyocho shita no ka?", 1-13.

[72] Nagai, *Seimei no kawa*, 706.

[73] Rebecca Herzig, *Suffering for science: reason and sacrifice in modern America* (New Brunswick, N.J.: Rutgers University Press, 2005).

[74] "American Martyrs to Science Through the Roentgen-Rays", *Annals of Internal Medicine* 10:1 (1936), 124. The literature on the martyrs to Western radiology is comprehensive. See e.g. the review in Kaustubh Sansare, V.

Medical Association, in a positive review of a book on the early history of medical work with X-rays, commended it for its "sobering lessons" in its account of "the painful and mutilating consequences" of applying roentgen rays in medicine. "It deserves to be widely read by physicians and laymen also," the review concluded, "for too many persons today avail themselves of modern medical technics without appreciating the price that medical investigators have often had to pay for their discoveries."[75]

Suffering in the undertaking of science and in the name of science constituted a longstanding tradition in America and Europe. It was a theme common to portrayals of many fields, including bacteriology, polar exploration and medicine. Radiology in particular furnished a plethora of individuals whose work fit this interpretation, and Herzig explicates how radiological work in medicine and scientific research produced a long roll of martyrs on Western fronts, within a framework of voluntary suffering for a higher cause.[76] The same theme can be seen in writings about science for a popular audience in Japan, such as a 1928 piece in the popular science magazine *Kagaku gahō* (a publication discussed in Chapter 5) that commemorated researchers who had bet their lives on conducting experiments for the progress of medicine: two of them were radiologists.[77] Nagai, too, gained overseas recognition from his radiological colleagues as a martyr to their field. This is evinced from the entry of his name, along with the names of 27 other of his Japanese colleagues', in the 1959 edition of the

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Khanna and F. Karjodkar, "Early victims of X-rays: a tribute and current perception", *Dentomaxillofacial Radiology* 40:2 (2011), 123–125.

[75] "X-Ray Treatment: Its Origin, Birth and Early History*", Journal of the American Medical Association* 142:15 (1950), 1251.

[76] Herzig, *Suffering for Science*.

[77] Murakawa Kikunosuke, "Saishin igaku no kenkyū ni seimei wo toseshi hitobito," *Kagaku gahō* 10:5(1923), 914-916.

Ehrenbuch dedicated to radiologists. This *Ehrenbuch* was a "book of honor", annually published by a German society of radiologists as a memorial tribute to their fellow practitioners all over the world whose lives had ended during their work.[78]

Scientific sacrifice shared clear parallels with suffering in Christian spirit, both in service of a greater good. In Nagai's case, his career and post-bombing experiences, when viewed alongside the remarkable history of Christian persecution in Japan – particularly in Nagasaki's Urakami District, in which their residences were most concentrated – reveals striking parallels in themes of suffering, sacrifice, persistence and regeneration. The Catholics of Japan had been forced to go into hiding if they did not renounce their faith, following the edicts against Christianity promulgated by the overlord Toyotomi Hideyoshi in the sixteenth century. Small underground communities held out until Christianity was decriminalized in the late nineteenth century, and in 1925 they built the Urakami Cathedral, the largest church in East Asia until the atomic bombing, where it was destroyed – along with 8,500 or so Catholics taking shelter in its walls.[79] The history of destruction and suffering that pervaded the Urakami Christian community, though, is resurrected in Nagai's writings. Viewing the bombings as divine Providence allowed Nagai to say, as he did in *Bells*, that even in a "devastated atomic desert" it could be that "fresh and vigorous scientific life began to flourish."[80]

Nagai's pre-bombing work in radiology, as described in his memoirs, was shot through with themes of sacrifice and suffering. These themes are even more present after the bombing.

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[78] Hermann Holthusen, Hans Meyer and Werner Molineus. eds., *Ehrenbuch der Roentgenologen und Radiologen aller Nationen* (Berlin: Urban & Schwarzenberg, 1959), 173, 175.

[79] See e.g. Motoshima Hitoshi, "Urakami kirishitan no junan – kinkyorei, yonban kuzure, genbaku", *Seibo no kishi* (2000.10), http://www.seibonokishi-sha.or.jp/kishis/kis0010/ki03.htm (accessed October 30, 2014).

[80] Nagai, *Bells*, 60.

The shortage of material and medical resources it produced, combined with a huge jump in the numbers of the wounded and ill, made the team of relief workers Nagai headed – many wounded and undernourished themselves – severely overworked. Nagai himself manifested symptoms of acute atomic illness on September 20. He came down with a high fever that lasted for a week, after traveling to a remote mountain village to help a patient, and lapsed into a series of comas, from which he miraculously recovered. And even following that he continued to fulfil his teaching duties, though it taxed his diminishing reserves of health and energy ever more.[81] Images of Nagai in Nyokodō, the small hut he lived in with his two children, often portray him lying on his sickbed writing, his head bald, his limbs emaciated, but smiling (Fig. 1). They recall Herzig's observation that that radiological investigations did not simply use martyrdom as a rhetorical device; in their profession, sacrifice acquired material form in the tattered flesh of X-ray investigators", their scars and lost limbs embodying the cause of science just as stigmata constituted material signs of an divinity.[82]

[81] Kataoka, *Nagai Takashi*, 212.

[82] Herzig, *Suffering for Science*, 97.

Figure 1. Nagai, daughter Kayano and son Makoto, in Nyokodō. Courtesy of the Nagai Takashi Memorial Museum, Nagasaki.

Nagai was not the only doctor who wrote eyewitness accounts of the atomic bombing. In similar vein, Akizuki Tatsuichirō and Shirabe Raisuke, both doctors and *hibakusha* in Nagasaki, also published writings on the bombing and their experiences of it, aimed at a general readership.[83] However, Nagai's memoir appeared in print long before either of these later works. Akizuki, Nagai's former student, did not get around to writing his memoir until late in life, and Shirabe, a senior stalwart in Japan's surgical academy, initially focused on publishing essays aimed at expert audiences rather than popular ones.[84] Nagai's status as a medical doctor and researcher lent authority to his enthusiastic support of nuclear energy. In addition, the broad reach of his writings and the media spinoffs of *Bells* made him one of the most important

[83] Akizuki Tatsuichirō, *Shi no dōshin'en: Nagasaki hibaku ishi kiroku* (Tokyo: Kōdansha, 1972); Shirabe Raisuke, *Nagasaki bakushinchi fukkō no kiroku* (Tokyo: Nippon Hōsō Shuppan Kyōkai, 1972).

[84] See e.g. Shirabe Raisuke, "Nagasaki ni okeru genbaku geka kōishō chiryō no jissai," *Nihon ishikai zasshi* 32:11 (1954), 633-636.

popularizers of nuclear energy, even before the Atoms for Peace program now notorious for inaugurating an era of government and industry promotion of the nuclear energy industry in Japan.[85] Nagai, and indeed other researchers from the various fields of science and medicine who worked with radiation technology in the form of X-rays and radium during the war, must thus be viewed as trans-war figures whose life and work link up to positive associations and images of radiation in Japan's post-WWII history.

Evaluating a Scientific Martyr

Nagai Takashi's post-1945 publications vividly illustrate the state of radiology in Japan's imperial era. Many fascinating stories are found in Nagai's conversion to radiology – a process as contingent as his conversion to Catholicism, and his re-invention of himself as a promoter of science and peace in the new Japan. The main issue in using Nagai's publications after the Nagasaki bombing as sources is that which surrounds every memoir or autobiography: to what degree can we rely on it to provide an accurate picture of the past? When looking at memories recorded ex post facto, we need to ask what silences lie in their descriptions, and what claims of theirs require questioning. The destruction of Nagasaki Medical College in the Fat Man bombing makes it difficult to corroborate many of Nagai's memoirs specific claims against other sources.

One important record that remains, however, is a series of graduation albums from the College made by former students. The photos and notes in these albums confirm the initial smallness of radiology, under the official designation of the Department of Physical Therapy, relative to the more established specialties such as surgery and internal medicine. Personal

[85] An era so named for U.S. president Dwight D. Eisenhower's 1953 address to the United Nations on the establishment of an international agency to govern the peaceful use of atomic energy.

correspondence, official speeches and laboratory notebooks may, despite their formalistic nature, possess evocative utility as sources; as Herzig notes in her research on scientific martyrdom, "even their rhetorical excesses suggest the significance of governing norms and ideals."[86] In the same way, Nagai's popular writings after 1945 illuminate tropes of sacrifice, the endurance of pain, and hopes for renaissance – thus bringing together radiology, Christianity, and the Nagasaki bombing onto a spectrum of suffering for a higher purpose.

The end of the war forced its survivors to rethink the meaning of what they had done. Chad Diehl's work provides an excellent summary of Nagai's importance as *the* voice of Nagasaki in the post-war period, arguing that he benefited from the American occupation due to the growing prominence of Christianity, which boosted his status as a Catholic and lent visibility to his religious rhetoric. Diehl notes that Nagai's literary efforts drew national and international attention to the history of Nagasaki and its suffering, in ways that benefited the political interests of local, national and American officials.[87] Furthermore, Nagai's status as a Christian who supported Japan's imperial wars makes him a problematic figure to position in the history of the atomic bombings in Japan. It is not enough to simply view him as a martyr to the atomic bomb, as so many have done. But regardless of how we evaluate Nagai's life and legacy, to read his writings is often to admire how he crafts his narratives of events in laboratory and clinical spaces. On recounting a 1944 visit to RIKEN, for instance, he closes the episode with describing the effect of ionizing radiation from radium on a swallowtail butterfly as shown to him by a colleague there:

[86] Herzig, *Suffering for Science*, 6.

[87] Diehl, *Resurrecting Nagasaki*, 112.

> [The RIKEN scientist said] "So I experimented with exposing the chrysalis of these swallowtail butterflies for a certain period of time to gamma radiation emitted by radium. And doing that induced these mutations in the butterflies' wings --"
>
> The swallowtail butterfly was usually a beautiful creature, but the specimens shown to me in the case had all turned brown where they had been struck by radiation, erasing the lovely patterns there. Their wing shapes were deformed, small and shrunken, and as a whole they somehow gave one an impression of baseness.
>
> On looking at those ugly, shrunken, radiation-stricken wings, for some reason they made me think of Japan's end, and I violently shook my head.[88]

Nagai uses the products of radiation experiments on animals to foreshadow the atomic bombings, in a striking evocation of the tragedy to come. As earlier mentioned, support for scientific endeavors and the promise of nuclear energy as the motive force of the post-atomic bombing age is a constant theme in Nagai's writings. The episode cited above is a rare instance, in his texts, of radiation used in the service of science depicted as dark and foreboding, and a suggestion that even so fervent a prophet of scientific progress as him had moments of doubt.

Indeed, Nagai's belief in the promise of science has been severely challenged by post-war Japan's checkered relationship with nuclear energy. In the wake of the triple disaster of March 11, 2011, Yamaguchi Kenichirō penned an essay which took a critical stance on Nagai's report on the atomic bombing of Nagasaki and his Christian-inflected humanism, concluding that his statements were used to promote the interests of the post-war Japanese government and American political strategy.[89] Even before Fukushima, Nagai's optimistic faith in science and his religiosity had attracted criticism. For instance, Inoue Hisashi pointed out in 1987 that "upholding [the idea of] divine providence allows one not to look for those responsible in the

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[88] Nagai, *Nyokodō zuihitsu*, 185.

[89] Yamaguchi Ken'ichirō, "3.11 ato no iryō, igaku no dōkō to 'sanji binjogata shihon shugi' ka ni okeru sekai no jōsei'", *Jōkyō* 11-12 (2013), 148-155.

human realm", an idea further expounded on by the philosopher Takahashi Shinji and others in Nagasaki.[90] In a more holistic attempt to judge Nagai's work by contextualizing his vocation and personal circumstances, the scholar of religion Nishimura Akira argues for a more compassionate view of Nagai's life and work that is grounded in his experiences not only as a *hibakusha* of the atomic bomb, but also a *hibakusha* of his radiological work, and a veteran of military medicine on the war front. Critically judging the political ramifications of Nagai's views and his patriotism, as Nishimura suggests, need not preclude a more broad-minded evaluation of his resilience in surviving a horrific tragedy, and an evaluation of the impact his writings made beyond mere "sentimentality" and "idealism".[91]

Spinning out Threads

Nagai Takashi's life and work integrates many themes the following chapters will explore as it goes back in time. His memoirs written during the U.S. occupation of Japan highlight the vital roles played by technicians and the X-ray machines themselves in radiology before and during the war – roles that deserve closer examination. In addition, his story underscores the role of the military and war in promoting medical radiology on both war and home fronts, as military medicine and public health policy. Finally, it emphasizes the importance of popular culture and the mass media in providing conduits for images and ideas about radiation to circulate amongst non-specialist audiences. This last phenomenon grew especially marked in the post-war period, but its origins lie in preceding decades.

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[90] Inoue, "Besutoserā no sengoshi", 369. Takahashi Shinji, *Nagasaki ni atte tetsugaku suru: kaku jidai no sei to shi* (Tokyo: Hokuju Shuppan, 1994); Yamada Kan, "Gizensha Nagai Takashi e no kokuhatsu," *Ushio* (July 1947), 231-237.

[91] Nishimura Akira, "Nagai Takashi ni okeru genbaku saika jūgun taiken to shokugyō hibaku ni chūmoku shite", *Shūkyō kenkyu* 86:2 (2012), 179-200.

Nagai emphasized the potential dangers that atomic energy posed to humans as a risk long faced by men and women working in radiation science and technology. Classifying radiation exposure as a hazard primarily occupational in nature aligned with his positioning of X-ray machines and radiation research as part of a worthwhile quest for scientific progress. Yet Nagai's case also viscerally highlights *pain* as a defining physical experience of working with *rentogen*. His writings touch on the affective dimensions of pain, physiological and psychological; they stand in sharp contrast to the dispassionate presentation of illness and injury as described in technical essays written for specialists. The culture of experimental research on radiation, in medicine and in science, could impose grave physical costs on its practitioners. Nagai, in *Bells*, joined his fellow *hibakusha* who wrote about the pain of their survival for a general audience, and who presented the impact of atomic bomb sickness in the full details of its tormented reality.[92]

Nagai's life lay in the crosshairs of different kinds of knowledge circulation and indigenization – that is, the processes by which ideas and images of radiation spread to a general audience, and took on meanings that resonated in the immediate context of a defeated Japan. His writings, especially *Bells*, became vehicles for the U.S. occupation forces to impose their own views of war responsibility onto Japanese readers; his optimism about scientific progress and interpretation of the Nagasaki bombing provided a way of expiating American sin though enacting redemption by scientific research and education. It is also worth noting that Nagai's career as a radiologist had the hallmarks of Japanese medical practice as institutionalized from the Meiji period onwards. Only men who took certain educational trajectories and had certain

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[92] An important organization in the collection of Nagasaki *hibakusha* testimonies is the Nagasaki Shōgen no Kai. See the Nagasaki Shōgen no Kai, *Voices of the A-Bomb Survivors Nagasaki* (Nagasaki: Nagasaki Shōgen no Kai, 2009), 63.

inclinations could expect to gain entry into this profession. Chapter 4 discusses how this affected the technicians who were Nagai's subordinate colleagues in status, if not in fact. Chapter 5 then explores how the male-dominated world of medicine had consequences for how *rentogen* came to be linked to women in popular culture.

A final, crucial point is that the military formed an important locus of medical modernization and research. Nagai's service as a military doctor in China and practicing medicine in the context of total war is likely to have influenced his post-war views towards the radiological profession. *River of Life*, for instance, contains a description of Guido Holzknecht, an Austrian pioneer of radiology, as not only a "pioneer" (*kaitakusha*) but also a "courageous warrior on the frontlines" (*saizensen ni tatakau yūshi de atta*). The military metaphor was apt, for by the time Nagai earned his medical degree, war and radiology had already conducted a complementary relationship for several decades.

Chapter 2
Public Health: The State and the Military

> It is said that war is both the father and the mother of all creation, and this is indeed the case in the realm of medicine.[93]

X-rays left the laboratory soon after their discovery, transitioning from purely experimental devices that registered phenomena to tools of medicine and other industries. Doctors, engineers and physicists in the West refined Roentgen's basic apparatus, built their own machines and started to use them. In America between 1897 to the end of World War I, for instance, "a photographic novelty…became a medical necessity."[94]

The spirit of invention that produced technological novelty evolved in tandem with state-sponsored projects of mass killing in the twentieth century. This, in turn, accelerated the evolution of mass healing. Medicine became an essential part of modern wars; the prolonged conduct of warfare from the late 19th century onwards necessitated specialised medical facilities, specialised personnel and systems of healthcare.[95] There are detailed studies on colonial medicine and medical atrocities undertaken by Japan's imperial army.[96] However, the overall system of medical care that sustained Japan's wars against the Allied powers, as well as its

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[93] Takemura Bunshō, *Kindaisen to igaku* (Tokyo: Sangabō, 1942), 47.

[94] See Chapter 3 of Kevles, *Naked to the Bone.*

[95] On the relationship between modern warfare and modern medicine see e.g. Kevin Brown, *Fighting fit: health, medicine, and war in the twentieth century* (Stroud, Gloucestershire: History Press, 2008); also Mark Harrison, *The medical war: British military medicine in the First World War* (Oxford: Oxford University Press, 2010).

[96] Jing-Bao Nie, et al., eds., *Japan's wartime medical atrocities: comparative inquiries in science, history, and ethics* (New York: Routledge, 2010). See also Ruth Rogaski, *Hygienic modernity: meanings of health and disease in treaty-port China* (Berkeley: University of California Press, 2004). For Japanese studies related to colonial science and medicine see e.g. Katō Shigeo, "Shanhai shizen kagaku kenkyusho no setsuritsu kōsō: Taishō ki ni okeru kagaku to taigai bunka seisaku no hitosokumen", *Nenpō kagaku gijutsu shakai* 6 (1997), 1-34 and Shin Chang-Geon, "Shokuminchi shakai no iryōka: Tōkyō teidai ni yoru Chōsen shakai no eisei chōsa to sono genkai", *Kagakushi kenkyū* 51:264 (2012), 242-244.

colonial governance, remains relatively under-examined.

Japan first went to war as a modern nation-state in 1895 against Qing China, in a conflict that gave it sovereignty over Taiwan. The Japanese military embraced *rentogen* machines as part of the war effort as they permitted better diagnoses of soldiers' injuries, and thus better medical care, which in turn improved the rates of survival and recovery. Military interest in harnessing radiological equipment and expertise in Japan as a strategic resource therefore remained high from early after Roentgen's discovery. This interest eventually extended to the general population, which furnished the supply of soldiers. This chapter sketches the circumstances under which the Imperial Japanese Army, a key player in the history of Japanese radiology, incorporated X-rays into their regimes of health and hygiene at the end of the nineteenth century. Following that, it looks at the advent of mass X-ray screenings for tuberculosis in the mid-twentieth century. While later chapters explore the role of private industry and private medical institutes in establishing an infrastructure of radiology, the discussion here shows that the state also played crucial roles in that process.

Militarizing Medicine

By the first quarter of the 20^{th} century, medical tools and machines had become staples of the battlefield. X-ray apparatuses, in both full-size and portable forms, ranked amongst the most important of these devices. A tide of changes swept military technology at the end of the 19th century, including powerful magazine rifles which discharged high-velocity bullets that often passed through the body instead of lodging in it. Radiography, for the military surgeons in Europe of this time, provided a way to check for any trapped bullets without causing the patient further harm by trying to explore the wound. Early X-ray tubes had the distinct disadvantages of being both finicky and fragile, and the machines themselves required considerable patience and skill to operate. Nonetheless, a physician who succeeded in overcoming the difficulties of their use could take radiographs (or roentgenographs, as they were also called) of both bone fractures and foreign bodies to aid in treating patients.

The European wars of the late 19th and early 20th century produced a generation of young doctors specialised in military medicine as a profession (for instance, in Britain's Royal Army Medical Corps). From this period onwards, part of their professional training involved learning how to operate the machines that enabled the practice of military radiology.[97] As early as February 1896, the Munich *Medizinische Wochenschrift* reported that the Prussian War Ministry in Berlin was conducting experiments into the suitability of using X-rays on the frontlines of conflict.[98] And the earliest documented use of X-rays in warfare occurred in the Italo-Abyssinian war later that same year, where the director of the military hospital at Naples used them to locate bullets in the forearms of two wounded soldiers. By 1898, just three years after Wilhelm Roentgen's discovery of the "unknown rays", British military hospitals were installing X-ray apparatuses, and in 1903 the Army Medical School at the Royal Victoria Hospital started offering an instructor course in the use of X-rays.[99]

The Japanese Military and Radiology

In Japan, too, *rentogen* grew into an increasingly standard part of military medicine even off the battlefield. By the 1930s both the imperial army and navy had installed *rentogen*

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[97] Adrian Thomas and Arpan Banerjee, *The History of Radiology* (Oxford: Oxford University Press, 2013), 37-38.

[98] See Chapter 8 of Mould, *A Century of X-Rays and Radioactivity in Medicine.*

[99] Thomas and Banerjee, *History of Radiology,* 37-38.

apparatuses in their medical facilities. However, army doctors took a greater interest in the emergent technology, in part because their organization invested greater resources into incorporating it into their regime of military health training. A bountiful paper trail documents the army's involvement with *rentogen* technology, including research articles published in the flagship journal of its medical school, the *Journal of the Association of Army Doctors* (*Gun'idan zasshi*), photographs, and other texts that commemorate the army's procurement of *rentogen* apparatus. Army doctors' work with *rentogen* was even considered crucial enough to be the topic of a graduation address to the Army Medical School class of 1913. The speech presented the following conclusion, which highlighted the importance of *rentogen* in modernizing the medical treatment used by Japan's military:

> Although the progress of *rentogen* learning in our country has yet to reach a level equal to that of the Western countries, we should heartily celebrate the fact that our Army Hygiene Section has long since installed these machines as fixtures of our hygiene resources; moreover, since Meiji 41 (1908) our school has established a lecture series on *rentogen* studies as part of our surgery curriculum, which speaks to our constant efforts to promote knowledge on this topic. Go forth in future and refine your skills in the progress of this technology, which we hope will function in its own small way for the sake of our military nation.[100]

A short but comprehensive pamphlet on military roentgenology further elaborates the importance of *rentogen* for the army's medical regime in both war and peacetime. Published in 1940 (Shōwa 15), this manual has no identified author, but it is likely to have been written by one or more doctors employed in the *rentogen* section of the Army Medical School.[101] The tract outlines the history of *rentogen* use in the school and provides several kinds of basic technical information associated with the military medical use of X-rays, including how to treat soldiers on a battlefield, and the mechanical science of working with X-ray machines. Its contents

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[100] Rikugun gun'i gakkō, "Genkon igakukai ni okeru rentogen gaku no sūsei," *Rikugun gun'i gakkō gojū nen shi* (Tokyo: Rikugun gun'i gakkō, 1936), 258.

[101] Rikugun gun'i gakkō, *Gunjin rentogen igaku* (Tokyo: Rikugun gun'i gakkō, 1940).

underscore the importance of *rentogen* in particular, and medical science in general, for maintaining the army's health and, by extension, its power to attack or defend.

The exhibits of old military medical artefacts on display at the Japan Ground Self-Defense Forces Medical School museum, an obscure institution tucked away in the affluent Tokyo suburb of Setagaya Ward, include the first known *rentogen* machine used for medical diagnosis in Japan. Compared to later photographs of intimidatingly large apparatuses installed in hospitals – some higher than an adult, and arrayed in a mass of wires and secondary electrical equipment, this device is visually striking in its comparative smallness and simplicity. An induction coil and control panel are its two main components. (Figure 2-1) Its procurer, the military surgeon Haga Eijirō, purchased an accompanying assortment of accessories needed to operate the apparatus: besides screens, photographic developing fluid, glass plates and other equipment for X-ray film, he also acquired boxes of chrome batteries and interrupters (devices used to generate high-voltage electrical pulses from a low-voltage direct current flow).[102]

[102] Kimura, "Dōnyū shoki," 1038.

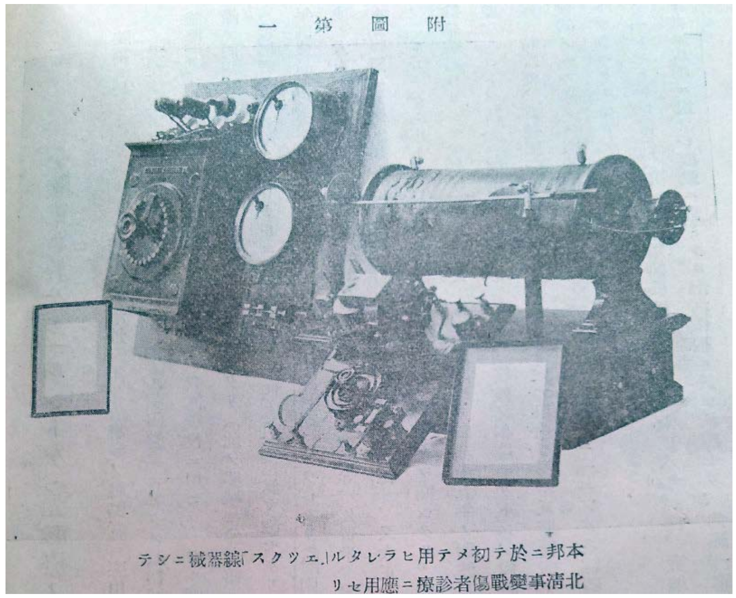

Figure 2-1. Haga Eijirō's *rentogen* device, used to treat casualties in the Boxer Rebellion.[103]

Researchers at the imperial universities of Tokyo and Kyoto, in collaboration with foreign lecturers and local manufacturers, had already begun constructing and experimenting with X-ray devices at their respective institutions, but at this early stage their work was limited to lectures and demonstrations.[104] The Imperial Army's German-made device was the first to see actual use in medical diagnosis. As earlier mentioned, it entered Japan through the auspices of Haga Eijirō (1864-1953). Haga had been dispatched to Germany as a military attaché, where he studied how to use X-rays for medical work. Under Major Stechow, a German military physician, he learnt how to operate the machine, along with the auxiliary skills of taking, developing and reading radiograph films.[105] He returned home in 1898 (Meiji 31) together with the aforementioned X-ray machine, which he had purchased with personal funds. "My attachment to this machine grew

[103] Rikugun gun'i gakkō*, Gunjin rentogen igaku*, 3.

[104] Kimura, "Dōnyū shoki dai ippo," 1037.

[105] Fujikawa A. et al., "Scenes from the Past: The Dawn of Radiology in Japan," *RadioGraphics* 23:4 (2003), 1011.

ever increasing," he wrote in his autobiography, "and I wanted to bring it back to my country as soon as possible."[106] His grandson, Haga Minoru, who later became the eighteenth head of the Army Medical School and a major-general, estimates that his grandfather's machine cost just under 1000 yen, a substantial sum for that period. Haga's own monthly salary was 95 yen – a sum almost ten times more than the monthly salary of a lower-ranking civil servant in the same period, which would have been 8 or 9 yen![107]

Haga Eijirō donated this device to the Army Medical School in 1898, the year he returned to Japan. In doing so, he contributed – along with his Western counterparts – to making X-rays a transnational technology. The practice of military medicine allowed X-rays to travel to foreign fronts; Haga's first-generation machine proved portable enough to be taken out to the battlefield as a tool for screening wounded soldiers. Its earliest use at the frontlines occurred during the Boxer Rebellion of 1900, and again in the Russo-Japanese War of 1904-1905.[108] Japan entered the former skirmish as a member of the Eight-Nation Alliance, which fought a conglomeration of militant spiritualists and the Qing government that was attempting to drive out foreigners from China.[109] Haga managed to install his machine to one of the field hospitals on the Chinese front, where he used it to screen wounded soldiers. The Boxer conflagration also provided the army with an unexpected opportunity to purchase another X-ray unit.[110] A fascinating photographic record of the various kinds of medical machines used by the members of the Eight-Nation

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106 Kimura, "Dōnyū shoki dai ippo," 1038.

107 Interview with Haga Minoru conducted by Kimura Masuo in ibid.

108 Ibid., 1012.

109 For a general history of the Boxer Rebellion see e.g. Joseph Esherick, *The Origins of the Boxer Uprising* (Berkeley, CA: University of California Press, 1987).

110 Rikugun gun'i gakkō, *Rikugun gun'i gakkō gojū nen shi*, 46.

Alliance, made by the Japanese troops, shows images of the Siemens-made X-ray apparatus installed on a horse-drawn wagon for use by the German soldiers. The Japanese army found this device particularly appealing, and they ordered a similar model through the Japanese attaché in Berlin that was sent to the First Garrison Hospital in Tokyo.[111] Portability further increased with the subsequent development of motor-powered *rentogen* vehicles. These "*rentogen* cars" were first test-made at the Army Medical School in 1920 (Taishō 8), and taken into the field for the Manchurian Incident of 1931 (Shōwa 6), when the army seized the city of Mukden as a prelude to the later invasion of Manchuria.[112]

On the home front, the army continued to install *rentogen* machines in military medical institutions. In February 1899 two devices joined the facilities in the Hiroshima and Nagoya army hospitals, and their numbers continued to rise in 1900. The next year, the Army Medical School acquired a second machine, while the Tokyo military hospital installed its first. With the inclusion of portable devices for combat use that the army ordered in 1901, there would have been around 20 devices acquired for military use by that same year.[113]

While no clear records remain about the patients examined by these machines, there are a few surviving anecdotes surrounding the elite army officers who underwent screenings in this early period of radiology. The most dramatic of these is the tale of one General Terauchi Masatake, Minister of the Army from 1902 to 1911, first Governor-General of Korea under Japanese rule from 1910 to 1916, and Prime Minister for the last two years of World War I.[114]

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[111] The *Dai'ichi eiju byōin* in Tokyo. Ibid.

[112] *Gunjin rentogen igaku*, 1.

[113] Kimura, "Dōnyū shoki dai ippo", 1040-1.

According to the memoirs of Ueki Daizaburō, a military doctor and Haga Eijirō's right-hand man in the operating X-ray machine brought back by the latter from Germany, Terauchi visited the Army Medical School for a *rentogen* screening shortly before assuming the post of Minister of the Army. During Terauchi's visit, Ueki produced a radiograph of his chest that showed damage to the bones of the upper right arm, using the biggest plate available at the school and taking an exposure time of ten minutes.[115]

Terauchi had sustained a serious gunshot wound to his right shoulder in the Satsuma Rebellion of 1877 (Meiji 10). He was further diagnosed with broken bones in his upper arm. The normal procedure would have involved amputating the affected limb in order to prevent sepsis, an infection of the blood liable to cause death through organ failure. Had Terauchi's arm been amputated, he would have been discharged from military service, and suffered a sharp setback to his political career. However, the intervention of one Satō Susumu, the surgeon who treated him, avoided this fate. At the Osaka military hospital, where Terauchi was sent, Satō wielded a sardine shop's knives to perform a Langenbeck incision, then a new surgical technique in Japan, which basically allowed him to remove bone fragments from the damaged part of the arm while preserving the surrounding tissues. The result of the surgery was that Terauchi lost the use of his right arm - but since the arm itself appeared to be intact, he maintained active service in the army (and received special permission to salute with his left hand during ceremonies). As earlier mentioned, he journeyed on to an illustrious career in the highest ranks of the central government

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[114] For a concise biographical portrait of Terauchi see e.g. the National Diet Library of Japan's encyclopedia of modern historical figures, "Terauchi, Masatake" http://www.ndl.go.jp/portrait/e/datas/137.html (accessed December 10, 2014).

[115] Kimura, "Dōnyū shoki dai ippo", 1046-1047.

of Imperial Japan.[116] Terauchi's visit to the Army Medical School some years later for his X-ray, then, was a remarkable outcome of historical contingency, and the radiograph that survives from this visit is a memorial to the same. [117]

Novelties and Memorials

The army produced many of the earliest radiographs taken in Japan. Curators at the Shōkokan and Shōkeikan Museums consider the oldest known medical radiographs in Japan to be of military provenance.[118] A group of 42 radiographs came to light in a storage room of the Shōkokan in 1999, before being bound into an album by the museum's curator. The radiographs are likely to have been taken using one of the machines installed at the Army Medical School, and present a varied group of photographic subjects, organic and inorganic. The former kind are of various small animals (some identifiable, some not) and a human foetus; the latter group consists of everyday objects like a coin purse and a personal seal. There is no surviving record of who took them, when, and why, but the varied nature of the pictures suggests that they were all experimental. Their taker, it seems, was interested in testing the quality of the radiographs that

[116] Permanent exhibition plates, Rikujō jieitai eisei gakkō igaku jōhō shiryōshitsu, Shōkokan museum. Author photographs taken in 2015.

[117] The drama in Terauchi's case stems from the discovery of records on another army officer who had suffered the exact same wound as Terauchi, but on his left arm. This luckless casualty had his arm amputated by a different surgeon, consigning him to exile from military service. Watanabe Jun'ichi, a popular novelist and plastic surgeon, wrote an award-winning fictional account of the divergent fates of these two soldiers. Watanabe Jun'ichi, *Hikari to kage* (Tokyo: Bunshun Bunkō, 1970).

[118] The Shōkokan 彰古館 is the military medical museum of the Japan Ground Self-Defense Forces, which exhibits and preserves historical materials related to military medicine in early modern and modern Japan. It is located in the Mishuku garrison site in Setagaya Ward, Tokyo. Another institute, the Shōkeikan しょうけい館 is also a military-related national museum located in Kudanshita, Tokyo, with a focus on exhibiting historical materials related to wounded and sick soldiers.

could be produced when exposing a range of objects to X-rays, living or otherwise.[119]

In this initial period, *rentogen* machines did not only serve utilitarian ends. They also constituted objects of wonder both in and of themselves, and through the images they penetrated the body to produce. Military figures used the new technology to take radiographs of their appendages, even if they did not require medical diagnosis or treatment, turning the films into medical souvenirs of battle. The most famous example of this is Nogi Maresuke, celebrated commander of the Russo-Japanese war, who had a radiograph taken of his left foot, wounded by a bullet during the Satsuma Rebellion, on a tour of the Hiroshima hospital in 1906. (Figure 2-2):

Figure 2-2. Radiograph of left foot of General Nogi Maresuke[120]

X-rays were also used, in some cases, to shed light on old medical cases. Aside from Terauchi Masatake, a fascinating instance of this involves one Nakaoka Moku, later the bureau chief of the Army's personnel division. Nakaoka visited the Army Medical School at an unspecified date after the installation of its X-ray machines to have both his forearms radiographed. It is unclear whether this occurred at the invitation of the school's officers, or at Nakaoka's own behest. In

[119] Kimura, "Dōnyū shoki dai ippo", 1036, 1041.

[120] Image on display in the permanent exhibition of the Shōkokan, reproduced from the webpage of the National Museum of Nature and Science, *Rekishi de miru – Nihon no ishi no tsukurikata*, http://www.kahaku.go.jp/event/2011/02medical/content_3.html (accessed June 02, 2014).

any case, the purpose of this screening was not to facilitate medical treatment, but to produce a radiographic documentation of Nakaoka's arm wounds that he sustained in the Shinpūren Rebellion of 1876 (Meiji 9). This uprising was one of the last civil insurrections raised by the former warrior class against the then-newly established central government of Meiji Japan. It took place in Kumamoto, on Japan's western coast, led by a group of ex-samurai disenchanted with what they perceived as the excesses of Western-style modernization. Their specific grievances included the abolition of their elite status and their right to carry swords, which led them to use swords in their battle against firearm-wielding government troops, and which contributed to their swift defeat by the latter.[121] Nakaoka had sustained two deep cuts on his forearms, near his elbows, in that skirmish. Some three decades later, he visited the Army Medical School to take a *rentogen* record of those badges of honour.

Photographing war wounds whose traces remained inside the body served both memorial and medical purposes. The wounds sustained by government troops in the Shinpūren Rebellion in particular carried meaning for Ishiguro Tadanori, decorated viscount, doctor of medicine, and army surgeon inspector general who had commissioned paintings of the Shinpūren injuries, including Nakaoka's. For Nakaoka, and perhaps his other colleagues who got radiographed, the experience of seeing *scientific* images of the same wounds reportedly moved him to tears and feelings of awe at the great progress of science. For these were images produced by the most cutting-edge medical technology of the period, revealing the body's hidden interior. It is likely that Nakaoka reported his experience with X-rays to colleagues, prompting them to come and see

[121] For more about the Shinpūren Rebellion see John M. Rogers, "Divine Destruction: The Shinpūren Rebellion of 1876," in *New Directions in the Study of Meiji Japan*, eds. Helen Hardacre and Adam L. Kern (Leiden: Brill, 1997), 408-439. On insurrections in Meiji Japan by both elites and commoners, see Stephen Vlastos, "Opposition movements in early Meiji, 1868-1885," in Marius B. Jansen, ed., *The Emergence of Meiji Japan* (Cambridge, UK: Cambridge University Press, 1995), 203-267.

the machines for themselves.[122] Ueki Daizaburō, earlier referred to as the roentgenologist who X-rayed Terauchi Masatake, penned a series of miscellaneous observations on the X-ray devices at the Army Medical School and examinations of soldiers wounded in the Shinpūren and Satsuma Rebellions. In Ueki's notes, he recalls that so many interested military personnel came on excursions to examine the new machines, to the point where it became a nuisance trying to accommodate all of them.[123]

Tuberculosis Prevention

As previously mentioned, the army prioritised healing wounded soldiers with cutting-edge medical care. Health and hygiene later became two further areas of concern for the armed forces, in order to prevent the hollowing-out by disease of the empire's human reserves of soldiers. In particular, preventive measures were deemed crucial in battling the epidemic of tuberculosis that emerged at the end of the 19th century and inflicted peak mortality during the early 20th in Japan, and which occasioned copious amounts of medical research, policy-making, and cultural production.[124]

Military interest in X-rays as a potential weapon in fighting the scourge of tuberculosis manifested as early as 1898, the same year that Haga Eijirō donated his Siemens X-ray machine

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[122] As discussed in Kimura, "Dōnyū shoki dai ippo", 1042-1043.

[123] Ueki Daizaburō, "Shinpūren, Seinan eki fushōsha ni kanshi kyōmi aru jikō" [unpublished manuscript, 1954], diary entries. It should be noted that Ueki wrote this diary record in 1954, at the age of 84, but Japanese researchers who have cross-examined his statements with other archival records consider it to be a fairly reliable source with minor reservations. See Kimura Masuo, "Dōnyū shoki no rinshō ni okeru X sen no unyō shiryōshū", *Nihon hōshasen gishikai zasshi* 48(11), 1546-1547.

[124] See Chapter Two of William Johnston, *The modern epidemic: a history of tuberculosis in Japan* (Cambridge, Mass.: Harvard University Press, 1995) for statistics on the tuberculosis epidemic; see the chapters in Parts Two and Three for details on the social, political and cultural activities generated around tuberculosis.

to the Army Medical School. A tract discussing the bacteriology of tuberculosis and the tuberculin treatment promoted by the German physician Robert Koch - which later proved to be illusory – carried an appendix on the "X-scatter rays" (X 放散線 *hōsansen*) that noted their potential as a means of medical treatment in addition to a tool of medical diagnosis. Written by Amako Tamie, an army physician, the pamphlet's section on the "scatter rays" expressed the author's hopes that they might be used in treating tuberculosis, and cited experiments where application of the rays appeared to inhibit the growth of bacteria.[125]

Amako's hopes failed to bear fruit, as did Japanese attempts to create a tuberculosis vaccine.[126] Nonetheless, in the area of diagnosis, *rentogen* apparatuses came to constitute an important part of tuberculosis prevention, though it took several decades before they became integrated into social policy. State involvement in managing tuberculosis was piecemeal until the 1930s, when it finally began a concerted mobilisation of resources in addressing the epidemic. In the 1910s and 1920s, civilian-based organisations and the Japan Anti-Tuberculosis League (founded in 1913), took the lead in public education campaigns against the disease. Though the state made gestures at sponsoring research for a cure and issued some laws aimed at preventing personal behaviour that physicians believed contributed to disease transmission, it was not until the 1930s that it enacted measures such as BCG vaccination programs and surveillance of labour conditions, effectively recognizing tuberculosis as a national health issue. This occurred following the escalation of Japan's military incursions into China from July 1937 onwards.

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[125] Amako Tamie, *Shin tsuberukurin ryōhō* (Tokyo: Maruzen, 1898), 122-124. The fraudulent nature of Koch's claim that tuberculin could treat tuberculosis was later proved; however, medical journals in Meiji Japan reported extensively on the "tuberculosis cure" for a while following the first few years of its discovery. Johnston, *The modern epidemic*, 185-186.

[126] Ibid., 258.

Military and government leaders drew up plans for social, ideological and economic mobilization, culminating in the passage of the National Mobilization Law in 1938 to control the distribution of capital, labour, production, and material resources. Health formed a part of this strategic control program, including tuberculosis control. X-ray screenings as part of this mobilization of health continued well into the 1950s, and continue to be used in tuberculosis treatment in Japan even today.[127]

In 1938, mass X-ray screenings were first carried out amongst new army recruits, and from 1939 *rentogen* screenings became a mandatory part of health inspection during the process of conscription, and successfully discovered many cases of tuberculosis in new soldiers. Seino Yutaka, a radiologist at the Army Medical School, reported that the increasing mechanization of physical inspections through the use of *rentogen* was greatly welcomed by the military. It speeded up the mass examination of soldiers, and he considered that *rentogen* screenings had become a necessary part of health inspections for soldiers newly recruited or discharged from military service.

In addition to the army, the imperial navy had also integrated *rentogen* into their military medical system. Seino writes that his colleagues in the navy were interested in the efficacy of *rentogen* for tuberculosis screening and had thus acquired state-of-the-art equipment for their institution. A history of the Imperial Japanese Navy's systems of medical education and medical treatment, published in 1926 by the Naval Society of Military Doctors, shows that the acquisition of *rentogen* equipment and related facilities had begun by the mid-1920s.[128] Unfortunately,

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[127] Japan International Cooperation Agency Research Institute (JICA), "Chapter 5: Infectious Diseases," *Japan's Experiences in Public Health and Medical Systems*, 121. http://jica-ri.jica.go.jp/IFIC_and_JBICI-Studies/english/publications/reports/study/topical/health/pdf/health_07.pdf (accessed December 14, 2014).

neither Seino nor the 1926 manual mentions whether or not X-ray screenings had also come to be a mandatory part of the navy's health regimen.[129] Nonetheless, it is more than likely this was also the case, given the eventual advent of compulsory screenings even for Japan's civilian population; the health of bodies on the frontlines of war would surely have been prioritised. As a 1925 pamphlet for an Imperial Japanese Army training course in hygiene put it, two purposes of having a regime of military hygiene was to reduce the number of sick and dying troops. While not directly related to the 1940 national law on fitness, this earlier tract already specified that the health - specifically, the physique - of (male) civilians and that of the army were directly linked, since the former supplied the ranks of the latter.[130]

But military men were not the only people irradiated for the purpose of promoting the health of the national body. William Johnston's pioneering monograph on the history of tuberculosis in Japan shows that the central government also deployed mass screenings in their effort to combat the malaise amongst imperial Japan's civilian subjects during the latter stages of World War II. The training course mentioned at this chapter's beginning took place in 1939, following a decade of rising tuberculosis mortality rates in rural areas. The Great Depression had caused a crash in the prices of agricultural commodities, including silk, and the onset of full-blown war with China in 1937 worsened nutritional quality and living conditions.[131] Rising tuberculosis mortality rates on the home front spurred central government concerns that this

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[128] Kaigun Gun'i kai, ed., *Kaigun eisei seidoshi* (Tokyo: Kaigun Gun'ikai, 1926).

[129] Seino Yutaka, *Mune no shashin: kansetsu satsuei yori dansō shashin made* (Tokyo: Konishiroku, 1941), 325.

[130] Rikugunshō Imukyoku, *Gunjin eiseigaku kyōtei* (Tokyo: Rikugunshō Imukyoku, 1925), 1.

[131] Japan was primarily rural during World War II. Johnston, *The modern epidemic*, 95 [note 79]. Johnston also notes that one reason for the increasing mortality rates was increased rigor with which physicians took mortality statistics in this period.

would impact military conscription and industrial labour.[132]

In 1939 the Japan Anti-Tuberculosis Association (JATA) was formed by imperial decree within the Ministry of Welfare, and a national research institute for tuberculosis located at the Kiyose Sanatorium also appeared the same year. Oka Harumichi, director of the research institute, recommended X-ray screening as part of a structured program for controlling the spread of the disease.[133] In addition, the National Physical Fitness Law, promulgated in 1940, mandated that all males from the ages of fifteen to nineteen undergo annual physical examinations that included tuberculin testing and X-ray screening. In 1942 the law broadened to include males up to the age of twenty-five. Moreover, workers, students and teachers covered by national health insurance also received tuberculin and X-ray examinations. Taken together, these prophylaxes exposed more than ten million Japanese to the light of X-rays between 1942 and 1944, according to one set of medical statistics cited in research on the history of tuberculosis in Japan.[134] *Rentogen* were not part of everyday life for the majority of the population outside the medical practitioners who worked with them, of course, but it is fair to say that the rays became an increasing source of exposure for civilians following the large-scale implementation of tuberculosis screenings by the latter half of the twentieth century.

Video footage of the mass screenings, likely to have been taken by one of the public health organizations involved, shows grainy images of people, mostly women and children, lining up outside a van equipped with an X-ray machine, and entering it to be screened by elderly

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[132]Ibid., 69.

[133] Oka Harumichi, "Kekkaku no kansen to hatsubyō ni tsuite," *Ikai jihō* 2375 (1940), 664-666.

[134] Johnston, *The modern epidemic*, 282.

doctors in white coats.[135] At a roundtable on conquering "diseases of the lungs" (namely, tuberculosis) held in 1935, medical doctors working in sanatoriums asserted the importance of using X-rays for early diagnosis of the illness and as part of preventative measures; in a remark about the superiority of radiographs over stethoscopes, one of them remarked that "diagnoses today use the eyes, not the ears."[136]

Since no effective treatment for tuberculosis existed before the advent of streptomycin and other drugs towards the end of World War II, early screening and diagnosis thus constituted a crucial part of the disease control program.[137] Coupled with a shortage of medical personnel on the home front, this necessitated the mechanization of medical care where possible. Or, as Tsukada Jisaku, M.D., explained in an article written for a popular science magazine, a single physician could diagnose two to three hundred patients per day, but armed with only a stethoscope, he was likely to miss spotting a tuberculosis sufferer. While the stethoscope could discover one tuberculosis patient out of a hundred screened, the X-ray machine could triple or quadruple that rate of diagnosis. Moreover, the indirect exposure method, which used a camera and a roll of film to take reduced-size radiographs, saved costs and increased the number of people one doctor could screen in a day from around fifty to a few hundred.[138]

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[135] Ibid., 282-3. The footage referred to exists at the Nagai Takashi Memorial Museum in Nagasaki City, in the informational video section.

[136] "Haibyō seifuku zadankai," *Kagaku gahō* 24:10(1935), 89.

[137] An accessible and comprehensive history of tuberculosis treatment can be found on the official website of the Global Tuberculosis Institute at the New Jersey Medical School, "TB History," http://globaltb.njms.rutgers.edu/tbhistory.htm (accessed December 12, 2014).

[138] Tsukada Jisaku, "Shūdan kensa ni shiyō suru rentogen kansetsu satsueihō," *Kagaku gahō* 31:9(1942), 57-61.

The Struggle to Control Exposures

Tsukada Jisaku praised the merits of X-ray screenings, but also cautioned his readers that there remained technical issues to overcome in developing high-quality lenses and machines of domestic manufacture, so as not to rely on foreign-made devices.[139] In the larger picture of X-rays, those were not the only problems that authorities had to consider. On August 2, 1937, the Ministry of Home Affairs (*Naimushō*) promulgated Ordinance No. 32, a series of twelve stipulations on the management of X-ray apparatuses for medical diagnosis and treatment (*shinryōyō X-sen sōchi torishimari kisoku*). These regulations oversaw a variety of logistics pertaining to the use and maintenance of X-ray machines in treating patients. Article 2, for instance, mandated that the operators of dental and medical clinics who wished to install X-ray equipment on their premises had to register the machines with the district chief (地方長官 *chihō chōkan*), and listed several conditions for getting the registration approved: protective facilities had to be included on the grounds of the institution, and details about the manufacturer and machine operators had to be provided.[140]

In 1939, the 14th year of Imperial Japan's Shōwa era, a training course in the medical use of X-rays took place at the Health Centre in Tokyo's Kanda district. Hosted by the Japan Society for Hygiene, the event spanned eleven days and hosted a grand total of 253 participants from all over Japan, who came to hear lectures that expounded on the theory and clinical usage of X-rays in medical science. A two-volume set of books that collects these lectures in edited form, produced by the Japan Society for Hygiene two years later, further informs us that the event's

[139] Ibid., 61.

[140] Text of the law available in Nihon Eisei Kai, ed., *Ekkusu-sen igaku no riron to rinshō* (Tokyo: Kanahara Shoten, 1941) 3-6.

sponsors included two major government organisations: the Ministry of Welfare (厚生省) and the Metropolitan Police Department. The course instructors, reflecting this organizational diversity, did not only comprise medical doctors, but also technicians, university researchers, and government ministry personnel.[141] Why would an event of this nature been deemed important enough to organise, and its proceedings published for posterity, at a time when Japan was knee-deep in a war with China started two years ago?[142] The answer, in brief, is public health. Government interest in overseeing the installation, use and maintenance of X-ray equipment stemmed from using it to identify diseased bodies for treatment, thereby strengthening the national polity in wartime.

At the training course in the medical use of X-rays held in 1939, Noma Masaaki, section chief of the Ministry of Welfare's Hygiene Bureau, gave a detailed lecture on Ordinance No. 32. He explained that government oversight of the use of X-rays in medical diagnosis and treatment stemmed from a growing awareness that the rapid increase of X-ray machines in medical practice (more than in other areas of application, such as industry and engineering) had resulted in a marked increase in the number of X-ray related accidents in that field. The need to standardize and oversee the installation and operation of such equipment, therefore, was paramount. Noma identified injuries from fire and electrical shocks as the two main areas of risk, but said nothing about the potential risks of over-exposure to X-ray radiation either to operators or patients. Moreover, in his explanation of why less powerful X-ray machines were not covered

[141] Nihon Eisei Kai, *Ekkusu-sen igaku no riron to rinshō*. It is unspecified whether the lecture series was open to the public, but given the technical and highly specialized nature of the course content, it is more than likely that it was a closed event that required application in order to participate.

[142] On the Second Sino-Japanese War, which lasted for about eight years (1937-1945), see e.g. Rana Mitter*, China's War with Japan, 1937-1945: The Struggle for Survival* (London: Allen Lane, 2013).

by the ordinance, he suggested that X-ray apparatuses with a power capacity of under 20,000 volts emitted rays that "mostly cause no damage to the human body"! These less powerful machines, Noma continued, were adequately covered under the provisos issued by the Ministry of Communications and Transportation, and the Ministry of Home Affairs did not see any need to have their regulations cover the risk of injuries from exposure to X-rays.[143]

Yet, as Chapter 4 explores in greater detail, the dangers of overexposure to ionising radiation had been gaining worldwide recognition from doctors, scientists and workers since the 1920s. The British X-ray and Radium Protection Committee had officially adopted radiation protection recommendations in 1921; the American Roentgen Ray Society followed suit in 1922, and the Dutch Board of Health announced the first regulatory exposure limit for radiation workers - 1 skin erythema dose per 90,000 working hours. The International Commission on Radiological Protection (ICRP) had issued its first set of guidelines for X-ray and radium protection in 1928, and set the exposure limit for human bodies at 0.2 roentgen per day; the *r* (roentgen) had been adopted as the unit for exposure to X-rays that same year.[144]

In Japan, too, *r* had also been incorporated as the new standard for measuring X-radiation dosage. This official decision is stated clearly in Ordinance No. 52, Guidelines on Measuring X-Ray Quantities, a document promulgated by the Ministry of Transport and Communications in 1937.[145] Article 3 of the ordinance gives an excruciatingly detailed scientific definition of the roentgen unit, which appears to have been taken directly from the 1928 regulations given by the

143 Nihon Eisei Kai, *Ekkusu-sen no igaku*, 8. The Ministry of Communications and Transportation regulations Noma referred to were Nos. 51, Partially Revised Regulations on Electrical Articles (*Denki kōsakubutsi kitei ichibu kaisei jōbun* 電気工作物規程一部改正条文) and 52, Guidelines on Measuring X-Ray Quantities (*Ekkusu senryō kentei kisoku* エックス線量検定規則); p.28 of ibid.

144 Mould, *A Century of X-Rays*, 184.

145 Nihon Eisei Kai, *Ekkusu sen no igaku*, 62.

International Congress of Radiology.[146] Moreover, Articles 3 and 4 of the Ministry of Home Affairs regulations from 1937 stipulated the safety regulations that had to be built into the physical infrastructure and equipment in the case of X-ray treatment. For instance, relative to the power of the X-ray machine being used, the ceiling, floor and walls of the screening room had to be covered with a certain amount of lead; moreover, the fluorescent screen used to capture the X-ray image had to be paired with a shield that contained a certain proportion of lead in the same fashion. However, many treatises on *rentogen*, X-rays or radiation medicine aimed at academic or medical audiences paid only cursory attention to the issue of radiation safety practices. This remained the case until around the mid-1950s. In the case of the military, this may in part have been due to how the contingencies of war affected the supply of lead for making shielding apparatuses for the use of machine operators. Seino, for instance, penned no more than a few paragraphs on the need to prevent electrical shocks from taking *rentogen* photographs with a naked bulb, and to control the dose of radiation those being screened were exposed to. While acknowledging the potential for danger in overexposure to *rentogen* rays, he asserted that chronic problems characterised by a sense of fatigue and weakness, as well as a reduced number of white blood cells upon inspection, was not primarily the result of exposure to *rentogen* radiation but "other continuous activities" (what these are, he does not specify) and "not the unique product of *rentogen* rays". The easiest way to measure the amount of radiation being produced, Seino further suggested, was simply to expose photographic film within the screening area of the *rentogen* apparatus being used, and in so doing to gauge the resultant density (the

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[146] Specifically, that r constituted "the quantity of X-radiation which, when the secondary electrons are fully utilised and the wall effect of the chamber is avoided, produces in 1 cc of atmospheric air at 0°C and 76cm of mercury pressure such a degree of conductivity that 1 esu of charge is measured at saturation current." J.R. Greening, *Fundamentals of Radiation Dosimetry*, 2nd ed. (Bristol: Adam Hilger Ltd, 1981), 57. The ICRU changed its definition of *r* in 1937 to measure it by air mass instead of temperature and pressure, but the Japanese regulation did not reflect this change.

measure of the degree to which film darkens on exposure to light).[147]

This cavalier proscription, as with Noma Masaaki's explanation of why Ordinance No. 32 did not cover the risk of injuries from X-ray exposure, diverged significantly from international recommendations on how to protect patients and operators from radiation injuries. A look at the literature published in the West readily bears this out. For instance, a radiology textbook published in England by one Edward Morton, M.D., listed the need for X-ray proof gloves and a shield for the X-ray tube made out of either lead glass or a rubber-lined wood treated with lead oxide as the basic protective gear operators needed to employ. "[U]nder no circumstances," the text sternly says, "should an unshielded tube be used for any purpose." Morton further instructed that the tube be tested by means of a "penetrometer" or radiometer to check that it was in proper working condition, and emphasized the following points in regard to conducting X-ray examinations:

> In the interests of both patient and operator, screen examinations should not be prolonged unduly. The part of the patient under examination is not protected, and long exposure may set up an acute dermatitis, or epilation. It should be remembered that as nothing is absolutely opaque to the X-rays, the protective devices adopted may let through sufficient to more or less seriously affect an operator who makes a large number of prolonged radioscopic examinations.[148]

Morton's text, published 25 years before Seino's monograph on chest X-rays, also highlighted the need for protection to be "rigidly observed" in the realm of therapy, since the lengthier applications required of treatment raised the risk of damage to both operator and patient relative to the shorter exposure times that enabled diagnoses.[149]

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[147] Seino, *Mune no shashin*, 305.

[148] Edward Reginald Morton, *A Text-Book of Radiology With 26 Plates and 72 Illustrations* (London: Henry Kimpton, 1915), 102.

[149] Ibid., 198.

Nakaizumi Masanori (1895-1977), appointed the first professor of radiological medicine at the Tokyo Imperial University in 1934 and who continued to be of the most established authorities in radiology even after the end of the Pacific War, was an exception to the broad trend of medical indifference to radiation protection. In a treatise first published in 1932, he stated that radiological protection comprised three main subjects: 1) the biological damage caused by radiation; 2) electric shocks caused by high-voltage current and 3) fires caused by the combustion of photographic film.[150] Nakaizumi went on to list several examples of injuries and deaths caused by overexposure to X-rays both to patients and to operators:

> In the case of full-body injuries, a certain pioneer of X-ray therapy in our country is thought to have died of anaemia induced by radiation. In the case of localised injuries, these are starkly seen from the fingers of X-ray personnel in both the Kanto and Kansai regions. Recently, a certain X-ray technician who served at the Nagano Red Cross Hospital finally succumbed to a cancerous tumour. This is the same as the death of the famous Holzknecht in Vienna. Personnel staffed in locations with rather incomplete protection from radiation should check to see if their right palm is drier than their left palm. Those who handle radium should impress their fingerprints on a sheet of paper and check. And those who examine their own blood are often able to determine whether they have, at some point, succumbed to radiation damage.[151]

The previous discussion does not imply that medical practitioners, technicians and government officials in Japan were ignorant of the dangers and risks of X-ray radiation. Indeed, the preamble to the Ministry of Transport and Communication's Ordinance No. 52, regulating the measurement of X-rays, stated that "the dosage and maximum dose of X-rays are often extremely close, which frequently leads to calamities, and from this perspective it is necessary to accurately measure the amount of X-rays *no matter what*" (emphasis added).[152] Knowledge of the biological effects of ionizing radiation existed in Japanese medical and government circles by

[150] Nakaizumi Masanori, *Rinshō hōshasen gaku* (Tokyo: Kanahara Shoten, 1942 [1932]), 269.

[151] Ibid. Holzknecht refers to the Austrian radiologist Guido Holzknecht, inventor of an early dosimeter (a device for detecting and measuring the amount of ionizing radiation something is exposed to) for X-rays who died as a result of over-exposure to the same rays he worked with.

[152] Nihon Eisei Kai, *Ekkusu sen igaku*, 68.

the time World War II was in full swing, and the same held true for the Western countries that took part in the same conflict. But this knowledge was for the most part restricted to privileged circles of medical practitioners. It would take two atomic bombings and the establishment of joint research councils with American scientists after 1945 for an awareness of the risks of radiation illness and radiation medicine to reach a broader Japanese public.

Rentogen and State Regulations

In a 1937 ordinance issued by the Ministry of Home Affairs (No. 32), the machines themselves were classified according to how much power they could channel in their functions. The very first article of the ordinance defined X-ray machines for medical treatment in terms of the capacity of their tubes to generate electric power: only machines with X-ray tubes that generate a maximum voltage of at least 20,000 volts could be considered in this category. The use of such machines required that medical practitioners who worked with X-rays needed some knowledge of electrical engineering as well as medicine. In 1917, an American medical doctor named Benedict Lust published a treatise on the Principles of Electro-Medicine, Electro-Surgery and Radiology, in which he asserted that "a successful electro-therapist must be an expert electrician, as well as a good physician".[153]

The necessity of radiologists understanding something about electricity in this period is suggested in Figure 2, which shows two X-ray machines manufactured by Japan's Shimadzu Corporation, as they appeared in a company catalogue of 1931 (Figure 2-3):

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[153] Benedict Lust, *Principles of Electro-Medicine, Electro-Surgery and Radiology: A Practical Treatise for Students and Practitioners With Chapters on Mechanical Vibration and Blood Pressure Technique* (Butler, New Jersey: Benedict Lust, 1917), 5.

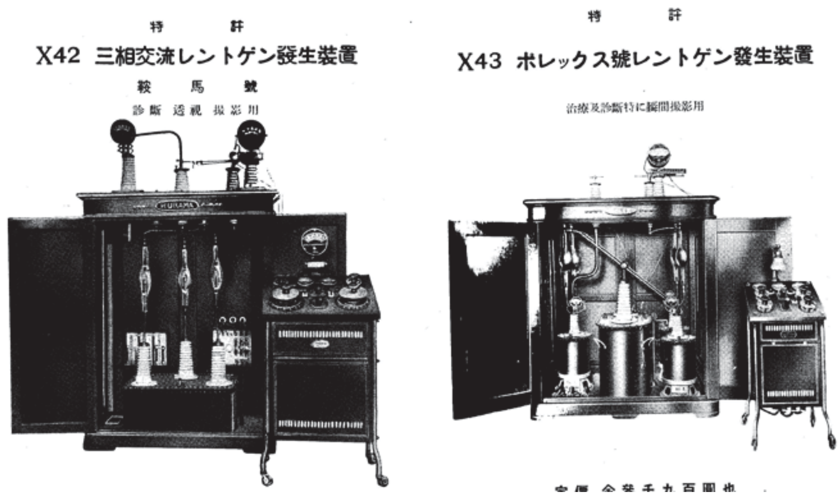

Figure 2-3. Kurama and Polex models of *rentogen* apparatus, Shimadzu Corporation[154]

Shiga Tatsuo identified five main categories of X-ray equipment necessary to have on the premises of radiological facilities for diagnosis and treatment: 1) high-voltage generators, 2) X-ray-tubes, 3) control panels, 4) 'patient handling devices' and 5) photography apparatus. He further listed another twelve types of supplemental equipment, including protective gear and fluorescent screens for taking X-ray photographs. Indeed, the complex nature of maintaining facilities that allowed the use of X-rays required multiple kinds of people and knowledge to use and maintain. An idea of this in the Japanese context may be gleaned from a description of the duties of medical personnel who worked with X-rays. In the case of the Imperial Navy, there was a whole team of people who staffed the X-ray section in its hospitals. The duties of the section chief (*shitsuchō*) in the section consisted of the following:

1. To prepare the room for conduct of X-ray screenings or treatment, according to the schedule of notifications, and submit reports to the section head (*shunin*)
2. To undertake operations involving X-rays, as well as to maintain the equipment in good working order

[154] Image taken from a catalogue (not for sale) printed and distributed by the Shimazu Corporation. Shimazu seisakusho rentogen bu, *Rentogen sōchi nami ni fuzoku hin* (Kyoto: Shimazu seisakusho, 1931), 12-13.

3. To take normal photographs [possibly because the processing of regular photographic films and X-ray films was similar]
4. To make negatives and positives and make recorded entries on them in organized fashion
5. To note X-ray photographs taken in the ledger of photographic records and to submit the ledger to the section head[155]

A look at the requirements of the application that medical institutions had to fill out to have their X-ray facilities approved by the government further highlights the official recognition that X-ray medicine was a highly technical and potentially dangerous area. A total of eleven forms required submission, in addition to detailed plans of the layout of the institution's facilities as a whole, and any changes made to equipment already registered also had to be submitted in excruciating detail. Ultimately, these regulations were mandatory only on paper, and it is unclear how many clinics and hospitals actually complied with them. Nonetheless, the existence of three government ordinances aimed at regulating and standardizing the use of *rentogen* in Japan from the late 1930s onwards is remarkable.

The ordinances are also important reminders that knowledge about the harmful effects of exposure to ionizing radiation beyond a certain amount on biological tissue did not occur in a vacuum after the atomic bombings of Hiroshima and Nagasaki. Research into the biological effects of radiation, in Japan, as in Europe and America, had already been carried out from the first decades of the twentieth century. Japanese X-ray research into radiation and its biological effects in the first decades of the twentieth century, and aligned with growing international concerns about radiation dosimetry and the establishment of the International Committee on Radiation Protection in 1928. Medical and scientific researchers accomplished this by conducting studies on living organisms (primarily animals and humans, though plants and

[155] Kaigun Gun'ikai, *Kaigun eisei seidoshi*, 204.

microscopic organisms were sometimes included). Scholarly articles in medical journals like the *Igaku chūō zasshi* (Central Magazine of Medicine) appeared from the 1910s onwards detailing experiments with X-rays as a therapeutic agent. One of the earliest articles, from 1911, is a report by one Hida Shichirō on his investigations into the effects of X-rays on the testicles of domesticated rabbits and roosters. Hida's findings included the assessment that rooster gonads were more sensitive than rabbit ones to X-radiation. This was no earth-shaking discovery, but it is notable that Hida prefaced his article by introducing the prior results gained by Western researchers experimenting with *rentogen*, summing them up in the following manner:

> the deleterious effects caused by *rentogen* rays...not only to mammalian animals, but also to humans...it can be deduced that when the testicles of mammalian animals are irradiated with rentogen rays, the epithelium that makes seminal fluid is clearly damaged.[156]

Indeed, the potentially hazardous biological effects of ionizing radiation in the form of X-rays constituted common knowledge amongst Japanese scientist-doctors who worked with *rentogen* and radium. A key figure in this group is Tsuzuki Masao, a scientist-doctor fluent in English who had studied radiation biology at the University of Pennsylvania from 1925 to 1926, and an eminent figure in Japanese research on the biological effects of radiation. Like Hida Shichirō, Tsuzuki had also conducted research into radiation via exposing rabbits to X-rays, and later played a key role in the Japanese representatives to the Atomic Bomb Casualty Commission.[157] Chapter 4 further explores the research role that he and his colleagues played.

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[156] Hida Shichirō, "Rentogen sen no kato oyobi ondori no kōgan ni oyobosu eikyō ni tsuite", *Ishigaku chūō zasshi* 9:14 (1911), 1305-1317.

[157] Lindee, *Suffering made real*, 24; Masao Tsuzuki, "Experimental Studies on The Biological Action of Hard Roentgen Rays," *The American Journal of Roentgenology and Radium Therapy* 16:2 (1926); reproduced in *Tsuzuki Masao kenkyū gyōseki mokuroku*, ed. Hiroshima-shi Shihensan Shitsu (Tokyo: Nakamoto Honten, 1981), 21-37.

Conclusion

> I know not of what things were like in the age of Chinese medicine, but regardless, in the ages of Meiji and Taisho, doctors ply their trade by doing *rentogen* screenings.
>
> -- Seino Yutaka, Army Medical Commander, M.D., (1941)[158]

The Imperial Japanese Army was one of the earliest organizations to acquire X-ray equipment for medical use. The close linkage of X-ray equipment and screenings with the military and the central government is an important factor that facilitated the integration of X-ray technology into civilian medical practice in Japan.[159] This sets the Japanese radiological world apart from the American one, where private organizations and individuals primarily propagated the use of the "unknown rays". In Japan, the army saw itself as a key player in spreading X-ray technology and medical know-how to the non-military world – even as it collaborated with other organs of the state like the Tokyo Imperial University. Establishing the new *rentogen* lecture series in the Army Medical School, its leaders later declared, served to highlight not only army initiatives in applying *rentogen* to medical diagnosis and treatment, but also to pave the way for improvements in the manufacturing of X-ray technology, medical pedagogy and research, and thus to "lead the way in Japan's *rentogen* knowledge".[160]

As the epigraph by the army doctor Seino Yutaka suggests, *rentogen* were a key technology that sharpened the break with Chinese medical practices and traditions that had structured Japanese medicine for centuries, at least at the level of institutions.[161] Since radiology

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[158] Seino Yutaka, *Mune no shashin*, 2. Seino's official title, in Japanese, is *Rikugun gun'i chūsa igaku hakase* (陸軍軍医中佐 医学博士) – "Army Ground Forces Military Medic Lieutant Colonel, Doctor of Medicine".

[159] Fujikawa et al., "Scenes from the Past," 1012.

[160] Rikugun gun'i gakkō, *Rikugun gun'i gakkō gojū nen shi*, 70.

was a new, emergent area of medical knowledge at the time of its introduction in the late 19th and early 20th centuries, it is a good field with which to assess the impact of modernization on Japanese medicine, as enmeshed with various agents in state and society. Change occurred not only on the level of practice but also in attitudes and understandings of what purpose bodies served. From the perspective of the state, bodies required irradiation and had to be rendered transparent to the gaze of the doctor, who would evaluate them to protect the health of the national body.[162] The risk of injuries due to radiation overexposure thus received comparatively little attention relative to how warnings against mechanical and electrical accidents due to the operation of X-ray devices. The process of rendering the body transparent to the eyes of radiologists who ultimately worked in service of the state, even if their immediate customers were individual patients, imparted the ability to successfully transform the interior of the body into data about its utility to that state. Chapter 3 will discuss two other groups essential to the radiologists – manufacturers and technicians.

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[161] This is not to argue that there was a complete disjuncture with former practices and traditions in the modernization process. See Suzuki and Suzuki, "Cholera, consumer and citizenship".

[162] The "transparent body" is a phrase taken from José van Dijck's essays on the cultural history of medical imaging. José van Dijck, *The transparent body: a cultural analysis of medical imagine* (Seattle: University of Washington Press, 2005).

Chapter 3
Manufacturing Machines and Managers

> In recent times the epoch-making strides taken by our country's industrial sector has borrowed greatly from the progress of our technology, particularly in industrial technology, a fact clear to all; however, as the cultural weight of technology grows larger, the duties of technologists and the raising of their social status acquire progressively greater importance.[163]

Government agencies and medical universities aside, what else comprised the establishment of radiology as a medical specialty that could be put into actual practice? When considering the various agents implicated in the practice of modern medicine, the role of machine manufacturers and machine operators cannot be overlooked. This chapter takes up the particular case of radiology, a term that here refers to medical radiology, including the two areas of diagnostic imaging and radiotherapy. How networks of manufacturing in radiology took shape and wielded impact before the atomic bombings – that is, in the decades of the twentieth century up till 1945 – is a fascinating topic that can illuminate the process of medical modernization in Japan. Examining the background factors involved in producing a *rentogen kikai* – an X-ray machine, or radium needles, for instance, reveal links between individuals and institutions. This also highlights the transnational nature of medical, scientific and technological developments that foreground the persistence of such connections into the post-WWII period.

The case of Japanese healthcare shows that private industries played a big role in providing and orchestrating the practice of medical care together with state actors. This was especially true for medical specialties that relied heavily on machines as well as research and

[163] Monbushō Jitsugyō Gakumu Kyoku, ed., *Gijutsusha to keizai* (Tokyo: Seibidō Shoten, 1937), 1. For a recently authored and comprehensive monograph on public and private initiatives to train technologists in Japan, see Shōji Yukihiko, *Gishu no jidai* (Tokyo: Nihon Hyōronsha, 2014).

development.[164] Radiology occupied a prominent place in the medical market over the first half of the twentieth century, and Shimadzu's contributions to this field helped make medicine synonymous with technological innovation and market enterprise.[165]

The X-ray machines used in Japan before the advent of nuclear medical technologies and computerized medical treatment are wondrous to behold – works of art and craftsmanship at the same time they served as tools (or weapons, from the perspectives of the government and the military) of medicine. [166] Making and using this *rentogen* equipment required companies and technicians. The first half of this paper focuses on one of the major companies involved in the manufacture and sale of X-ray machines, the Shimadzu Corporation (島津製作所), a company headquartered in Kyoto. The second half of this paper will examine the emergence of radiological technicians and engineers in the early twentieth century, looking at the experiences of a special class of medical workers who developed an identity distinct from doctors and nurses. Here Shimadzu also wielded influence: from 1927 onwards, the company started a program to train X-ray technicians, the earliest of its kind in Japan.

Starting Up Shimadzu

The company that produced Japan's first domestically manufactured X-ray apparatus holds a long and colorful history. The Shimadzu Corporation started in 1875 as a manufacturer

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[164] The active role of private companies in spurring technological development in Japan is also noted in, for instance, the case of shipbuilding. See Matsumoto Miwao, "Reconsidering Japanese Industrialization: Marine Turbine Transfer at Mitsubishi," *Technology and Culture* 40:1 (1999), 74-97. For an overview of frameworks towards technological development in Japan see Chapter 4 of Tessa Morris-Suzuki, *The Technological Transformation of Japan: From the Seventeenth to the Twenty-First Century* (Hong Kong: Cambridge University Press, 1994), 71-88.

[165] See the business historian Pierre Yves-Donzé's valuable and pioneering study of the medical business around radiology. Donzé, "Making medicine a business in Japan".

[166] Shimazu Seisakusho, *Rentogen sōchi nami ni fuzokuhin* (Kyoto: Shimazu Seisakusho, 1931), 12-13

of physical and chemical instruments. It was located fortuitously nearby the so-called "Chemistry Bureau" (*Seimi kyoku*) in Kyoto, an institution devoted to the promotion of Western learning about science and technology. The first Shimazu Genzō, the company's founder, had originally followed his father in the business of manufacturing implements used in Buddhist rites. But following the Meiji Restoration of 1868, which saw the rise of a new government seeking to promote modernization through Westernization, Genzō left his family trade to seek a new living in manufacturing instruments of scientific learning seven years later.[167] The "Chemistry Bureau" possessed both educational and manufacturing facilities, the latter of which produced a range of Japanese and Western products including enamel (*shichihō*), ceramics and soap. Genzō's new company took on the new frontier of machine making with bold entrepreneurship, and just three years after its establishment successfully made a hot air balloon, complete with a gondola carrying human passengers, and flew it at an industrial exhibition in Kyoto. This spectacle-making item had been commissioned by the prefectural governor as a celebration of local achievements in industry.[168]

In December 1895, Wilhelm Roentgen delivered his epoch-making paper of the existence of the "new kind of ray" at a congress of physicists in Germany.[169] News of the discovery reached Japan just two months later, via correspondence from the physicist Nagaoka Hantarō,

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[167] Shimazu Seisakusho, *Shimazu seisakusho shi* (Kyoto: Shimazu seisakusho, 1967), 1.

[168] The only other hot-air balloons that had graced Japan before this had been two experimental products made by the Meiji government during the Satsuma Rebellion (*Seinan sensō*) that never made it to actual use. Shimazu Seisakusho, *Shimazu seisakusho shi*, 5-6.

[169] For a historical overview of the scientific and technological work that led to the discovery of X-rays, including a discussion of Roentgen's work and his original paper in German, see George Sarton, "The Discovery of X-Rays", *Isis* 26:2 (March 1937), 349-369.

then on academic exchange in Germany, to his Japanese colleagues.[170] By then Shimadzu had continued to steadily expand its operations, and Genzō's oldest son Umejirō had taken over his father's business as Genzō II. Genzō II, in 1895, began making inroads into battery manufacturing and electrical generation, and naturally felt a strong interest in the news of the new rays, which related to both those ventures. In October of 1896, together with his brother, Muraoka Han'ichi, a professor of physics at the Kyoto Third High School (later Kyoto University), and two other Shimadzu employees, Genzō II successfully took several of the world's earliest radiographs. The enterprise combined Muraoka's knowledge of physics, paired with the high voltage generated by an America-made Wimshurst-style electrostatic generator and two Crookes tubes imported from Germany that a medical colleague had procured. Thus Shimazu Genzō and his colleagues accomplished a feat, one that could not have succeeded at the time without a combination of scientific understanding and material resources from all over the West. Every step of getting their apparatus to work required multiple experiments and improvisations, including suspending the Crookes tubes from the ceiling with silk strings, attaching the Wimshurst machine to the electrodes, and waiting a full two hours for an X-ray of a one-yen silver coin to form on a photographic plate made in England.[171]

Happily, their machine managed to produce more radiographs, confirming their success. Further images were produced of a coin purse, Muraoka's spectacles case (with its contents showing), and the ring-clad hand of one of Shimadzu's technicians, Kasuya Munesuke. This accomplishment led Shimadzu to begin producing X-ray machines for educational use, though

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[170] Gotō Gorō, *Nihon hōshasen igaku shi kō: Meiji Taishō hen* (Tokyo: Nihon Igaku Hoshasen Gakkai, 1969).

[171] Details for this paragraph taken from Imaichi Masayoshi and Hara Mitsumasa, "Honpō ni okeru X sen no shoki jikken: Nihon hōshasen gijutsu shi kō I", *Kagakushi kenkyū* 16 (1950), 26-27.

the road towards this manufacturing process continued to be challenging. Even after their initial attempts to take radiographs worked, for instance, the Shimadzu brothers tried and failed to use three different kinds of batteries – Bunsen, dichromic and radon – to provide electricity at a voltage high enough to power the Crookes tube. The problem was only solved by cobbling together an induction coil apparatus made up of several coils.[172]

More successes followed. In 1909, the company unveiled Japan's first domestically manufactured medical-use X-ray machine, which it installed in the Chiba garrison hospital run by the Imperial Army. Two years later, in 1911, it unveiled a large-scale machine of the same kind purchased by the Ōtsu branch hospital of the Japanese Red Cross. The size of the machine can be seen from how it looms behind the doctor standing in front of it: (Figure 3-1)

Figure 3-1. Shimadzu medical-use X-ray machine, Ōtsu Red Cross hospital[173]

[172] Gotō Gorō, *Nihon hōshasen igakushi kō*, 57.

[173] Shimadzu Corporation, "1894-nen (Meiji 27~) | History | Visionary | Shimazu seisakusho", http://www.shimadzu.co.jp/visionary/history/1894.html (accessed May 2, 2015).

In terms of radiological equipment, along with X-ray machines for medical and industrial use, the company also produced radiation meters, storage batteries, protective gear and other accessories to be used together with the machines. By the first decades of the twentieth century, Shimadzu was thus unquestionably the major player in the Japanese radiological market, and also a heavyweight amongst producers of scientific instruments generally.[174] It continued to roll out new devices throughout Japan's wartime period in the 1930s and 1940s, including portable X-ray apparatuses and *rentogen* automobiles.[175]

In addition, Shimadzu manufactured a wide range of educational and industrial tools and devices, including mannequins for clothing stores.[176] But the place of pride that radiological equipment had in its factory lineup is apparent from the "Roentgen Festival" (*Rentogen matsuri*), an annual celebration held within the company since 1924, and the emphasis it continues to accord, in its own literature, on the importance of the radiological machines it manufactures. While Shimadzu was not the only Japanese company that eventually acquired the ability to manufacture X-ray machines, it certainly produced the most comprehensive array of radiological equipment. Other companies tended to be smaller and thus continued to imported machines from overseas, like Gotō Fu'undō, or specialized in making X-ray machine parts – the medical instrument section of the Shibaura corporation, (later Tōshiba), for instance, specialized in

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[174] In 1914, for instance, Shimadzu garnered gold medals at the Taishō industrial exhibition held in Ueno Part for its products, amongst them the large-scale X-ray apparatus provided to the Ōtsu Red Cross. In 1917, the company supplied over half of all the scientific instruments and models in Japan. Shimazu seisakusho, "Nenpyō," *Shimazu seisakusho shi*, 4.

[175] Taken from the chronology in Umegaki Yōichirō, "X sen hakken igo 100 nen no gijutsu hatten no rekishi nenpyō", *Medical Imaging Technology* 13:1 (January 1995), 5-6.

[176] A product line started in response to a surge in popularity of Western-style clothing after the Great Hanshin Earthquake, acquired from American donations. Shimazu Seisakusho, *Shimazu seisakusho shi*, 57-59.

vacuum tubes and fluorescent plates.[177] It thus has ample grounds to be considered Japan's strongest brand in radiological manufacturing. At the same time, Shimadzu's achievements in Japan were involved a processed that employed both domestic and foreign agents, especially German ones.

Gaining Market Exposure

The German influence on Japan is more often discussed in terms of political and military influence, but important economic ties also existed. At the end of the nineteenth century, Britain and the United States had stronger economic connections to Japan than Germany, as seen from, for instance, the proportion of joint ventures started with British and American companies. Nonetheless, German-Japanese trade was rising, facilitated by German superiority – rivalling that of American companies – in scientific and technical products. Within the sector of electrical machines, German companies exported the largest value of machines and appliances in 1913, on the eve of the First World War.[178]

A growing market for medical machines also appeared in Japan during the late nineteenth and early twentieth centuries. This expansion is recorded in the registration of over 1500 patents for medical machines between 1885 and 1937, for instance, or that, by 1935, X-ray machines made up 19.2% of Shimadzu's gross sales, to the tune of 1.7 million yen.[179] World War I fuelled

[177] From the official site of Tōshiba Medical Systems Corporation, "History | Toshiba Medical Systems Corporation", http://www.toshibamedicalsystems.com/tmd/english/company/aboutus/history/index.html (accessed April 28, 2015). For a detailed chronology of the various devices within medical imaging technology in Japan see Umegaki, "X sen hakken igo 100 nen".

[178] Takenaka Tōru, "Business activities of Siemens in Japan: A Case Study of German-Japanese Economic Relationships before the First World War," in Kudō Akira, Tajima Nobuo and Erich Pauer, eds., *Japan and Germany: two latecomers to the world stage, 1890-1945*, Vol. I (Folkestone, UK: Global Oriental, 2009), 114-149.

part of this growth, as it did for businesses in Japan generally. The conflict severed their economic ties to German corporations. Japanese authorities ceased the import of German products ceased, confiscated the holdings and patents of German companies.[180] As Donzé observes, since German companies had controlled the X-ray machine market in Japan until 1914, their overnight disappearance allowed Shimadzu and other Japanese firms to concentrate resources into developing mass-market products. Shimadzu's "A" model, its first medical-use X-ray machine produced for general sale, debuted in 1915.[181] Before then, as mentioned earlier, the two models of medical-use X-ray machines it had produced were one-time manufactures sold privately to Imperial Army and Red Cross hospitals.

Shimadzu's rise in Japan also traces the emergence of a fundamental innovation in X-ray technology, produced in the laboratory of the American enterprise General Electric (GE): the Coolidge tube. Named after its inventor, the GE-employed physicist William D. Coolidge, the tube improved on its predecessor, the Crookes tube. Whereas the Crookes tube produced X-rays by generating an electrical current between its two electrodes that ionized the gas inside it, the Coolidge tube had a high vacuum and generated X-rays by the thermionic emission of electrons from a tungsten cathode filament heated by electric current.[182] (Figure 3-2)

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[179] Pierre-Yves Donzé, "Patents as a Source for the History of Medicine: The Example of the Japanese Medical Instrument Industry, 1885-1937 *Journal of the Japanese Society for the History of Medicine* 59:4 (2013), 505. See also Donzé, "Making medicine a business in Japan", 245-246.

[180] For analysis on the Japanese-German situation in the first half of the twentieth century see the essays which give an orienting overview of this period in Vol. I of Kudō, Tajima and Pauer, eds., *Japan and Germany*, 1-44.

[181] Donzé, "Making medicine a business in Japan", 244-245. See also Gotō, *Nihon hōshasen igaku shi kō*, 126.

[182] The finicky nature of the Crookes tube is discussed in e.g. Cleveland Moffet, "The Rontgen Rays in America," a document reprinted in Harry LeVine, *Medical Imaging* (Santa Barbara: Greenwood Publishing Group, 2010), 150-151. For a technical explanation of how Coolidge tubes work see e.g. the official homepage of the Oak Ridge Associated Universities, "Coolidge X-Ray Tubes", https://www.orau.org/ptp/collection/xraytubescoolidge/coolidgeinformation.htm (accessed April 27, 2015).

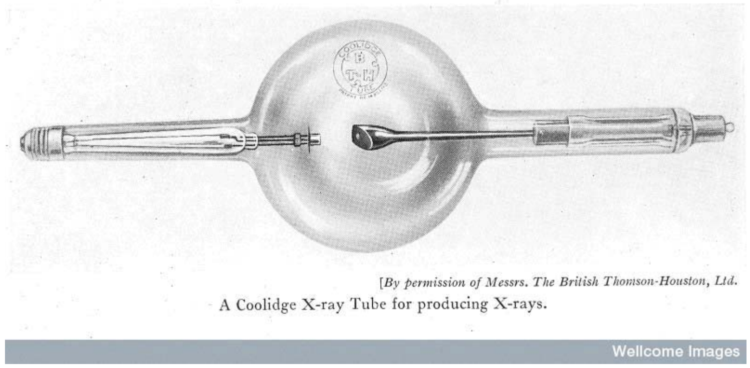

Figure 3-2. Coolidge tube (London, 1921)[183]

As a result, the Coolidge tube proved far more reliable and easy to use in taking radiographs than its predecessor. Unlike the Crookes tube, the Coolidge tube did not require constant checking of internal pressure, which also made it more durable. (An idea of how frustrating the Crookes tubes could be to use is seen, for instance, in their denouncement by American physicians as "temperamental" and "worse than a hysterical woman".[184]) The sole Japanese company licensed to import and sell Coolidge tubes was the Tokyo Electric Company (Tōkyō Denki; TEC), which became an affiliate of GE in 1905.[185] In 1917, Shimadzu brokered a deal with TEC to use Coolidge tubes for Shimadzu X-ray machines, which provided its X-ray machines with a reliable supply of the most effective X-ray tube on the global market at the time.[186] In sum, the absence of German competition and collaboration with GE via TEC gave Shimadzu the ability to

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[183] Courtesy of Wellcome Images, "Wellcome Images", http://wellcomeimages.org/ (accessed March 11, 2016). Image database no.: M0015310.

[184] Quoted in Robert G. Arns, "The High-Vacuum X-Ray Tube: Technological Change in Social Context," *Technology and Culture* 38:4 (October 1997), 852.

[185] TEC was founded in 1896 as the Hakunetsushō, a limited partnership company linked to the Shibaura Corporation. Not to be confused with the Tokyo Electric Power Company (Tōkyō Denryoku Kabushiki Gaisha; TEPCO), utility operator of the Fukushima nuclear power plant, incorporated in 1951. See the Tōkyō Shibaura Denki kabushikigaisha Matsuda shiten, *Tōkyō denki kabushikigaisha gojū-nen shi* (Tokyo: Tōkyō Shibaura Denki kabushikigaisha, 1915).

[186] Donzé, "Making medicine a business in Japan", 245.

establish itself as the leading manufacturer of X-ray machines in Japan.[187]

International Expansion and Engagements

The business of making X-ray machines did not stop at the borders of Japan's main islands. Shimadzu began exporting one of its early alternating-current models of X-ray device to Argentina via its Kobe store from 1917 onwards. This export network was gradually extended to cities in Northeast China (Harbin), Inner Mongolia (Manzhouli), and Russia (Khabarovsk and Vladivostok).[188] Within Japan, the company occupied offices in Tokyo, Osaka, Kyushu and Hokkaido. Following Japan's incursion into Manchuria in the 1920s and 1930s, Shimadzu also established five more offices in Taiwan and mainland China, located in Dalian (1920), Fengtian (1929), Taipei (1931), Xinjiang (1934) and Beijing (1939).[189] Its role as a provider of radiological equipment to medical institutions in those places deserves further study, unfortunately beyond the scope of this present work.

Chinese markets, in the words of one author writing in 1932, provided potential "new lands" for Japanese products.[190] Following the Manchurian Incident, Shimadzu sought to expand its business into China in order to take advantage of the new connections between Japan and Manchuria. Their efforts were facilitated by Japan's anxiety to show success in governing the Guandong (Kwantung) leasehold in Manchuria, acquired after its victory in the Russo-Japanese

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[187] Ibid.

[188] Shimazu Seisakusho, *Shimazu seisakusho shi*, 44.

[189] Ibid., 65-66. In Europe, the company also had a Berlin office, opened in 1923.

[190] Ujihara Sakura, "Shina no iikuteki kaihatsu to ikaki", *Ika kikaigaku zasshi* 1:1(1923), 37-40.

war. The construction of a model public health infrastructure served that end.[191] As a notable instance of this, the South Manchurian Railroad (Mantetsu) built a large hospital that, according to the glowing observations of a visiting American journalist, was "the finest in all the Far East, with a thousand beds, ten or twelve operating rooms, four X-ray rooms and every appliance of modern medicine and surgery… If Dairen is destined to become the city of refuge for foreign business in China, it will be…clean, healthy and up-to-date."[192] The expansion of Japanese enterprise also provided an opportunity for the export of advanced Japanese products to modernize its colonies.

Shimadzu conducted another important foreign deal concerning radiation medicine in 1930, when it became the sole company in Japan (and Manchuria) authorized to import radium from the Joachimsthal mine in Czechoslovakia, one of the oldest and most famous sources of radium, as confirmed in a letter from the Czechoslovak ambassador to Japan.[193] It hence became, by its own account, the primary supplier of radium for scientists and medical practitioners in Japan. In addition, Shimadzu also acquired the exclusive distribution rights within Japan for Radiumchema, a Czechoslovak company founded in 1927 which manufactured a range of radium commodities including soaps, shampoos and novelty devices. Shimadzu acquired the rights to sell Radiumchema wares including radium compresses, radon inhalers and other

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[191] For a study of Japanese public health works in Manchuria see Robert John Perrins, "Doctors, Disease and Development: Engineering Colonial Public Health in Southern Manchuria, 1905-1926," *Building a Modern Japan*, ed. Morris Low (New York: Palgrave Macmillan, 2005), 103-132.

[192] Quote taken from Perrins, "Doctors, Disease and Development," 123.

[193] The mine goes by its Czech name, Jáchymov, in Japanese. See Roger F. Robison, *Mining and Selling Radium and Uranium* (Cham: Springer International Publishing, 2015). For Shimazu's involvement with Czechoslovakian radium see Shimazu Seisakusho, *Rajiumu* (Kyoto: Shimazu Seisakusho, 1937), 24-25.

pharmaceutically inclined products.[194] (Figure 3-3)

Figure 3-3. Radium compress manufactured by Radiumchema[195]

Radium therapy, although radium was costly and hard to obtain, formed an important part of radiation medicine in the first three decades of the twentieth century, and a popular craze for radium diffused throughout Europe and America also reached Japan.[196]

From Instruments to Machines

Radiology was one of the first modern medical specialties which relied on a category of physical tools better called *machines* rather than *instruments*. Up till the emergence of the X-ray machine, mechanical devices used in medicine consisted of instruments made to be used by hand, and mostly in surgery: surgical blades, forceps, syringes, and a pantheon of metal-worked

[194] Robison, *Mining and Selling Radium*, 44-45. Radium therapy experienced a decline following the mid-century advent of cheaper, easier-produced radioisotopes.

[195] Image sourced from Oak Ridge Associated Universities, "Box for Radiumchema Radioactive Compress (ca.1930)", https://www.orau.org/ptp/collection/quackcures/radchema.htm (accessed May 2, 2015).

[196] For a study of the radium craze in America see Levine, *The First Atomic Age*, 25-88; for the radium boom in Japan see Nakao, “Kindaika wo hōyō suru onsen”.

implements. Prior to the emergence of X-rays, auscultation – examination by sound – was the main method of diagnosing the problems of the body's interior. The instrument that allowed sound to be used as a tool of diagnosis was the stethoscope, which, in its initial forms during the early nineteenth century, essentially consisted of a variety of wooden tubes.[197] In contrast, the X-ray machine was a far more complex device. Its assembly, prior to the emergence of companies specializing in its manufacture, required knowledge of physics, and the effect it produced on a patient came not from its direct application but from the electromagnetic rays it generated. On top of that, its successful use required both a steady source of electrical power and also accessory equipment used to form and develop the X-ray image – a photographic plate or film, and the necessary chemicals for processing that media. These also required the presence of someone with knowledge of the photographic process.

The term "machine" captures the sense of a complex device comprising numerous parts. In 1867, the German engineer Franz Reuleaux defined the machine as "a combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work accompanied by certain determinate motions".[198] Following the gradual development of electrical power infrastructure in cities, this definition also included machines that required the presence of electricity to compel the forces of nature into work. X-ray machines embodied the revolutions in electrical engineering and science that transformed urban life in the nineteenth century world. From the late twentieth century onwards, X-ray equipment grew

[197] For a concise overview of the stethoscope in the history of medicine see Stanley Joel Reiser, "The Science of Diagnosis: Diagnostic Technology," *Companion Encyclopedia of the History of Medicine*, Vol.2, eds. W.F. Bynum and Roy Porter (Routledge: London, 1993), 826-851.

[198] Franz Reuleaux, *Kinematics of Machinery: Outlines of a Theory of Machines*, trans. from the German by A.B.W. Kennedy (London: Macmillan and Co., 1876), 35. Available online from Cornell University Library at http://ebooks.library.cornell.edu/cgi/t/text/text-idx?c=kmoddl;idno=kmod029 (accessed April 21, 2015).

increasingly sophisticated. Radiological practice expanded to include digital systems of diagnosis and therapy: computerized tomography (CT), position emission tomography (PET) and magnetic resonance imaging (MRI). Images today of this equipment and the clinical spaces they are used in give a strong impression of futuristic, minimalist and technical efficiency.

In Japanese, the commonly used term for "machine" in this late nineteenth-century sense was *kikai*, written with the characters 機械. This helped to distinguish the modern, often large contraptions that required an external power source from a set of things also referred to *kikai*, written with the characters 器械. The different first character of this second term referred to a wide range of objects: vessels, weapons, puppets, measurement devices, and hand-held tools (*dōgū*; 道具) used for various trades.[199] Hand-operated medical instruments, for instance, were often called *kikai*, in the second sense, or *dōgū*.[200] In the case of X-ray machines, though, the term most often seen in the pre-WWII literature is *sōchi* (装置), "apparatus", or *kikai* in the first sense, or with both terms conjoined, 機械装置, "machine apparatus". This gives the sense of a complex, multi-machine or multi-instrument congregation of devices. And in Japan, as in many Western countries in the early twentieth century, X-rays were also often eponymously called "Roentgen rays": *rentogen sen*.[201]

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[199] Dai Nihon Kokugo Jiten, "Ki-kai," [き‐かい 【機械・器械】], available online from the Japan Knowledge database, http://japanknowledge.com.ezp-prod1.hul.harvard.edu/lib/display/?lid=20020105b1469CQREmRZ (accessed April 20, 2015). Access provided by Harvard University.

[200] See e.g. the exhibition catalogue of Sakai Shizu et al., *Rekishi de miru: Nihon no ishi no tsukurikata – Nihon ni okeru kindai igaku kyōiku no yoake kara gendai made* (Tokyo: Dai 28-kai Nihon Igakukai Sōkai, 2011), 30-31.

[201] *Rentogen* (レントゲン) came to be the dominant *katakana* transliteration of "Roentgen", although there were initial variants of how that German word should be pronounced. See e.g. a column discussing this in the popular science magazine *Kagaku gahō*. "Roenchen ka Rentogen ka," *Kagaku gahō* 1:1 (1923), 90. X-rays, meanwhile, were simply rendered directly as *X-sen* (X 線) but also occurred as "X-scatter rays" or "X-radiation rays" (X 放散線; X 放射線) and other variants.

What were the *rentogen sōchi* of the early to mid-twentieth century like? Pictures from Shimadzu's catalogues reveal the evolution of contraptions that bear little resemblance to their forerunners, over a relatively short span of time. The most basic X-ray apparatus, in the earliest period following Roentgen's discovery, involved an electrical source, an electrical transformer (induction coil), a vacuum tube containing at least two oppositely charged electrodes and a small amount of gas at low pressure (the Crookes tube, a forerunner of the cathode ray tube). It also required materials with which to capture the image. Before the advent of film, a photographic plate (a glass plate coated with a light-sensitive emulsion of silver salts). The educational-use apparatus Shimadzu unveiled in 1897 also followed this model, using a mercury interrupter type of induction coil and Bunsen cell batteries.[202] Before the advent of Coolidge tubes, as earlier mentioned, the Crookes tubes proved notoriously difficult to calibrate for use. Japanese radiologists would have empathized with the struggles of their American and European counterparts in getting the machines to work as desired. Technological innovations appeared in terms of equipment and methods, but hurdles in operation remained. Contrast media was introduced in the 1920s, for example; iodine-based solutions that made radiographs clearer and easier to read by heightening the contrast between light and dark areas on the image.[203] However, in the words of Amikawa Takami, "it would be very hard to say that this made all the photos [radiographs] taken good ones; even if the bones were all right, the chest would be too black, or one would become handy at shooting the chest but leave the digestive tract in a sorry state; the

[202] For an introduction to Bunsen batteries see the entry on the National Museums of Scotland official website, "Battery, known as Bunsen cell", http://nms.scran.ac.uk/database/record.php?usi=000-190-004-730-C (accessed April 07, 2015).

[203] Mohammed A. Quader, Carol J. Sawmiller, Bauer E. Sumpio, eds., *Radio Contrast Agents: History and Evolution* (New York: Springer, 2000), 775-776.

intensities wouldn't match up." Yet there is something in the complex make-up of X-ray machines that also sparked professional pride and attachment in those trained to operate them, recalling models of yore with affection.[204] Shimadzu's machines, in particular, possessed names that evoke the sense of wonder associated with radiation in the first decades of the twentieth century. Some members of its Coolidge tube-equipped machines sported names drawn from Greco-Roman mythology and astrology: Diana, Juno, Jupiter and Luna, for instance.[205] This raises the issue of how these machines were marketed to potential buyers.

Advertising Radiation Products

When Shimadzu had first started to make educational-use X-ray machines for use in schools in 1897, Genzō II had given public demonstrations of the device at municipal conventions all over western Japan: Kyoto, Osaka, Kobe, Wakayama, Ehime, Okayama, Hikone and several other locations.[206] As Pierre Yves-Donzé has shown, it also made efforts to include doctors in its business expansion strategy: when Shimadzu became a joint stock company in 1917, for instance, its managing board comprised 12 doctors out of 42 directors. One of these doctors was Hida Shichirō, an army surgeon who had helped Shimadzu produce its first successful medical-use X-ray machine. Donzé argues that the presence of these doctors served more to boost the commercial presence of Shimadzu within medical circles than as a source of medical knowledge to help manufacture new devices, showing in a careful analysis that they

[204] Oral interviews with Amikawa Takami and Umetani Yūkichi in Nihon Hōshasen Gijutsu Gakkai, *Nihon hōshasen gijutsu shi*, 258, 249.

[205] Shimazu Seisakusho, *Shimazu seisakusho shi*, 359; also the company's periodical: Shimazu Seisakusho, "Wagakuni no iryōyō X sen sōchi no kotohajime", *Boomerang* 3, 17-18.

[206] Gotō Gorō, *Nihon hōshasen igaku shi kō*, 18.

constituted part of a medical elite who had graduated from the top imperial universities of Tokyo or Kyoto, or who had trained in Western institutions (and presumably equipped with the cultural knowledge necessary to appreciate machines named after Western gods). When they joined Shimadzu, they were all running their own private clinics and also belonged to several professional societies. Collaboration with Shimadzu is likely to have given them better access to newer, better machines for their practice; from the company's end, the professional networks these doctors had access to also opened up new avenues for their products to circulate.[207]

Part of the attraction of Shimadzu for medical practitioners must have stemmed from its comprehensive range of radiological products. Company catalogues reveal a wide range of equipment produced as accessory devices to the main X-ray apparatus: radiometers, devices to facilitate the examination of developed radiographs, timekeeping devices to control the exposure dose of X-rays, as well as films and chemicals for film development. The company was an emporium of radiological equipment; a hospital wishing to start a radiology department or a practitioner desirous of opening an X-ray clinic could have procured everything they required from Shimadzu's product line. Its trade catalogues provide fascinating sources of information on medical instruments manufactured from the nineteenth century onwards, when they also became mass market products. Shimadzu's dissemination of information about X-ray machines to the medical world served the dual purpose of brand advertising and product explanation, the latter function necessary given the fledgling status of radiology in the early twentieth century and competition from overseas companies like GE and the German firm Siemens.[208] Its trade catalogues, as those of its American and English (and doubtless other European) counterparts

[207] Donzé, "Making medicine a business in Japan", 249-251.

[208] Ibid., 249-250.

contained photographs of their products accompanied by text that explained their structure and function. In addition, the presence of technical terms and the Not For Sale note that sometimes appeared in the publication information of certain catalogues indicates that they were circulated to an internal target audience – most likely physicians. Other catalogues could be purchased, like the Shimadzu catalogue for radium and radium products; by narrating the history of the product and its specific role in medical practice, perhaps this was intended for a broader audience.[209]

General catalogues of medical instruments and machines also circulated; a good specimen of these is the "Catalogue of Medical Machines in Japan" (*Nihon ika kikai mokuroku*), published in 1937, intended to help physicians and medical institutions start specialized practice, and containing products of both national and foreign manufacture. For X-ray machines, Shimadzu's are the only domestic-manufacture ones featured alongside machines made by the British firm Sanitas Electrical. The steep cost of purchasing the basic X-ray machine, without all the necessary accessory devices, is seen at a glance from price charts tabulating the total cost of basic implements for various medical specialties like opthamology and surgery: the former's price tag around two to ten times the latter.[210]

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[209] The above points on the utility of trade catalogues in the history of medicine are sampled from the detailed discussion found in Audrey B. Davis, *Medicine and its Technology: An Introduction to the History of Medical Instrumentation* (London: Greenwood Press, 1981), 21-22.

[210] For instance, the cheapest X-ray machine by Shimadzu featured in this catalogue, the Yasaka model, cost 2,150 yen, whereas the total cost of basic implements for a surgical room totaled just under 1,000 yen. Nihon ika kikai mokuroku hensansho, ed., *Nihon ika kikai mokuroku* (Tokyo: Dai Nihon insatsu kabushiki gaisha, 1937), 282-291, 515-519.

Making Technicians and Technologists

Figure 3-4. Control panel of Shimadzu *Diana* model[211]

Machines, however capable they are, require operators, or even if they are automata, maintenance personnel. The technical challenges faced in successfully operating an X-ray machine of the early twentieth century required an operator who specialized in handling the device. The earliest machines installed in the imperial army's garrison hospitals, for instance, did not always work even under the supervision of a doctor, as recalled in by Ishida Kumajirō, a member of the first generation of X-ray technicians, who witnessed one such failure at the Sendai garrison hospital in 1900.[212] Or as another technician, Amikawa Takami, later recalled: "For 15 years in Meiji, [X-ray] technology consisted of generating X-rays" – a statement that

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[211] From the Shimadzu Memorial Museum. Photograph from the Japan Association of Radiological Technologists. Nihon Shinryō Hōshasen Gishi Kai, "Kyō wa nan no hi? (3-gatsu 16-nichi)", http://www.jart.jp/news/what_was_today.html (accessed May 3, 2015).

[212] Nihon Hōshasen Gijutsu Gakkai, *Nihon hōshasen gijutsu shi*, 4.

suggests the difficulties involved in radiology's nascent period.[213]

In discussing the institutional developments that surrounded the growing use of X-rays in Japanese medicine, and the experiences of those trained to operate them, it is easy to overlook the equipment itself. Yet, in the words of one Japanese engineer, Shiga Tatsuo, "it is tantamount to armchair theory to discuss the medical science of X-rays without being well-versed in the realities of the [X-ray] apparatus."[214] And indeed, Shiga's colleagues in other countries would have agreed. On this point, Arthur Christie, an American radiologist, provides a useful and elegant summary of the many issues implicated in the use of X-rays in medical practice:

> It is not the object of this brief address to attempt even a summary of the historical development of medical radiology. It would carry us into the fields of physical and biological research, the development of complicated technical methods; the gradual accumulation of experience in interpretation of x-ray findings; the invention and production of constantly improving apparatus; as well as into the fields of hospital relations, methods of practice, education, and medical organization.[215]

Christie's speech addressed his American colleagues in radiology in the mid-twentieth century, but his words pertained to earlier decades of radiological work. What exactly did using an X-ray apparatus in the early twentieth century entail, and what were the machines operated like? Asking these questions furnishes a better understanding of state motivations for passing the ordinances discussed in the previous section, and ties into Chapter 3's study of manufacturers and technicians. Inquiring into the realities of the X-ray apparatus further reveals the complex array of personnel, systems and devices needed for its operation, and highlights the role of technical considerations in making public policy.

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[213] Ibid., 258.

[214] Nihon Eisei Kai, *Ekkusu sen no igaku*, 117.

[215] Arthur Christie, "Fifty Years of Progress in Radiology," The American Roentgen Ray Society, 1900-1950: Commemorating the Golden Anniversary of the Society (Springfield, Ill: Thomas, 1950), 25.

Shiga Tatsuo, the engineer referred to earlier, was an employee in the Health Section of the Metropolitan Police Department. He delivered the lecture on X-ray apparatuses for the 1939 training course in Kanda mentioned in the previous chapter. Shiga prefaced his lecture by noting that the complex nature of working with X-rays in medicine meant that physicians and dentists often buried themselves in areas of 'pure' medical knowledge, such as interpreting radiographs, or therapeutic methods and their results. This led to a tendency for many of them to leave the technical (i.e. mechanical, electrical and logistical) aspects of working with X-rays to technicians; but, Shiga added, it was still necessary for the medical doctors to understand the basic principles of the equipment they used in their work.[216] Electricity was the most basic requirement. In order to operate the X-ray machine, particularly the more powerful ones used for deep therapy, a stable and plentiful source of electricity was needed, "anything up to 100,000 volts or more," said Edward Morton.[217] And if radiologists were not going, or could not entirely master, the machines with which they plied their trade, they needed properly trained technicians.

Shimadzu clearly understood this need. The company did not only manufacture radiological machines; it was equally invested in making people who could operate its products. A shortage of such people prompted it to furnish its own supply of them. In 1921 it held its first series of "Roentgen Lectures and Praxis" (*Rentogen kōshūkai*), open to members of the public and advertised in newspapers like the national daily *Asahi shimbun*. After registering and paying an attendance fee, attendees could be taught by radiologists who worked at Shimadzu or at medical institutions to learn the basics of X-ray work. Its first session garnered 22 students, who heard six academic researchers in medicine, physics and engineering lecture on various aspects

[216] Nihon Eisei Kai, *Ekkusu sen no igaku*, 117.

[217] Morton, *A Text-Book of Radiology*.

of *rentogen*, and who also guided students in hands-on usage of the equipment that prodiced the rays (Table 2):

Table 2. Lecture roster for Shimadzu's first *Rentogen kōshūkai*, 1921:

Lecture	**Instructor**
On the essence of X-rays and X-ray bulbs 管球	Mori Sōnosuke (Bachelor of Physics)
On the X-ray photograph and its technology	Urano Tamonji (*Doctor Medicinae*)
On the use of X-ray technology in medical diagnosis and treatment and its indications	Urano Tamonji
On concepts of electricity and the X-ray generating apparatus	Fukuda Shunichi (Bachelor of Engineering)
Special lecture: Faith and Science	Aoyanagi Eiji (Doctor of Engineering)
Special lecture: On X-rays and the structures of material objects	Ishino Matakichi (Doctor of Physics)
Special lecture: X-rays in the field of internal medicine	Matsuo Iwao (Doctor of Medicine)

Subsequent lecture series kept drawing higher numbers of students: 80 for the second, 113 for the third, and so on until 1940, when the Japan Radiological Society took over the event.[218]

In 1927 Shimadzu opened an educational workshop (*kōshūsho*) for *rentogen* technicians (*gijutsusha*) in Kyoto, the first institution in Japan specialized in teaching radiological technology. Students embarked on a six-month course of learning to use and maintenance of X-ray equipment that combined both lectures and hands-on practice at Shimadzu's facilities.[219] For the first training session, the Osaka *Mainichi* newspaper reported that prospective applicants had travelled to the examination centers of Tokyo, Kyoto and Fukuoka from as far as Fuzhou, Manchuria and Karafuto (Sakhalin). Applicants needed at least secondary school education, and

[218] Table 2 and details for this paragraph taken from Shimazu Seisakusho, *Shimazu seisakusho shi*, 49.

[219] "Nenpyō," ibid., 5.

the company selected twenty of the best-performing candidates to undergo training alongside twenty other participants sent from the army and government ministries.[220] This workshop was later renamed the "Vocational School for *Rentogen* Technology" in 1935, and, after the end of WWII, garnered national endorsement as the "First X-ray Technician Training Institute". Initially, the program's instructors were radiologists who Shimadzu externally engaged, including some employees deemed capable of lectureship, but the company provided all the land, facilities and equipment necessary.[221] Here at some length is an excerpt from recollections penned by a former instructor, Takiuchi Masajirō. He paints a vivid portrait of the school, in the picturesque landscape of Japan's old imperial capital, when it first started:

> …Most of the lecturers had no prior experience teaching, and on top of that the students were a motley crew whose former occupations included railroad employees, professional photographers, magazine reporters, masseuses, administrative personnel and hospital X-ray technicians. Furthermore, the oldest student was 44, and most of the others were around 24, in contrast to the lecturers, also mostly in their 20s other than the head lecturer, Fukuda [Shunichi], who was 37; giving lessons caused the 20-something lecturers many difficulties. …In the training sessions for taking radiographs, the students took turns to provide a model radiograph by playing the patient being screened. Of course we tried to take all precautions against radiation injuries, so each student only played the role of patient once. Instead, for each model, all the students would watch, and the student-operator would use a lead screen and a lead-lined apron [as protective gear]. …We focused on thoroughly drilling the operation procedures for the [X-ray] apparatus into them. At any rate it was still the era of gas tubes and so the operating conditions constantly changed; it was quite hard to calibrate them. In particular it was especially hard to teach them how the intensity of the X-rays could be told from the colors that glowed on the tube walls, but somehow we got them to the point where they could apply this knowledge in 6 months.
>
> …At lunchtime there was a break of 1 hour, so it became our custom to take a walk from the Kiyamachi-sanjō to the Kyōgoku districts, or around the Kamo River, which the school faced. When afternoon lessons ran slightly over time and evening drew near, one could catch scattered glimpses of geisha, all made up, walking under our windows, scattering the students' attention and causing the instructors to fidget greatly.

[220] *Nihon hōshasen gijutsu shi*, 32; Shimazu Seisakusho, *Shimazu seisakusho shi*, 59.

[221] Shimazu Seisakusho, *Shimazu seisakusho shi*, 59.

This fascinating excerpt raises several issues: the extant awareness of the risk of radiation injuries on the part of the instructors, the diverse make-up of students seeking training in the emergent field of radiation technology, and the fact that Shimadzu did not equip its students and instructors with the more expensive, better Coolidge tubes in their training, but supplied them with the cheaper, older and harder gas-filled models. That the students found difficulties in training is further suggested by how, of the students selected by examination, almost a quarter failed to graduate.[222]

The evolution of this training center reflects the bumpy path taken by radiological technicians – or technologists, as some of them later preferred to call themselves, perhaps to emphasize the specialized nature of their work within radiology. They worked for more than a decade to achieve recognition for their particular role and contributions to the radiological field. Shimadzu's center trained students, and was recognized by the Kyoto prefectural government, but there were no broadly recognized or nationally granted licenses that those same students could obtain upon graduation. This led to an inevitable underplaying of the role that technicians filled – a role that grew ever larger with the increasing complexity of the machines used in radiological practice, and with increasing numbers of people licensed to work with those machines. One gauge of the rise in vocational interest for this field is the expansion of Shimadzu's lecture series, which went from accommodating 60 students to 150 in just one year, for instance.[223]

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[222] Excerpt and other details taken from Nihon Hōshasen Gijutsu Gakkai, *Nihon hōshasen gijutsu shi*, 32. There is discrepancy with the figures for the enrolment of students who sat for the entrance exam cited in ibid. and in Shimazu Seisakusho, *Shimazu seisakusho shi*, 59, but the latter does not give the number of students who passed.

[223] See the advertisements in the *Asahi Shimbun*, September 15 1925, 1; and September 15 1926, 7.

The relative invisibility of radiological technicians is vividly illustrated in an anecdote recounted by Hosoe Kenzō, chairman emeritus of the Japanese Society of Radiological Technology. (JSRT; *Nihon hōshasen gijutsu gakkai*) In 1942 Hosoe and his friend Takiuchi Masajirō, both radiological technicians, had gone to a hotel in Kyoto to meet with Nakaizumi Masanori, one of the most eminent pioneering radiologists in Japan, having assumed the first professorship in radiology at the prestigious Tokyo Imperial University (later renamed the University of Tokyo after WWII) from 1934 onwards. Hosoe and Takiuchi wished to gain Nakaizumi's backing for upgrading the status of the *rentogen* vocational school in Kyoto – i.e. the one run by Shimadzu – to that of a higher technical school. Hosoe does not explain why this was desirable, but it is likely that such an upgrade, by giving it national certification, would have increased the prestige both of the school and of the technicians it trained. In order to achieve this goal, Nakaizumi's support as a professor of the Tokyo Imperial University would be very helpful in convincing the Ministry of Education to acquiesce.

Nakaizumi's authority extended beyond radiology to the world of Japanese medical practice in general, as seen from his assumption of chair of the medical school of the University of Tokyo in 1952. Given his position, one might surmise that he sympathized with Hosoe and Takiuchi's cause. Instead, Hosoe relates regretfully, they were reprimanded with Nakaizumi's assertion that no such field as *rentogen* technology existed, hence requiring no such school, and furthermore, a company had no business to be privately operating an institute of higher learning. "He roared [these things] at Takiuchi," Hosoe recalls, "and we made a hasty departure." Further insult upon injury to their kind came two years later, at the 1944 conference of the Japan Radiological Society (JRS; *Nihon igaku hōshasen gakkai*), which tabled the motion to "abolish radiological technicians" – ostensibly a motion to do away with that occupation altogether.[224]

What are the roots of this hostility? Nakaizumi's brusque rejection of the proposal to promote the Shimadzu school to a nationally certified institution of higher technical learning, as well as the 1944 conference motion, gesture towards the rift between elite radiologists and the technicians who worked alongside them in the 1940s – a rift that would continue for several decades into the postwar period. Asking why this rift occurred brings up an issue familiar to historians of Western medicine, namely the gap between elite practitioners with official or academic licensing and those who worked without such credentials.[225] In the case of radiology, the situation is compounded by the newness of the field in medical practice, which, together with the complexity of the apparatus required, caused physicians to initially distrust X-ray technology. Within American medicine, for instance, it took a little more than two decades for hospitals to recognize X-ray departments as essential to their operations.[226] In Japan, too, radiological practice was not firmly established until the latter half of the twentieth century, and even the first few generations of elite radiologists remained relatively marginal presences within the medical world of their time. Until the end of WWII, for instance, only four chairs of radiology existed in Japanese universities: Keiō University's medical department (1919), Osaka Medical University (1925), Kyoto Prefectural Medical University (1929) and Kyūshū Imperial University's medical department (1929).[227] An academic chair was tied to an individual professor, who would direct

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[224] Hosoe Kenzō, "Taibō hisashiki gijutsushi no hakkan ni yosete", *Nihon hōshasen gijutsu shi*, 227-243.

[225] As a starting point for discussions of this theme in the history of medicine, see e.g. Harold J. Cook, "The new philosophy and medicine in seventeenth-century England," *Reappraisals of the Scientific Revolution*, eds. David C. Lindberg and Robert S. Westman (Cambridge, UK: Cambridge University Press, 1990), 397-436.

[226] Arns, "The High-Vacuum X-Ray Tube", 852-853.

[227] Shimazu Seisakusho, *Shimazu seisakusho shi*, 59.

assistant professors and assistants in his working group, and its establishment conferred prestige not only on the holder but also his research specialty.[228] In this context, Nakaizumi's rejection of Hosoe and Takiuchi, as well as the 1944 motion, might be interpreted as the desire of radiologists to shore up the foundations of radiology as a specialty of academic medicine, practiced by doctors licensed at the handful of elite institutions which had radiology departments in the 1940s. This context permits the hypothesis that some academic specialists like Nakaizumi, whose primary activities were research and medical practice at an elite national institution, would not have welcomed the efforts of a private company to set itself up as a competing source of expertise and authority in radiology – even if that expertise and authority complemented his own and his medical colleagues'. This is in contrast to the private practitioners who collaborated with Shimadzu, as earlier mentioned, and there were also doctors such as Segi Yoshikazu, founder of the Fluorescence Society (*Keikō kai*), one of the first collectives of radiological technicians, who sought to include them in professional activities.[229]

Making Technicians Visible

There was another class of people, unlike radiological technicians, who were nationally recognized in Japan during the early twentieth century as certified experts in machinery: graduates from engineering programs based in institutes of higher learning called *kōgakushi*, a term which translates to "bachelor of engineering", the holders of whom are engineers, *kōgakusha*, and who held status in their field equivalent to that of a bachelor of medicine,

[228] A singular feature of the power hierarchy in the bureaucracy of Japanese universities. See *Nihon hōshasen gijutsu shi*, 15.

[229] See the official webpage of the Japan Society of Radiological Technicians, "Gakkai no hatten ni kōken sareta katagata", http://www.jsrt.or.jp/data/about/kouken-01/ (accessed April 29, 2015).

igakushi. In the case of radiology, many practitioners in Japan after 1945 differentiate technicians, *gijutsusha*, from technologists, *gishi*, with the latter group seen as holding their own distinct, more prestigious status as compared to the secondary, "support" nature of the former. The official history of the Japanese Society for Radiological Technology, for instance, notes that one of the earliest progenitors of their field is better understood as a technician (*gijutsusha*) rather than a technologist (*gishi*) because his main role was to assist the medical doctors at the Tokyo Imperial University. The progenitor in question, Mizuki Tomojirō, is considered a *gijutsusha* because he played a supporting role in assisting doctors ill-equipped to cope with the electrical and physical operations and maintenance of the machines they worked with.[230] Since this article discusses the path traversed by these practitioners towards being recognized as an autonomous group of experts, it mainly uses the term "technician".

The JSRT identifies several key factors in the background of the start of training programs for X-ray technicians in the Taisho period. First, the military's medical needs and its network of hospitals provided an important stimulus for the increase in both X-ray machines and people who could operate them. Second, the growing clinical applicability of X-rays to medical work and the number of doctors trained overseas in radiology is thought to have given them better appreciation of the need for technical knowledge in handling the machines. Finally, machine manufacturers like Shimadzu took it upon themselves to start training programs for personnel who could use their products. But in the late Meiji and Taisho periods – that is, from the introduction of radiology in 1896 to 1912, technicians essentially remained helpmeets for physicians. They performed duties that covered a whole range of odd jobs for doctors, including, apparently, giving massages (whether to patients or doctors or both, it is unclear). In some

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[230] Nihon Hōshasen Gijutsu Gakkai*, Nihon hōshasen gijutsu shi*, 3.

clinical spaces, such as the hospital run by Keio University, doctors and technicians played distinct roles: the former decided which parts of the body, in what position and for how long, to be irradiated, while the latter worked the control panel of the X-ray machine.[231]

One of the earliest expressions of technicians' desire to be recognized and certified as professionals who commanded a particular expertise within the field of radiological practice appears in a 1934 issue of *Keikō* (*Fluorescence*), the journal of the Roentgen Society of Japan (*Nihon Rentogen Kyōkai*) that grew out of the earlier-mentioned Fluorescence Society. In an article on the issue of certification, the editors asserted that if, in this age, educated people claimed that medicine did not exist without *rentogen* – a saying common by the 1930s – then it also held that *rentogen* did not exist without technicians. The authors pointed out the hazards of using machines that operated at several tens of thousands of volts, where failure to do so correctly would cause injuries, possibly cancer, and fire hazards. It asserted that the key to achieving proper usage of *rentogen* was correct knowledge of the technology that composed its machinery, hence the need to employ people who specialized in that area. Why had Japan not yet adopted laws regulating the use of X-ray machines when Europe and America already had?[232] Echoing the sentiments of this author, national regulations on the installation and maintenance of X-ray equipment specifically intended for medical use came into force in 1937. These new regulations were motivated by an increase in the supply of X-ray machines and radium coincided with a rise in accidents and injuries involving medical radiation – seen in newspaper reports, for

[231] Ibid., 4; see also the interview with Amikawa Takami in ibid., 259.

[232] They quoted the German versions of these sentiments: Keine Medizin ohne Roentgen; Kein Roentgen ohne Techniker. "Shikaku mondai ni tsuite", *Keikō* 8:11 (1934), 1-2.

instance, as well as the medical literature of the time.[233] Those affected by these laws, of course, were not only doctors who worked with X-rays, but also the companies that supplied those doctors and their institutions with X-rays, and the technicians who often took responsibility for operating them correctly. The confusion and concern this caused manufacturers can be gleaned from a booklet that Shimadzu published for its clients and students at its training center, a document formatted as a series of 137 meticulously answered questions on what the new rules required and entailed.[234]

The fact remained that the pioneers of radiology in Japan were doctors and physicists, not machine operators. Technicians, as Steven Shapin has observed, are often rendered "triply invisible" in histories of science. First, they are often invisible to historians of science as subjects worth studying; second, they are also often invisible from the documentary records made by scientists, and they are further made invisible in their workplaces by superiors who do not consider their contributions relevant to the scientific results produced in that space.[235] The first and third of these observations also pertain to radiological technicians in Japan. Much of the existing scholarship on the development of radiology in Japan is written primarily without reference to technicians, and the writings of elite radiologists about their work also exclude them, even without hostile intent.[236] The trend brings to mind the observation by Audrey Davis, a

[233] For the second volume of his history of Japanese radiology, Gotō Gorō began including the category of "Injuries and Protection" for the medical literature published in the Taisho and Showa periods that he surveys and catalogues. Gotō Gorō, *Nihon hōshasen igakushi kō: Shōwa hen* (Tokyo: Dai 12-kai kokusai hōshasen igaku kaigi, 1970).

[234] Shimazu Seisakusho, *Ekkusu sen sōchi torishimari kisoku no kaisetsu* (Tokyo: Shimazu Seisakusho Rentogen Kenkyūka, 1937).

[235] See Chapter 8 of Steven Shapin, *A Social History of Trust: Civility and Science in Seventeenth-century England* (Chicago: University of Chicago Press, 1994), 360-361.

[236] Gotō Gorō's pioneering work in the history of radiology, for instance, focuses mainly on the contributions of medical doctors to radiology as a medical specialty. Gotō, *Nihon hōshasen igakushi kō*.

scholar and museum curator of medical history, that physicians “are reluctant to see themselves as technicians or applied scientists, although they have come to place immense value on their scientific training and its techniques.”[237] This is despite how, as Hosoe Kenzō pointed out in an oral interview, the first generation of practicing radiologists were basically technicians themselves; they had to be, in order to use their equipment![238]

Fortunately, the second of Shapin’s observations does not apply in this case. Japanese radiological technicians banded together to form their own professional society in 1942, and went on to produce their own documentary records, beginning with their own magazine in 1944. They also fought for their own system of licensing recognized by the Japanese state and elite radiologists, a long struggle that finally bore fruit in 1951. That year, the central government established a national system of examination and licensing for radiological technicians based on the pedagogical curriculum used in Shimadzu’s school; the next year, a technical school affiliated with the Osaka University’s medical department also opened.[239] The story of radiological technicians in Japan and their efforts to get legitimation from the state also reflects the increasing visibility of X-ray equipment as part of medical practice, in part fueled by the products of companies like Shimadzu.

Naming Machines

As earlier mentioned, Shimadzu named three of its key pre-war X-ray machines Diana, Juno and Jupiter, after Greco-Roman gods. Shimadzu’s other machines took on different

[237] Davis, *Medicine and its Technology*, 3.

[238] Nihon Hōshasen Gijutsu Gakkai *, Nihon hōshasen gijutsu shi*, 227.

[239] Shimazu Seisakusho, *Shimazu seisakusho shi*, 60; Nihon Hōshasen Gijutsu Gakkai*, Nihon hōshasen gijutsu shi*, 41.

associations; those made in the early 1930s drew their names from natural landmarks in Japan and philosophical concepts: Hiei (for a mountain associated with Esoteric Buddhism), Katsura, (a river in Kyoto), and Hakuai (Universal Love), for instance. The machines of just a few years later, in the mid-1930s, reflected the political climate of total war through markedly patriotic nomikers including Aikoku (Patriotism) and Hōkoku (National Service).[240]

The names given to representative machines of the era of ionizing radiation's discovery provide windows into the aspirations of their manufacturers or commissioners. Shimadzu's X-ray machines named after Greco-Roman gods names drew on Western traditions of heavenly power apposite to the Western scientific and technical foundations of the radiological apparatus. They may be juxtaposed with two nuclear reactors in post-war Japan named Fugen and Monju, after the Buddhist bodhisattvas of wisdom and compassion. These two reactors were prototypes for Japanese-manufactured mixed-oxide fuel reactors that could reuse the plutonium generated from the usual uranium nuclear cycle.[241] Commissioned in 1979 and 1995 respectively by national nuclear agencies, both reactors suffered operational difficulties and failures; Fugen was closed in 2003, while Monju ceased operations mere months after it opened.[242] In Buddhist iconography, Fugen rides a white elephant and Monju rides a lion on either side of the Buddha.[243] The choice to name nuclear reactors after these bodhisattvas who control large,

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[240] Shimazu Seisakusho, *Shimazu seisakusho shi*, 359.

[241] For more on MOX fuel see Eric A. Croddy, James J. Wirtz and Jeffrey A. Larson, eds., *Weapons of Mass Destruction: An Encyclopedia of Worldwide Policy, Technology, and History* (Santa Barbara: ABC-CLIO, 2005), 219-220.

[242] For information on the Fugen and Monju reactors and Japanese R&D programs into emergent nuclear energy generation technologies, see e.g. E.Takeda et al., "Progress of Fast Breeder Reactor and Heavy Water Reactor Development in Japan", *Advanced Reactors: Physics, Design and Economics*, eds. J.M. Kallfelz and R.A. Karam (Elmsford, N.Y.: Pergamon Press, 1975), 19-32.

powerful beasts suggests an analogy to the human (Japanese state and industrial) control of nuclear power generation, via an older and more nativist religious idiom.[244] Or, as the Japan Atomic Energy Agency describes Monju iconography, the "prodigious powers possessed by the lion is [sic] judiciously subjected to the wise control of its rider."[245] In that sense, Shimadzu's X-ray machines furnish a fascinating comparison with the nuclear reactors of post-WWII Japan. They also provide another avenue with which to consider similarities between these two fields of radiation technology that developed at particular conjunctures of the nation- and state-building process in modern Japan.

Conclusion

Medical technology may be understood as an intermediary between medical practice and mechanical craft, the latter subsumed under the general category of what is now called "applied science".[246] In Japan, medical technology played this intermediary role since the start of the twentieth century. The increased manufacture and import of machines and machine parts by Shimadzu and its competitors went hand in hand with an increase in the use of *rentogen* in

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[243] Fugen and Monju are the Japanese titles for the bodhisattvas whose Sanskrit names are Samantabhadra and Manjusri respectively. See e.g. the section on Buddhism in the introduction to Royall Tyler, *Japanese Tales* (New York: Pantheon, 1987).

[244] While Buddhism is not native to Japan, it has been a major religious institution in the country since at least the 6th century A.D. See e.g. Kenji Matsuo, *A History of Japanese Buddhism* (London: Global Oriental, 2007). On the issue of names and nativist power it is also worth noting that Shimadzu's company name also looks back to Japanese history, drawing upon its connection to the Shimadzu clan (*han*), a samurai domain that wielded great influence in the revolution that thrust Japan into nation-statehood at the end of the nineteenth century.

[245] Japan Atomic Energy Agency Fast Breeder Reactor Research and Development Center, "Monju | Origin of Monju", http://www.jaea.go.jp/04/monju/EnglishSite/contents01-5.html (accessed May 2, 2015).

[246] Davis, *Medicine and Its Technology*, 3.

medicine and industry, which hit a peak in the 1930s.[247] The advent of total war in the 1940s led to a sharp decrease in new product manufacturing, and the U.S. air raids that devastated 67 Japanese cities also destroyed much urban medical infrastructure, including hospitals and the factories that supplied them with equipment.[248] Shimadzu, however, had the good fortune to be headquartered in Kyoto, the one major Japanese city which the U.S. spared from aerial bombing, and managed to resume manufacturing just two months after Japan's surrender, producing machines to assist with the mass X-ray screenings incorporated into national anti-tuberculosis campaigns.[249]

Shimadzu's activities and entrepreneurship drives home the transnational nature of the medical manufacturing business. Its overseas operations were shut down after the end of WWII and the assets transferred to China and Korea respectively, ending its representation of Japan's metropolitan presence, via medical and industrial manufacturing, in those former colonies.[250] When it resumed business after the war, reduced to a domestic scale, its commemorative publications highlighted the patriotism of its first two founders, and the company's contributions to advancing Japanese manufacturing of electrical and mechanical equipment, particularly radiological machines. However, the role of foreign locals, and foreign agents, including Wilhelm Roentgen himself, is inseparable from Shimadzu's success in adopting and adapting X-

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[247] On the use of radiology in industry see e.g. Shimura Shigetaka, *Kōgakuteki X sen shashin* (Tokyo:Seibundō, 1936).

[248] On the aerial bombings by the U.S. see Mark Selden, "A Forgotten Holocaust: US Bombing Strategy, the Destruction of Japanese Cities and the American Way of War from World War II to Iraq", *Japan Focus* (May 2007), http://apjjf.org/-Mark-Selden/2414/article.html (accessed May 1, 2015).

[249] Shimazu Seisakusho, *Shimazu seisakusho shi*, 105; Nihon Hōshasen Gijutsu Gakkai, *Nihon hōshasen gijutsu shi*, Vol. 2, 6.

[250] Shimazu Seisakusho, *Shimazu seisakusho shi*, 101.

ray machines for the use of Japanese medical professionals.[251] Furthermore, via a contribution to producing a steady supply of personnel to operate X-ray machines, Shimadzu's role in training, utilizing, and promoting radiological technicians is analogous to the role played by DuPont in reconfiguring the hierarchies of nuclear science and technology, by supplying nuclear engineers who eventually gained power in national laboratories.[252]

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[251] Many electronic products that symbolize the economic rebound of post-WWII Japan, such as the sewing machine, camera and automobile were all imports from the United States and Europe in the early twentieth century. For an overview of technology transfer from Germany to Japan see e.g. Kōda Ryōichi, "Technology Transfer from Germany to Japan in the Machine Tool Industry before the Second World War," *Japan and Germany: Two Latecomers to the World Stage, 1890-1945,* eds. Kudō Akira, Tajima Nobuo and Erich Pauer, Vol. III (Folkestone, UK : Global Oriental, 2009), 511-529.

[252] Sean F. Johnston, "Making the Invisible Engineer Visible: DuPont and the Recognition of Nuclear Expertise", *Technology and Culture* 52:3 (July 2011), 548-573.

Chapter 4
Exposing and Quantifying

> Webster defines dose as: (a) The measured quantity of a medicine to be taken at one time or in a given period of time. (b) A definite quantity of anything regarded as having a beneficial influence. (c) Anything nauseous that one is obliged to take.
>
> The radiotherapist presumably accepts definition (b) in considering the radiation effect on his patients, and definition (c) in considering the effect upon himself.[253]

As mentioned in the introduction, the Japanese term *hibakusha* refers to people exposed to ionizing radiation. The term first denoted the survivors of Hiroshima and Nagasaki, and from the late 20th century onwards, also referred to the casualties of nuclear accidents.[254] But again, the *hibakusha* of Hiroshima and Nagasaki were not in fact Japan's first radiation casualties. This chapter examines the ends to which *rentogen* were deployed in medical and scientific experiments over the first part of the twentieth century. In particular, as the epigraph to this chapter suggests, the metaphor of radiation being measured in a *dose* provided a powerful analogy to medicine, and by extension, the idea that the benefits of consuming it outweighed its potentially unpleasant or harmful dimensions. From the early twentieth century onwards, Japanese scientific and medical experts, like their Western counterparts, understood and experienced the biological effects of ionizing radiation via the use of X-rays/*rentogen* and, to a lesser extent, radium. They acquired this knowledge in three main ways: through painful personal injuries incurred in the course of their research, through exposing animal, plant and

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[253] S.T. Cantril and H.M. Parker, "The Tolerance Dose," Argonne National Laboratory document, United States Atomic Energy Commission (MMDDC-1100), 1945, 1. Available from the database of Oak Ridge Associated Universities, https://www.orau.org/ptp/Library/Cantril1945_MDDC-1100_CH-2812_Tolerance_Dose.pdf (accessed September 28, 2015).

[254] As stated in the prologue, the two commonly used ways of writing *hibakusha* in *kanji* characters distinguish between survivors of nuclear weapons explosions (被爆者) and those of all other radiation exposures (被曝者). The first term has the radical for 'fire' and the second for 'light'.

human bodies for the sake of that same research, and through reading scientific reports of the same phenomena undertaken by their colleagues in Europe and America. Moreover, as Chapter 5 will show, contemporary mass media coverage of radium and X-ray science and medicine communicated to the public the basic fact that exposure to excessive amounts of radiation would harm living flesh – a concept that was also international knowledge by the 1920s.

The previous two chapters examined the organizations that provided *rentogen* with institutional homes. In Chapter 2, hospitals, medical schools and government ministries established locales for the medical use of *rentogen*; they also developed regulations and laws to oversee *rentogen* screenings. Chapter 3 then turned to examining Shimadzu as a key organization that literally enabled medical *rentogen* use, by manufacturing the material equipment and training the machine operators of *rentogen* apparatuses. Both these chapters focused on exploring the actions taken by actors on the end of those conducting and facilitating *rentogen* use – licensed doctors, medical schools, bureaucrats, manufacturers and technicians. This raises the question of what it was like to be on the other end, as a body receiving X-radiation. The current chapter traverses two angles of inquiry, which may be summed up in the ideas of *exposure* and *expertise*. First, it examines which kinds of bodies were irradiated, and for what purposes. It then proceeds to ask how medical researchers measured the exposure of these bodies, in a period when scientific knowledge about radiation was in intense flux.

The social history of medicine privileges attempts to reconstruct the experience of being a patient, in order to raise awareness of the human dimensions of pain and suffering often elided in more orthodox accounts of medical practitioners and institutions.[255] While such a perspective

[255] An emblematic figure of this school is Roy Porter, former director of the Wellcome Institute for the History of Medicine. See e.g. Roy Porter, *A Social History of Madness: The World Through the Eyes of the Insane* (New York:

is obviously important, this chapter returns its focus to the professional side. As the case of Nagai Takashi recalls, medical radiologists comprised a substantial number of the irradiated, due to their constant handling of *rentogen* generating machines. They were responsible for preventing the over-exposure of their patients, and also for managing the exposure rates of their own bodies in the course of their work. Examining the production of knowledge that underpinned these responsibilities also allows us to examine the process of how they understood the risks of radiation use. To that end, the analysis here traces the activities of experts, mostly in Europe and America, who created knowledge about radiation, and discusses how that knowledge was legitimized and adopted by their Japanese counterparts. In doing so, it also exposes the contingent nature of how expertise on radiation was produced, and how much ambiguity and ambivalence it contained from its earliest days.

Measuring the Invisible (I): Visible Damage

Medical radiation has a complex relationship with the ailments it treats, as demonstrated by cancer.[256] In the early twentieth century, most Western doctors considered leukemia – cancer of the bone marrow or blood – to be a chronic, incurable disease. But only a few years after Roentgen's discovery of X-rays, clinical studies provided proof that this form of radiation could shrink tumors. The next couple of decades leading into the 1920s saw, in the U.S., X-radiation becoming a normalized part of leukemia therapy. However, the growing use of X-rays also demonstrated, in due course, that radiation could cause the disease it intended to treat. Many of

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Weidenfeld & Nicolson, 1988); more recently, see e.g. also Joan Lane, *A social history of medicine: health, healing and disease in England, 1750-1950* (New York: Routledge, 2001).

[256] For an accessible account of the history of cancer treatment, see Siddhartha Mukherjee, *The emperor of all maladies: a biography of cancer* (New York: Scribner, 2011).

the pioneering generations of radiologists used themselves as test subjects for their X-ray machines, checking the calibration of the device by exposing their hands or arms to test the strength of the rays produced.

Radiological screening and therapy were dramatically new medical practices that presented their users with significant health hazards from the earliest days of their use. The final years of the nineteenth century and the first decade of the twentieth saw, all over the world, a growing awareness of radiation syndrome, a term to describe the damage to living tissue that could be caused by overexposure to ionizing radiation from X-rays or radium. The first generations of radiologists and their patients faced high risks of over-exposure leading to burns and even cancers. An 1896 article in a British medical journal detailed the case of a male patient, 35 years old, X-rayed twice to see if he had a kidney stone. The twin exposures gave the luckless man a sore that, his attending physician reported, "had all the appearance of an acute irritative eczema, with exfoliated epidermis, and a profuse sero-purulent-discharge" that caused him much pain and discomfort.[257]

Initially, the only way for radiologists to gauge the dosage actually produced by the machines they used was to observe how the skin reacted. They did this by observing an “erythema dose”, defined as the amount of radiation needed to cause inflammation of the skin through injury or irritation. Skin damage, in other words, was measured by how red the skin became after the application of X-rays. The absence of scientific knowledge about the precise biological effects of radiation resulted in the co-production of dosimetry with radiation injuries. Initially it was difficult to tell whether the burns that X-ray practitioners and patients suffered

[257] Henry C. Drury, "Dermatitis Caused By Roentgen X Rays," *The British Medical Journal* (Nov. 7, 1896), 1377-1378.

resulted from electrical malfunctions or the rays themselves. However, from the very beginning of their use, evidence existed that the rays themselves constituted a source of danger – a source distinct from electrical short circuits in the machines that produced them. In the same year Elihu Thomson, a former Harvard-trained physicist who left academia to work for the General Electric Company, exposed the last joint on his left little fingers in a bid to prove that X-rays could harm the human body. He irradiated his finger joint for half an hour, at about an inch and a half from the X-ray tube, for a week. It then developed redness, pain and stiffness, and continued to display soreness and eventually a large blister into the next week.[258]

Despite the X-rays occasionally proved efficacious in treating some kinds of cancers and superficial skin lesions. But the complete picture of how radiation from X-rays or radium affected living tissue remained unknown, and researchers struggled to understand what it did or did not do.[259] In the first years of radiation use, for instance, medical researchers across the West and Japan labored under the assumption that X-rays, like ultraviolet light (sunlight) had disinfecting properties effective against bacteria, which eventually proved false. A key reason for this persistent lack of precise scientific understanding was the immense difficulty of calculating the amount of radiation present in a particular situation. This required the knowledge of several quantities, the accurate measurement of which all posed formidable obstacles in the first decades of the twentieth century: how much radiation did a certain source generate in a given space, after a certain period of time, and how much did a specific target absorb?

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[258] Ruth Brecher and Edward Brecher, *The Rays: A History of Radiology in the United States and Canada* (Baltimore: Williams and Wilkins, 1969), 89.

[259] See Chapter 1 of Kevles, *Naked to the Bone*.

Measuring the Invisible (II): Quantities

Chapter 2 discussed, with respect to state policy, how the dangers of overexposure to ionizing radiation from X-rays or radium had been common knowledge in medical and scientific communities since the earliest days of X-ray use. Radiation professionals knew the necessity of equipping their machines with shielding and to limit the amount of time they spent on their work. But in the first place, how could the authorities enact radiation protection measures at all? How did experts manage to issue guidelines for measuring radiation, an invisible substance that did not register on the human senses unlike, for instance, other invisible physical forces including gravity or temperature?

As also previously mentioned in Chapter 2, the creation and adoption of formal international standards for radiation dosimetry began in the 1920s. Dosimetry is a system of measurement to calculate the amount of ionizing radiation received by the human body, a "post-hoc estimation of exposure" first raised in regard to radiation workers when various Western European countries made committees and guidelines in the 1920s.[260] The International Commission on Radiation Units and Measurements (ICRU) emerged in 1925, out of the first International Congress of Radiology (ICR), held in London. At that session, ICRU attendees considered the need for a protection committee, which they established at a second congress of the ICR in Stockholm held in 1928. The outcome of this second congress was the unit of the roentgen, defined as the electric charge that resulted from ionization that occurred at a specific temperature and pressure, and the formation of a committee called the International X-ray and

[260] Susan Lindee, "Survivors and scientists: Hiroshima, Fukushima, and the Radiation Effects Research Foundation, 1975–2014", *Social Studies of Science* (March 9, 2016), DOI: 10.1177/0306312716632933.

Radium Protection Committee (IXRPC).[261] International efforts to make a common system of measurement for radiation of course produced specific local histories similar attempts to accomplish the same end – namely, a system of measuring the amount of ionizing radiation present in particular situations, and the effects it induced in life forms.[262]

Dosimetry's origins stem from a growing wave of concern in Western scientific and medical circles about radiation injuries in the first two decades of the twentieth century. Elihu Thomson had concluded, from his experiments, that "there is evidently a point beyond which exposure cannot go without causing serious trouble."[263] Almost a decade later, Thomson's conception of a maximum exposure point was reformulated by Arthur Mutscheller, a German-born physicist. In 1924 Mutscheller published an article in a U.S. journal of radiology. It described his idea of a "tolerance" dose rate for radiation workers that he judged – based on his personal observations of radiological physicians and technicians at work – to have no upper limit. The notion of tolerance, Mutscheller suggested, was appropriate for labeling an amount "which an operator can, for a prolonged period of time, tolerate without ultimately suffering injury."[264] Support for Mutscheller's proposal, as imprecise as that definition was, grew amongst his American colleagues. This eventually led, a decade later, to the U.S. Advisory Committee on X-

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[261] In exact terms: "the quantity of x-radiation which, when the secondary electrons are fully utilized and the wall effect of the [X-ray tube] chamber is avoided, produces in 1cm3 at 0oC and 760cm of mercury pressure such a degree of conductivity that 1 esu of charge is measured at saturation current." This technical definition and committees on ICRP history is drawn from R.H. Clarke and J. Valentin, "The History of ICRP and the Evolution of its Policies," *Annals of the ICRP*, ICRP Publication 109 (Elsevier: 2009), 78.

[262] J. Samuel Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century* (Berkeley: University of California Press, 2000).

[263] Percy Brown, *American Martyrs to Science through the Roentgen Rays* (Springfield, Ill.: Charles C. Thomas, 1936), 11.

[264] Arthur Mutscheller, "Physical Standards of Protection Against Roentgen Ray Dangers," *American Journal of Roentgenology* 13 (1925), 67.

ray and Radium Protection issuing a formal 'dose limit', or a maximum threshold for exposure to X-rays, in 1934, to wit, "the evidence at present available appears to suggest that under satisfactory working conditions a person in normal health can tolerate exposure to X rays to an extent of about 0.2 international roentgens (r) per day."[265]

Mutscheller's notion of the "tolerance dose" pointed to a pressing question: how could those who worked with radiation figure out safer, more precise ways of measuring the invisible tool they wielded – methods that did not involve exposing themselves to its potential harms? The hurdles involved in this were made higher by France and Germany utilizing different measurements for the roentgen.[266] The international roentgen unit decided at the 1928 congress of the ICR only provided a formula for measuring the physical quantity of radiation present; it did not measure the effect of ionizing radiation on people. To fill that gap, over the course of the twentieth century a variety of units emerged with the aim of measuring not only the amount of radiation present but also its biological effects – the rem and the sievert being two such quantities.[267] Radiation measurement involved a myriad of factors that affected its calculation: the source and type of radiation emitted, as well as the physical and biological properties of the material it passed through, including air. X-radiation and gamma radiation produced different values. In the case of radiology further complications arose from the use of different instruments

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[265] Clarke and Valentin, "The History of ICRP and the Evolution of its Policies," 87.

[266] The French and German roentgens were both denoted with a capital R; to avoid confusion with these older units, the ICR denoted the new roentgen in lowercase (r). See e.g. Chapter 2 of Tateno Yukio, *Hōshasen to kenkō* (Tokyo: Iwanami Shinsho, 2001), 32-33.

[267] Different terms (i.e. units) were needed to describe and quantify radiation in different situations – the rate of its emission from a source, the amount in air, and the amount absorbed by material it passes through. The complications of this system were intensified with the emergence of both International Standard (SI) units and U.S. customary units. For a detailed account of this conundrum see Chapter 6 of Lauriston Taylor, *X-Ray Measurements and Protection 1913-1964: The role of the National Bureau of Standards and the National Radiological Organizations* (Washington: U.S. Government Printing Office, 1981), 59-107.

made by different manufacturers. Even for X-rays, the degree of "hardness" of the rays affected how the irradiated subject would respond. Other factors to consider included the length and frequency of exposure.

The ICRU and IXRPC's proposed roentgen unit served the purposes of radiotherapy, where the crucial variable which required understanding was how much radiation soft body tissue exposed. The calculation of the roentgen became inaccurate when attempting to calculate the amount of radiation absorbed by either skin or bone (i.e. biological material with different densities).[268] Although Britain, the United States and the Netherlands adopted exposure limits for radiation workers in the 1910s and 1920s, actual protective measures took longer to develop. Individual radiological workers recommended the use of lead shielding over the glass tubes of machines from early on, but no formal standards for protective gear existed before the 1928 recommendations of the second International Congress of Radiology.[269]

Six Japanese radiologists attended the second international congress – the most attendees from any Asian country, and responded positively to these international attempts at standardizing measurements, which they shared with their colleagues back home.[270] Thus, although Japan was not at this time a recognized producer of international expertise on radiation, its radiologists were part of the circulation of this knowledge. Medical and technical journal articles had noted the need for better protection measures to shield practitioners from the harmful effects of X-rays

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[268] Cantril and Parker, "The Tolerance Dose," 1.

[269] Reproduced in various locations. See e.g. the International Congress of Radiology, "X-Ray and Radium Protection: Recommendations of International Congress of Radiology," *Radiology* 12 (June 1929), 519-524.

[270] The Asian countries present at this meeting were China, India, Japan, Java, and the Philippines. They sent 1, 3, 6, 1 and 1delegates respectively. For the full list of attending countries to the second congress see the editorial on the "Report From the Second International Congress of Radiology, Stockholm, July 23-27, 1928", *Radiology* 11 (Oct. 1928), 349-352.

from the 1920s onwards. At professional gatherings, the issue of standardized measurements and protection measures continually appeared. The persistent confusion over how to align physical quantities with observable biological effects remained, however, and individual practitioners submitted articles discussing their attempts to use particular instruments to measure different kinds of X-rays, whether for diagnostic or therapeutic purposes, well into the 1930s.

The sense of fear and unease that pervaded Western professional efforts to adopt radiation safety standards aimed at protecting professionals proved far more muted in Japan. Technicians – those who actually worked the X-ray machines – clearly expressed concerns in their professional journal, *Keikō* (*Fluorescence*). Radiological technicians submitted columns and essays that bemoaned their occupation's lack of recognition, and the need to protect themselves in the face of professional neglect from some of their more snobbish physician colleagues.[271] But on the whole, widespread awareness amongst Japanese radiation professionals about the possible negative effects of X-rays in Japan did not generate substantial attempts to increase protection for either themselves or their patients, even after the implementation of mass screenings for tuberculosis amongst the population at large from the late 1930s onward. Japan did not adopt formal national regulations on radiation protection until the late 1930s. In August 1937, the Ministries of Health and Communications issued two sets of guidelines that ordered operators of X-rays to observe specific guidelines in installing and using X-ray machines.[272] A

[271] Sugimura Tsuneo, "Shusse montō," *Keikō* 5:7(July 10, 1931), 27-31. See also the introductory essay by Hosoe Kenzō, chairman emeritus of the Japanese Society of Radiological Technology, on his failure to get Nakaizumi Masanori, an eminent radiology professor at the Tokyo Imperial University, to support the independent licensing of technicians. Hosoe Kenzō, "Taibō hisashiki gijutsushi no hakkan ni yosete", *Nihon hōshasen gijutsu shi*, 227-243.

[272] Full text of laws in the Nihon Eisei Kai, *Ekkusu-sen igaku no riron to rinshō*: Ministry of Home Affairs, Ordinance No. 32, Guidelines on the management of X-ray apparatuses for medical diagnosis and treatment, 3-6; Ministry of Transport and Communications, Ordinance No. 52, Guidelines on the measurement of X-Ray Quantities, 62.

national licensing system for radiological technicians also did not emerge until after WWII.[273]

Exposed Japanese Bodies

Radiological practitioners in every country were most at risk of developing radiation syndrome and associated cancers. They reported, as Elihu Thomson and many others did, on their symptoms. They also produced a large number of reports on the effects seen in patients and experimental subjects. The former category included amateur enthusiasts of X-rays. One of the earliest Japanese studies of X-ray skin burns, made in 1902, began with a case report of a 47-year old man, a former soldier in the first Sino-Japanese war of 1895:

> Born healthy, he became afflicted with syphilis at the age of 22 and recovered after 45 months. In Meiji 26 [1893] he developed hemorrhoids, bled copiously while in the military during the Sino-Japanese war; at that point he was merely diagnosed with bleeding from the transition he had made [from civilian to military life], and appears to be without pain and mostly recovered at present. His current ailments are traceable to his public demonstrations of X-rays at the World of Rarities in Asakusa Park from January 6 of this year, where he would take objects by his right hand and expose them to X-rays for about 2 minutes for about 50-60 times daily. Although initially nothing happened, after two weeks had passed his hand began feeling abnormally stiff, and his skin thickened and swelled. He had no pain or fever, but his palm turned a dark brown from February 23 onwards, and developed red spots. One week after that the color progressively darkened and he lost control of his hand's motor functions. In addition to this pain started, spreading a burning sensation across a large area, and his skin cracked…following which his symptoms continued to worsen…[274]

The luckless man's occupation in using X-rays as a performing spectacle for a company cost him the use of his right hand. Mizoguchi Kiroku, the doctor who saw this patient, further reported that his patient, at present time, continued to suffer from intense pain, stiffness in his hand, and shrinking of his thumb joints. Mizoguchi noted too that he went to Asakusa Park and

[273] Shimazu Seisakusho, *Shimazu seisakusho shi*, 60; Nihon Hōshasen Gijutsu Gakkai, *Nihon hōshasen gijutsu shi*, 41.

[274] Mizoguchi Kiroku, "X kōsen ni yurai suru kyūsei hifuen no ichirei," *Okayama igakkai zasshi* 150 (1902), 14-15.

investigated the strength of the electrical current and the physical features of the machine behind his patient's affliction, and found that it was smaller and produced weaker X-rays than the apparatus he used in his own practice. This case study foreshadowed subsequent research into the effects of continuous exposure to low-dose radiation on humans.[275]

Case studies in the above vein remained a staple of the medical literature for a decade or so following the discovery of X-rays. Initially doctors did not discern that radiation syndrome constituted a generalized affliction attributable to specific characteristics of X-rays or radium, even if its symptoms varied across individuals. In the U.S. and Western Europe, many doctors initially presumed that the effects of exposure depended on "individual disposition" or idiosyncrasy. A British medical textbook written in 1915, for instance, had a chapter on 'Idiosyncrasy and dosage' that featured 13 "radiologists of repute" offering explanations for the disparity in skin erythema suffered by different patients who had been exposed to similar radiation doses.[276] Idiosyncrasy formed a pillar of nineteenth-century Western medical thought, offering the idea that every patient possessed a specific physiological makeup that required explained why individuals exposed to similar sources of disease presented a range of responses (e.g. immunity versus illness).[277] Idiosyncrasy as a medical paradigm gradually faded as medicine acquired scientific characteristics from the late nineteenth century onwards – a trend

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[275] The LNT model is today often used in health physics and radiation protection studies to express the idea that the damage caused by radiation is linear and cumulative i.e. proportional to the dose; opponents of it have argued that low-dose exposure under certain conditions may actually stimulate the growth and health of organisms. For the public controversy in the United States over LNT see e.g. Kenneth L. Mossman, *Radiation Risks in Perspective* (Boca Raton, FL.: CRC Press, 2007), 53-55.

[276] Quoted in Mould, *A Century of X-Rays and Radioactivity in Medicine*, 176.

[277] For a discussion of idiosyncrasy see Carla C. Keirns, "Germs, Vaccines, and the Rise of Allergy," *Crafting Immunity: Working Histories of Clinical Immunology, eds. Kenton Kroker, Pauline Mazumdar, and Jennifer Keelan* (Burlington, VT: Ashgate, 2008), 77-106.

commonly understood as the shift to the laboratory and the hospital as the key sites of practicing medicine. Medical treatment adopted experimental methods for the detection of disease, while the hospital became a new center of clinical practice that provided empirical evidence for scientific modes of analyzing symptoms and signs in patients.[278] Scientific medicine took root in Japan as well, with the adoption of Western – primarily German – medical practices from the Meiji (1868-1912) period onwards. In Japan, prior to the Meiji period, Chinese medicine (*kanpō*) constituted the main form of medical treatment available to ordinary people, but the central government institutionalized Western medicine with the Regulations for Medical Practice (*Isei*) in 1874.[279]

Japanese researchers, like their European and American counterparts, began experimenting with X-rays and radium from the first years of the twentieth century. By the 1920s and 1930s, professional journal articles numbered in the hundreds, and regional chapters of medical radiation research societies emerged. Researchers tested radiation on an array of flora and fauna: human beings and domesticated animals constituted the majority of experimental subjects, with plants also making frequent appearances in the medical literature. This dovetails with the vast amount of research, particularly experiments on small and medium-sized animals, undertaken in during the first half of the 20th century until the immediate aftermath of WWII.[280] The goals of radiation experiments in Japan largely overlapped with those of their scientific and medical counterparts in the United States and Western Europe. From the 1900s onwards,

[278] See e.g. Andrew Cunningham and Bridie Andrews, "Introduction: Western medicine as contested knowledge," *Western Medicine as Contested Knowledge* (Manchester, UK: Manchester University Press, 1997), 1-23.

[279] For a concise description and references to further reading on the *Isei* see the entry by Roberto Padilla II, "Isei", *Japan at War: An Encyclopedia*, ed. Louis G. Perez (Santa Barbara, CA: ABC-CLIO, 2013), 468-469.

[280] William C. Inkret, Charles B. Meinhold and John C. Taschner, "A Brief History of Protection Standards," *Los Alamos Science* 23 (1995), 119. See also Chapter 9 of Mould, *A Century of X-Rays*.

Japanese medical journals, both general and radiology-specific, also printed abstracts of foreign-language research papers for the benefit of local colleagues who did not read English, German or French. Even a cursory review of the Japanese medical literature unearths dozens of experiments that used X-rays with the aim of better understanding particular populations. Medical researchers wielded X-rays as a diagnostic tool in the hope of illuminating ethno-national traits in the pathology of diseases in Japan, along with the physiology of the Japanese population, as well as the peoples of Japan's colonial territories. It is difficult to get accurate estimates of how many people within the Japanese empire were experimentally exposed to X-rays. In the 1930s, contemporary statistics suggest, mass screenings for tuberculosis irradiated as many as ten million people.[281]

Japanese radiological departments, in many medical schools and hospitals, lacked the status of an independent specialty. The practice of Western medicine in Japan was dominated by internal medicine and surgery, creating a hierarchy that relegated radiology, as an emergent field, to the margins. Although X-ray machines and imaging techniques were used in surgery, pediatrics, gynecology and dentistry, radiologists were not given equivalent status as their colleagues in the established disciplines. In the hospitals operated at medical universities, for instance, X-ray and radium treatments fell under the category of physical therapy (*rigaku teki ryōhō*). This term encompassed a range of physical treatments externally applied to the ailing body. In the Japanese context it included hot spring (*onsen*) baths, electrotherapeutic treatments (such as electroshock therapy to cure hysteria), and ultraviolet light exposure. One medical historian has described the American practice of electrotherapeutics as "a medical specialty that at the time mixed the bells and whistles of charlatans with respectable procedures", combining

[281] Johnston, *The modern epidemic*, 280-282.

medicine and performance.[282] The foregoing description also applied to the medical advertisements for ‘physical therapy’ gadgets of various kinds in Japanese newspapers and magazines of the period – including, for instance, an “Ozone-therapy” device supposedly of German pedigree. Nonetheless, physical therapy methods drew substantial attention and energy from licensed physicians, who enthusiastically commandeered *onsen* and light treatments to use on their patients. Elite doctors with the means to purchase radium and X-rays experimented with using them on patient with a variety of ailments. A monograph on leprosy treatments published in 1914 by one such doctor, Sugai Takayoshi, contained a section on the use of radiation from radium, *rentogen* and an evaluation of their efficacy in treating the disease; both methods, he concluded, were promising, but required more experiments. Radium in particular, he judged, could alleviate pain, and he recommended that patients take it via a mixture of baths, subcutaneous injections, and ingestion. How many of his patients or his colleagues could actually afford to procure what he noted as an “extremely expensive” (*atai no hanahada takai*) medicine, he does not say.[283]

Japanese radiological researchers also expressed concern over potential damage to the blood-forming organs, reproductive organs, and genes, similar to their counterparts in the U.S. and Western Europe. In 1924, Tsukamoto Tsuneo, a surgeon at the Japanese Red Cross (Nisseki) reported the earliest published case of cancer thought to be induced by *rentogen*. The patient, Tsukamoto said, was a 49-year old X-ray technician with a twenty-year career as a radiological worker. In 1904 he first began taking radiographs and conducting X-ray screenings at the Tokyo Army Garrison Hospital. In 1910 he transferred to the Red Cross hospital in 1910 to do the same

[282] Kevles, *Naked to the Bone*, 37-38.

[283] Sugai Takeyoshi, *Rai no chiryōhō* (Tokyo: Sanshūsha, 1914), 39-45.

work. In 1911 he added X-ray therapy to his list of professional duties. Subsequently, the backs of his fingers developed a burning sensation, turned red, and then a dark brown. From 1916 onwards, the palm of his right hand sprouted a series of hard, variously sized warts. Following this, persistent ulcers appeared on his palms and the backs of his fingers. Four years after the ulcers, he developed skin cancer on the ring finger of his right hand, which had to be amputated.[284] Tsukamoto's report on this unfortunate technician included the observation that tests on blood drawn from him ten times over a four-week period revealed no anemia or changes in white blood cell count. This led him away from concluding that long-term exposure to X-rays produced deleterious effects on the human body's capacity to produce blood cells. In fact, however, it is likely that the technician's blood-forming abilities had already failed at the time of testing; a later physician would note that the apparent absence of changes signaled extant damage to his bone marrow and other organs.[285]

The case of this technician is far from the most grisly of medical radiation casualties. Worldwide, radiological workers lacked knowledge about the chronic, cumulative effects of radiation exposure. If erythema burns did not result, the usual assumption made was that continuous irradiation posed no problems. Before the discovery that radiation disproportionately affected the normal growth of cells at an early stage of development, physicians experimented at will with irradiating pregnant women and their fetuses. Some doctors, like Sugai Takayoshi, considered X-rays a reliable method of preventing unwanted pregnancies. *Rentogen* rays, he said, "have the effect of shrinking the gonads (in humans, the sex organs that produce eggs and sperm),

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[284] Tsukamoto Tsuneo, "Rentogen ganshū no ichirei ni tsuite," *Rinshō igaku* 12 (1924), 435-451.

[285] Tateno, *Hōshasen to kenkō*, 82-83.

particularly on the ovaries, and therefore it can be used as a contraception method."[286] Some of Sugai's other medical colleagues, however, actually used *rentogen* to treat infertility, such as Suzuki Jinkichi, head of an obstetrics clinic in Tokyo. His practice during the 1930s and 1940s offered an infertility treatment that involved injecting the client with a contrast agent called molybdenol, before proceeding to screen their oviducts with *rentogen* to check for potential blockages.[287]

This brings us to the question of how we can know more about those who were screened. In general, the experiences of patients who received X-ray screenings or treatment in other countries suggests that it is likely to have been an unpleasant and bizarre process. Edward Morton remarked in his radiology textbook of "the difficulty of keeping the patient quite still" during the process of taking a radiograph.[288] This clinically detached observation glosses over the experiences of patients who had to be physically immobilized and sometimes cowed into staying still long enough for the radiologist to produce a picture of their insides with the X-ray apparatus. Indeed, X-rays presented a clear case of patients forced by medical practitioners to conform to the limitations of medical equipment, though one might also consider the practitioners prisoners of their own tools. In Matthew Levine's observations,

> The fragility of the tubes, and the fact that they were tethered to the sizable transformers or static generators that powered them, meant that they were largely immobile in early apparatuses. Consequently, patients, no matter how injured, were forced to conform to them. Bodies might be

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[286] Sugai, *Rai no chiryōhō*, 44.

[287] This information is taken from the memoirs of a midwife who was professionally trained in Western-style medicine during the 1920s. Nomoto Sumiko, *Atatakai osan – josanpu ichidai ki* (Tokyo: Shōbunsha, 1998), 78-79. The procedure is known in medical parlance as a hysterosalpingography, and combined both treatment by the injected contrast agent with the X-ray screening. I am indebted to the paediatrician Mihara Sayaka for this information and source. Personal communication, March 09 2016.

[288] Morton, *Text-Book of Radiology*, 106.

> slung headfirst over chairs, or strapped to boards and suspended by chains above the machine. In fluoroscopic examination, the doctor, too, had to adopt contorted poses. [289]

In addition to humans, a wide range of Japanese plants and animals joined their Western counterparts as sacrifices to hundreds of experiments across the first decades of the twentieth century. These experiments sought to discover the biological effects of ionizing radiation: to that end, plant researchers exposed a range of vegetable sprouts and flowering plants such as rice seedlings and geraniums and observed the impact of exposure on their developmental capacity.[290] Their animal researcher counterparts, in turn, experimented with a variety of domesticated species including chickens, mice, guinea pigs and frogs. Tsuzuki Masao, one of the leading lights of Japanese radiologists and a professor at Tokyo Imperial University, drew the interest of his Western colleagues with his X-ray experiments on rabbits in the 1920s.[291] In 1926 he managed to publish an English-language article in the prestigious *American Journal of Roentgenology and Radium Therapy* on three sets of such experiments, which he thus summarized:

> Normal rabbits were irradiated entirely by the hardest rays such as are employed in the so-called modern deep therapy, and the biological actions upon the internal organs were studied as to their variations from the normal.[292]

All three sets of experiments killed the animals. Their deaths occurred “sooner or later” (Experiment 1), “after intervals of from [sic] 15 minutes to 96 hours, counting from the beginning of the irradiation” (Experiment 2), and, in Experiment III, “were irradiated

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[289] See the second half of Chapter 2 of Levine, *First Atomic Age*, 74-84.

[290] See e.g. Yoshihama Kichizō, "Shokubutsu no hatsuikujō ni oyobosu 'rentogen' sen no eikyō ni tsuite," *Keikō* 5:5 (1931), 1-6.

[291] See also Lindee, *Suffering made real*, 24-26.

[292] Tsuzuki, “Experimental Studies”, 21.

continuously until they died." Tsuzuki also observed the physical symptoms of how the rabbits' health deteriorated following continuous irradiation: after a certain point, he said, "all animals look as if they were exhausted and gradually become thinner, frequently suffer from diarrhea, and their vital resistance is so much weakened that they die from the slightest injury. But few of them show power of recuperation." [293] Tsuzuki would later go on to be involved in the Atomic Bomb Casualty Commission as the chief Japanese scientist heading the team of researchers studying the biological effects of the atomic bombings. Many of his rabbits' symptoms formed an ominous precursor to his observations on the injurious effects of radiation from the bombings on the survivors of Hiroshima and Nagasaki, including diarrhea, weakness, and, for many, a swift death.[294]

Professional Attitudes Towards Radiation

The twentieth century's two world wars interrupted attempts to implement radiation protection measures internationally and nationally. Germany's defeat in both conflagrations gave American physicists and radiologists the upper hand, and they played key roles in the many experiments and attempts at measuring, quantifying and assessing radiation in the early twentieth century. These all shared a common assumption: that radiation was a tool that could be useful in the right ways, with the right precautions taken - even if the composition of the tool and the effects of its use remained essentially unknown. The persistence of ambiguity and uncertainty in the scientific understanding of radiation's nature did not stop scientists from projecting

[293] Ibid., 21-37.

[294] Atomic Bomb Casualty Commission General Report 1947, Appendix No. 9, "Report on the Medical Studies of the Effects of the Atomic Bomb", 71-74. See also Chapter 3 of Lindee, *Suffering made real*, 39-57.

confidence that they knew enough to wield it as an instrument for the greater good. This attitude is clearly seen, for instance, in a document written in 1945 at the Argonne National Laboratory in the U.S. "In the development of the science of radiotherapy," it begins, "a special nomenclature has grown up, which, for the most part, is clear and unambiguous to the doctors and physicists engaged in the field."[295]

In line with this confidence over harnessing a phenomenon whose precise character and consequences remained unknown, scientific and medical professionals constantly sought to mitigate or downplay the potentially harmful aspects of radiation. A key instance of this is the concept of a ‘tolerance dose’, which evoked the sense of radiation being unpleasant yet ultimately beneficial if appropriately used. Thus the Argonne National Laboratory’s 1945 report, also quoted in the epigraph, noted that:

> Webster has "tolerance" invariably a noun, the possible relevant meanings being (a) the act of tolerating, quality of being tolerant, or (b) constitutional or acquired capacity to endure a shock or poison, etc.[296]

It added that, for the purposes of its text, "tolerance dose will be assumed to be that dose to which the body can be subjected without the production of harmful effects."[297] The analogy with medicine here is clear. Yet this clearly assumed that there was a generalized, typical human body – one that, in practice, often turned out to be Caucasian, adult, and male.[298] In fact, as one medical historian aptly summarizes, evidence existed to support the argument that radiation was “harmful, but different for everyone.” An early source of this second stance came in 1927, when

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[295] S.T. Cantril and H.M. Parker, "Tolerance Dose," 2.

[296] Ibid., 3.

[297] Ibid.

[298] See the chapter on X-rays in Lisa Cartwright, *Screening the Body: Tracing Medicine’s Visual Culture* (Minneapolis: University of Minnesota, 1995).

the American geneticist Hermann Muller provided experimental proof of X-ray damage within the irradiated cells of *Drosophila* fruit flies. Muller's experiments clearly indicated that radiation could potentially harm all living beings.[299] Later generations of doctors and scientists would also point out that the ICRP's regulations only accounted for the body's external exposure; no accurate reckoning of radiation risk to any particular person could come without also estimating the amount of internal exposure they received from ingested radioactive substances.[300]

A curious juxtaposition appears in the history of American medical literature on radiation: a plethora of discoveries about and research into the harmful side effects of X-rays sits alongside a persistent reluctance to discuss its potential deadliness. On the one hand, deaths *directly* attributable to X-irradiation made up a fraction of the thousands of deaths, prior to 1945, from epidemics and industrial accidents. On the other, a link between X-rays and cancer existed from the first year of their discovery.[301] These observations, in large part, also proved true of the Japanese case. The distinguishing characteristic of medical radiation exposure as an iatrogenic phenomenon – that is, an affliction that emerges in the process of medical care – was the duration that symptoms of chronic exposure took to manifest. This undoubtedly contributed to the reluctance to acknowledge the life-threatening nature of this technology. Perhaps, too, something of the mystique of radiation in the public eye also spilled over to the experts who studied and used it.[302] While many medical and scientific reports made their observations in

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[299] Kevles, *Naked to the Bone*, 89-90.

[300] A recent articulation of this point from Japanese researchers appears in Koide Hiroyuki and Nishio Masamichi, *Hibaku rettō: hōshasen igaku to genshiro* (Tokyo: Kadokawa, 2014), 28-31.

[301] Tateno Yukio, *Hōshasen to ningen* (Tokyo: Iwanami Shinsho, 1974), 123-136. This point about the persistence of neglect alongside the knowledge of harm (and the concurrent need for protection) is also made in Kevles, *Naked to the Bone*, 123-124.

clinical, highly technical language, affective remarks occasionally broke through this detachment. Tsuzuki Masao, for instance, was moved to describe the ravaged spleen cells of his rabbits in the following manner:

> Spleen: Hyperemic to a high degree, literally full of chromatin granules; all lymphocytes in the follicles are destroyed completely, also lymphoblasts. So many chromatin granules lie scattered about as to resemble stars in a clear summer sky.[303]

The mixture of scientific and poetic writing in this excerpt from Tsuzuki's research arguably marks its origins in the era before the threat of nuclear war appeared. Growing fears about radiation had provoked the earliest international attempts to adopt safety standards, as well as to regulate and quantify its dosage. In the 1950s the Atoms for Peace movement, led by the Eisenhower government in the U.S., strove to build Cold War alliances against the U.S.S.R. through the promotion of U.S.-supplied nuclear power infrastructure and radioisotopes for use in medicine and industry. In part this aimed to counter the fears about radiation that peaked in the post-WWII period with atmospheric testing fallout.[304] But the framing of radiation risk in positive terms began long before the global propaganda of the Atoms for Peace movement in the 1950s.[305] Attempts to quantify radiation as a physical and biological phenomenon in the first decades of the twentieth century preceded the formation of a discipline eventually called "health

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[302] For a study of radiation culture in Japan before WWII see Nakao Maika, *Kaku no yūwaku: senzen Nihon no kagaku bunka to 'genshiryoku yūtopia' no shutsugen* (Tokyo: Keiso Shobo, 2015).

[303] Tsuzuki, "Experimental Studies," 26-27.

[304] See e.g. Barton C. Hacker, *The Dragon's Tail: Radiation Safety in the Manhattan Project, 1942-1946* (Berkeley and Los Angeles: University of California Press, 1987).

[305] For a recent perspective on the history of the Atoms for Peace program in Japan see Craig D. Nelson, "Nuclear Society: Atoms for Peace and the Origins of Nuclear Power in Japan, 1952-1958," Ph.D. dissertation, Ohio State University, 2014.

physics" – a field devoted, in the words of one of its official societies, to "managing the beneficial use of radiation while protecting the public and its workers from potential hazards".[306]

Evaluating Radiation's Dangers

As mentioned at the beginning, dosimetry was co-produced alongside radiation injuries. Creating a system of measurement for this invisible phenomenon required the systematic irradiating of biological organisms to the point of damage or death. In the latter half of the twentieth century, shifts in units and terminologies to some extent also reflected changes in conceptions of life and the limits on what lives could be exposed to radiation in the name of science, medicine or progress. A milestone in this trend is the 1960s, starting in the U.S., where the emergence of what is now called bioethics set guidelines for animal testing, along with prohibitions on human testing.[307] Decades after the end of WWII, exposes on the biological effects of the nuclear attacks on Japan and the human radiation experiments conducted by the U.S. on its own citizens raised deep public concerns about the potential harms of radiation. In turn, these provoked both American and Japanese authorities to respond with a mix of propaganda and new regulations on radiation use.[308]

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[306] See e.g. Thomas E. Johnson and Brian K. Birky, *Health Physics and Radiological Health*, 4th edition (Baltimore, MD.: Lippincott Williams & Wilkins, 2012). Definition of "health physics" taken from the Health Physics Society, https://www.hps.org/ (accessed September 24, 2015).

[307] An introduction to bioethics policy in the U.S. can be found in Daniel Callahan, "Bioethics and Policy—A History," *From Birth to Death and Bench to Clinic: The Hastings Center Bioethics Briefing Book for Journalists, Policymakers, and Campaigns*, ed. Mary Crowley (Garrison, NY: The Hastings Center, 2008), ix-x. For a useful primer on animal experimentation regulations in the U.S. see Stephen R. Latham, "U.S. Law and Animal Experimentation: A Critical Primer," online supplement to the *Hastings Center Report* 42:6 (2012). http://animalresearch.thehastingscenter.org/report/u-s-law-and-animal-experimentation-a-critical-primer/ (accessed September 30, 2015).

[308] On this topic see the expanded edition of the seminal work by Nakagawa Yasuo, *Hōshasen hibaku no rekishi: Amerika genbaku kaihatsu kara Fukushima genpatsu jiko made zōhō* (Tokyo: Akashi Shoten, 2011).

Before Hiroshima and Nagasaki, as well as atmospheric nuclear testing, the risks from using radiation were primarily considered an occupational hazard. Initial efforts to create international standards of quantifying ionizing radiation stemmed from concerned medical and scientific personnel who used it in their professions. Not until the post-WWII period did global concerns about civilian exposure to ionizing radiation arise. Historicizing the use of radiation in Japan lends a crucial context to Japanese positions on nuclear energy after 1945. At the same time, it also problematizes the notion of a unique Japanese experience of nuclear energy by following a trans-national trail of research activities and exposed bodies in the decades before the atomic bombings of Japan.

Early attempts to limit X-ray exposure did not arise from a quantitative, scientific observation of their biological effects. Instead, the thresholds proposed stemmed from an apparent absence of observable biological harm.[309] Moreover, confining the risk of radiation injury to professionals created a tendency to normalize this risk as an occupational hazard, a risk taken on by radiologists in the full knowledge that their work was potentially dangerous. This led to the eulogizing of the medical and scientific 'martyrs' who sacrificed their health and lives in the cause of advancing their fields of knowledge. Even during the Cold War period, the prestige attached to the radiological martyrs largely protected medical radiology from attracting the stigma of war and mass death attached to nuclear weapons. Across the 20th century, Japanese newspapers and magazines aimed at a mass audience provided a wealth of positive images of radiation as regards its putative medical powers. These positive images propagated did much to keep medical overexposure in the shadows of public awareness.

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[309] Inkret, Meinhold and Taschner, "Protection Standards," 118.

The politics of what is today called radiation risk management – a theme which the epilogue will discuss in more detail – continue to reflect concerns that date back to early attempts to quantify and to assess the effects of radiation on living beings. The primary difference is that much of today's discourse is conducted under the rubric of "health" management, and the targets of safety measures include not only professionals working with radiation, but the targets of that radiation. During the Cold War, the risk faced by the civilian public in times of bomb tests or nuclear accidents became a new locus of general anxieties. In the case of medicine, the risk that patients faced when undergoing treatment or diagnostic scans raised similar concerns.

The East Asian experience of utilizing medical radiation deserves consideration given that the average body presumed to be the model for radiation effects was a Caucasian, often male, one. The original erythema dose applied only to Caucasian skin, with its relatively low melanin content, and varied geographically as well as ethnically; in the U.S. context, for instance, it proved completely ineffectual at judging exposure in African-Americans.[310] Across the twentieth century, though, radiologists' patients and the general public expected that those who possessed the keys to the scientific and technical manifestations of X-rays knew what they were doing: that they understood how to handle their machines, control their dosage, and prevent the rays from causing harmful biological effects in humans.[311] The professional literature of the first half of the twentieth century, however, gives the lie to these former certainties. This situation proved true in East Asia as well as Western Europe and the United States. A half-century after radiation workers became alarmed about the occupational hazards they faced, public sentiment had also

[310] For a discussion of racial issues and medical radiation see Rebecca Herzig, "The Matter of Race in Histories of American Technology," *Technology and the African-American Experience: Needs and Opportunities for Study*, ed. Bruce Sinclair (Cambridge, MA: Massachusetts Institute of Technology, 2004), 155-170.

[311] Observations drawn from the material in Part I of Kevles, *Naked to the Bone*.

acquired similar concerns, associating X-rays in medical diagnosis and treatment with an increased risk of cancer and leukemia. How the calculus of risk in using medical radiation shifted from positive to negative over the course of the late twentieth century is another question that deserves further investigation on the side of experts.[312] Pursuing an answer to this same question from the angle of popular culture, Chapter 5 examines how Japanese newspapers and magazines aimed at a mass audience provided a wealth of positive images of radiation as regards its medical powers – images which were often furnished by doctors and medical instrument manufacturers.

[312] Tateno, *Hōshasen to kenkō*, 201, 229.

Chapter 5
<u>Radiation in Print: Mediated Science</u>

The invisibility of X-rays posed no impediment to their penetration of popular consciousness during the first decades of the twentieth century. Those who traded in words used various means to make them visible to the imagination, if not the eye. In Europe and America, the discovery of X-rays garnered intense interest in the commercial press, and they soon became the subjects of scientific journalism and salacious material. One historian remarks that the discovery of X-rays "was one of the nails in the coffin of Victorian prudery", and occasioned much speculation on the prospects for discerning that which outer- and under-garments kept in genteel concealment.[313] Specialist monographs and articles abounded amongst scientists, doctors, and technicians, but a non-expert audience also had plenty of reading material. Decades before concerns about public health led to the implementation of mass screenings for tuberculosis in 1940s Japan, as discussed in Chapter 1, newspapers and popular magazines were already disseminating a wide range of information about "the new kind of ray" for their readers to access. In addition, via these same mediums, a range of companies marketed their products to the public as consumers, and the same public could also learn about scientists conducting public experiments that strove to demarcate science from sorcery.[314]

X-rays were often called "Roentgen rays" in Europe and America, and they had even more alternative names in Japanese: *rentogen*, *ekkisu/ekkusu sen*, *X hōsha/hōsan sen* and various other permutations. This chapter traces the ways in which knowledge about *rentogen* was made

[313] Kevles, *Naked to the Bone*, 221.

[314] Nakao Maika, "'Kagakusha no jiyū na rakuen' ga kokumin ni hirakareru toki STAP/senrigan/renkinjutsu wo meguru kagaku to majutsu no shinfonī," *Gendai shisō* 42 (12), 146-159.

accessible to general audiences through various forms of mass media across the first half of the twentieth century. Focusing primarily on newspapers and magazines, it explores how popular publications presented radiation to a general readership. The two main forms of radiation that captured media and public attention in Japan, as in America and Europe, were X-rays and radium. But as mentioned in the introduction, the focus here primarily centers on the former. Radium's popular image overlapped with that of X-rays in some ways, but not entirely, and deserves a fuller analysis than is possible in this work.

The advent of atomic weapons shifted the stakes of popular discourse on radiation in the early postwar period, presenting nuclear energy – particularly in the Japanese context – as a source of destruction. But continuities in the framing of radiation as a tool of science and medicine provided a hefty counterpoint to that understanding. This is borne out by examining the information, ideas and images available for public perusal in the prewar period. What kinds of materials were available, when, and for whom? The implementation of compulsory education facilitated the growth of a commercial press circuit at national and municipal levels. While, as other scholars have noted, there is no incontrovertible proof that a person who graduated from six years of elementary school would certainly read newspapers, the increase in correspondence with editors, for instance, shows that the daily press had acquired a wide and diverse readership.[315] Newspaper publishing was in full swing by the start of the twentieth century, and provided a crucial medium for the creation of a broad reading public therewith.[316] Periodicals entered a similar boom from the 1920s onwards, especially those with lasting print runs and an

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[315] Carol Gluck, *Japan's Modern Myths: Ideology in the Late Meiji Period* (Princeton, N.J.: Princeton University Press, 1985), 173.

[316] Ibid., 68, 232-3.

established readership such as the entertainment magazine *King*.[317] An exhaustive survey of the vast array of printed material generated in these decades is beyond the resources of a single researcher working to a publication deadline. But even so, it is still possible to glean some insights from the material in major newspaper and periodical publications that commanded fairly broad readership bases. A focused examination of a few publications also gives a sense of each publication's individual flavor and character. The primary sources sampled here are a) two major dailies: the *Asahi shimbun* and the *Yomiuri shimbun* newspapers and b) two major magazines: *Taiyō* (*The Sun*), a semi-monthly publication that dealt with current events, commerce, the arts, and general knowledge; also the *Kagaku gahō* (*Science Illustrated*) periodical, a popular science magazine primarily aimed at older schoolchildren and interested adult readers. The *Asahi* and *Yomiuri* both began running in the late nineteenth century – 1879 and 1874 respectively – and are still in print today. *Taiyō* ran from 1895 to 1928, while *Kagaku gahō* ran from 1923 to 1961. Between these four selections, along with other sources introduced later in the chapter, a broad picture of *rentogen* and X-radiation in the popular imagination emerges.

How broad an audience did these publications reach? In terms of circulation figures, one scholar estimates the Tokyo *Asahi* and *Yomiuri* to have reached 158,209 and 70,000 readers by 1915, respectively.[318] Like most popular magazines in Japan before World War II, it is difficult to pin down precise figures for sales in the period up to 1945. However, *Taiyō* claimed a national

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[317] See e.g. Nakamine Shigetoshi, *Zasshi to dokusha no kindai* (Tokyo: Nihon Editor's School Shuppansha, 1997), 21-30, as well as chapters 3-4 and 6 for analyses of the impact of *Taiyō*, *Chuō kōron* and *King* in the Meiji to early Taisho periods.

[318] "Asahi" may be translated as "Morning Sun"; "Yomiuri" literally translates to "Reading and Selling", and derives from the early modern Japanese term for an itinerant messenger who read aloud the events of the day to public audiences from a condensed set of printed matter. On newspaper circulation statistics see James L. Huffman, *Creating a Public: People and Press in Meiji Japan* (Honolulu: University of Hawa'ii Press, 1997), 386-387; see also Nakao Maika, *Hōshanō no tankyū kara genshiryoku no kaihō made – senzen Nihon no popyurā saiensu* (Ph.D. diss., University of Tokyo, 2015), 15-16.

circulation of "almost 150,000 copies" in 1900, which would have been double that of the *Yomiuri's*, earlier mentioned.[319] In the case of *Kagaku gahō*, data from the U.S. occupation forces shows it acquired a circulation of around 50,000 copies by July 1946, just under a year after Japan's surrender, a figure which likely corresponds to its popularity in the pre-1945 period.[320]

What observations can be made from the welter of printed reports on the radiation of *rentogen* and radium in this period? The late nineteenth and early twentieth centuries have been evocatively termed "a period of commonplace wonders" in which human society witnessed a welter of landmark discoveries in the physical and biological sciences: X-rays, radioactivity, the electron, relativity, the nucleus, nuclear fission, to name some of the best-known examples.[321] In the United States, radiation from X-rays and radium in particular generated journalistic crazes that fed the curiosity of a general reading public, what one historian aptly calls "radiomania". In Europe as well as the United States, fantasies and fears about radiant energy abounded in the first few decades of the twentieth century.[322]

In Japan, too, newspapers shared in circulating glowing first reports of the epoch-making discovery of X-rays. Later reports would laud Japanese scientists and doctors who worked with radiation technology as researchers on the frontlines of modernity. Although not lacking in

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[319] From the company blurb printed at the beginning of the magazine's English-language section. *Taiyō* 7:2 (December 20 1900), 1.

[320] For a brief discussion of the popularity of *Kagaku gahō* and its related magazines see Mizuno, *Science for the Empire*, 144-5 and endnotes 5 and 6. On science magazine circulation statistics see Maika Nakao, "The Image of the Atomic Bomb in Japan Before Hiroshima," *Historia Scientiarium* 19:2, 121-122. Figures on popular science magazines in the immediate postwar period from Wakamatsu Yukuo, "'Kūzen zetsugo' no kagaku zasshi būmu," *Tsūshi Nihon no kagaku gijutsu*, Vol. 1, eds. Nakayama Shigeru, Gotō Kunio, Yoshioka Hitoshi (Tokyo: Gakuyō Shobō, 1995), 340-341.

[321] Peter Broks, *Understanding Popular Science* (Maidenhead: Open University Press, 2006), 39.

[322] Lavine, *The First Atomic Age*, 26; Weart, *Nuclear Fear*, Part One.

coverage of discoveries, inventions, and installations of advanced equipment in local institutions, the Japanese press and its readers produced far less of a "craze" compared to America and Europe – where, as Spencer Weart and other historians of nuclear culture have shown, fears and fantasies about the transformative and destructive powers of radiation and radioactive materials ran rampant long before the advent of nuclear weapons.[323] Nonetheless, a steady current of news about radiation science and technology circulated between 1895 and 1945 – a period that begins with the year of Roentgen's discovery and ends with World War II. One index of this is that the *Asahi* and *Yomiuri* newspapers published several hundred articles related to those topics.[324] In addition, scientific journalism aimed at younger readers also furnished a wealth of news about experiments and technological innovations with X-rays. The *Kagaku gahō*, one of the most widely read popular science magazines in pre-war Japan, is an important instance of publishing genre. It targeted an audience of adolescents and older readers, and on the subject of X-rays, often featured write-ups showing giant X-ray apparatuses and a broad variety of radiographs on its pages.

The earliest media reportage of X-rays in Japan appeared in 1896, a few months after Roentgen's discovery became public in December 1895.[325] The *Jiji shimpō*, a progressive daily founded by the prominent liberal educator Fukuzawa Yukichi, carried the first article on the

[323] See the first four chapters in Part I of Weart, *Nuclear Fear*; also Chapter 2 of Levine, *First Atomic Age*.

[324] Asahi Shimbun, *Kikuzō bijuaru*; Yomiuri Shimbun, *Yomidasu rekishikan* online databases. Accessed via Harvard University, December 2014. Asahi keyword search retrieves 1848 articles and advertisements done with the terms レントゲン+放射線+Ｘ線+Ｘ光線; Yomiuri search with the same terms retrieves 136 for レントゲン, 434 for 放射線, 259 for Ｘ線 and 44 for Ｘ光線. For both searches there is some overlap between the articles retrieved, and not every use of the term 放射線 is related to X-rays or radium; nonetheless, this still leaves the total number of articles retrieved in the hundreds.

[325] Roentgen made his discovery in November 1895, but only published a paper the following month, and reported to a Wurzburg congress of physicists and doctors in January 1896. See e.g. Otto Glasner, *Wilhelm Conrad Röntgen and the Early History of the Roentgen Rays* (San Francisco: Norman Publishing, 1993), 16-29.

“new kind of ray” in March 1896 (drawing its information from the British *Daily News*).[326] There soon followed, amongst others, reports by the Osaka *Mainichi shimbun*, as well as the Tokyo *Asahi shimbun* and the *Yomiuri shimbun* in April of the same year.[327] Gotō Gorō, appointed the first professor of radiology at the Kyoto Prefectural University of Medicine in 1928, and the most eminent historian of his own profession, remarked that the *Jiji shimpo*’s piece had caused "the various newspapers began running articles on *rentogen* as a wondrous phenomenon (*kimyō na genshō*), which greatly contributed to the enlightenment of the masses".[328]

Rentogen, as a phenomenon of the mass media, entered a media environment already saturated with print material, and with texts on science and technology aimed at a general readership. Japanese historians of science identify the latter kind of texts as a recognizable publishing trend around 1887. Many of them were serial magazine publications with a somewhat limited print run, and whose titles, such as *Young Nationals* (*Shō kokumin*) and *Garden of Youths* (*Shōnen en*) point to their target audience.[329] In the late Meiji period, this mostly consisted of children in compulsory education, and the publications produced for them may be considered extra-curricular material meant to supplement what they received from school textbooks.[330] The

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[326] Honda Ichiji, "Jiji shimpō no kagaku hōdō," *Fukuzawa Yukichi nenkan 5*, ed. Fukuzawa Yukichi kyōkai (Tokyo: Fukuzawa Yukichi kyōkai, 1978), 155. For a concise overview of Fukuzawa’s many contributions to modern Japanese history see the entry at Keio University, “Keio Founder Yukichi Fukazawa,” http://www.keio.ac.jp/en/about_keio/fukuzawa.html (accessed December 10, 2014).

[327] The *Asahi shimbun* used in the footnotes all refer to the Tokyo edition of the newspaper unless otherwise stated.

[328] Gotō Gorō, "Sanransen honpō nikkan shinbun ni hōzerareta rentogen sen no hakken," *Rinshō hōshasen* 8:4(1963), 308-312.

[329] “Kagaku gijutsu jānarizumu no seiritsu,” *Nihon kagaku gijutsushi taikei*, Vol. 9, ed. Nihon kagakushi kai (Tokyo: Dai Ippoki Shuppan, 1965), 149.

first four sections provide historically contextualized overviews of the main features found in the mass media presentation of *rentogen* in four broad periods from 1896 to 1944, just before the atomic bombings. Following that, the themes of magic and gender are singled out for analysis before concluding.

War, Science and Progress: 1890s to 1910s

In the newspapers, the first decade and a half saw a light but steady stream of *Asahi* and *Yomiuri* coverage on Wilhelm Roentgen's "new kind of ray". Many of these pieces reported on the progress of X-ray and radium science in Europe and America, as well as the efforts of Japanese scientists, doctors and government institutions to experiment with the new kinds of rays, and to obtain the machines which made it possible to do so. *Taiyō*, which began running in 1895, carried brief but regular reports on X-ray experiments conducted by researchers in Germany, England, France and America, such as the taking of photographs "that reveal the concealed" (*kenpi* 顕秘) – i.e. radiographs – for various purposes, including forensic evidence in court cases.[331] *Taiyō* printed a constant trickle of reports on new experiments and news for the first year after the new rays came to light, but switched to far more intermittent coverage of their applications in industry and medicine from 1897 onwards.[332]

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[330] In 1886, building on earlier laws, the Meiji government introduced a 9-year program of compulsory education, along with several orders that created systems of elementary, middle and higher education. For a concise but also detailed overview of trends in Japanese education since the early modern period see Choja Oduaran and Atsuko Kusano-Tsumoh, "Contexts and challenges of widening access to education in Japan," *Widening Access to Education as Social Justice: Essays in Honor of Michael Omolewa*, eds. Akpovire Oduaran and H.S. Bhola (Dordrecht: Springer, 2006), 284.

[331] "Kenpi shashinjutsu no shiken," *Taiyō* 2:9 (May 5, 1896), 162-164; also reports on X-rays in Vol. 2, issues 14 (July 5), 16 (August 5), 18 (September 5), 23 (November 20), 24 (December 5) for the year 1896. The forensic evidence in court refers to issue 16, "X hōsansen no ōyō ni ken," 175-176.

As discussed in Chapter 1, the military medical establishment was one of the first institutions to make use of X-rays, which also showed in newspaper coverage. The *Asahi* and *Yomiuri* both carried pieces on the military acquisitions of *rentogen* equipment for their hospitals.[333] The military also furnished a turning point in journalistic contributions to popular science. This came in Japan's victory over Russia in the Russo-Japanese War of 1904 to 1905. Despite a victory hard-won with a heavy casualty count on both sides, the peace settlement that concluded the conflict brought Japan none of the things it had hoped to acquire in terms of reparations or territorial gains on the Asian mainland.[334] This precipitated a period of intense popular violence that lasted until the so-called "rice riots" of 1918, with tens of thousands of people in Tokyo rioting in the streets. Hundreds got injured or arrested; the insurrections claimed at least twenty fatalities, and induced four changes of cabinet.[335]

The war changed the stakes of science by demonstrating its indisputable importance to the institutions of the nation-state.[336] It also changed the tenor of scientific reporting, and led to the inclusion of radium as a key component of news coverage. One indicator of the former point was the appearance of a new column titled "Scientific Possibility" that appeared in the Yomiuri

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332 From 1896 to February 1897, almost every issue of *Taiyō* carried an article about X-rays under the category of "science" (*kagaku*). From March 1897 onwards the column on "science" disappears and reports on X-rays from then on are mostly slotted into the category of "industry" (*kōgyō*).

333 E.g. "Rikugun no ekkisu kosen ki chumon," Asahi shimbun, November 30 1900, 1; "Doitsu sekijuji sha no atsui," Yomiuri shimbun, July 1 1904, 2. The former report is about the army's ordering of X-ray machines; the latter report is about the German Red Cross's donation of an X-ray machine to the navy during the Russo-Japanese war.

334 For a concise overview of the war see the entry on the official website of the Office of the Historian, U.S. State Department, "The Treaty of Portsmouth and the Russo-Japanese War, 1904-1905 – 1899-1913 - Milestones," https://history.state.gov/milestones/1899-1913/portsmouth-treaty (accessed March 15, 2015).

335 Andrew Gordon, *Labor and Democracy in Imperial Japan* (Berkeley, CA: University of California Press, 1991), 26-27.

336 See e.g. Chapter 13 of Okamoto Takuji, *Kagaku to shakai: senzenki Nihon ni okeru kokka gakumon sensō no shosō* (Tokyo: Saiensu, 2014), 126.

right after the end of the war, on September 15, and which ran for three months until December 3 of the same year. The column occupied a full page of the newspaper with stories about the triumphs of modern science. The company explained in an advertisement for the column that it was inviting specialists to discuss "the possible range of the power of science in the present and future" on a variety of topics from metallurgy to agriculture and astronomy. This column was one of the earliest science columns to appear in a major newspaper, and prefigured a general boom in similar serializations within other papers. The *Yomiuri* and its fellow publications provided conduits for scientists to communicate with non-specialist audiences, whether to educate or speculate about science and technology. Nagaoka Hantarō's musings in the "Scientific Possibility" column on the likelihood of a future where the atom's energy could be used to generate power on the scale of several thousand tonnes of coal occurred in this very context.[337]

Newspapers were becoming increasingly mercantile. In 1910 the political commentator and literary critic Yamaji Aizan acerbically observed that "newspapers today are commercial products…their aim is to increase sales and profits" – in contrast, Yamaji thought, to the more enlightened newspapers of yore.[338] One way in which papers accrued sales and profits was to generate revenue from the increasing placement of advertisements in their pages.[339] The *Asahi* from the 1910s onwards, for instance, printed a high number of advertisements for private hospitals and clinics that offered X-ray screenings and diagnoses. These advertisements mark the

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[337] The observations about the Yomiuri column and the importance of the Russo-Japanese war in this paragraph are borrowed from Nakao, *Hōshanō no tankyū*, 70-73.

[338] Yamaji Aizan, "Tokyo no shinbun kisha oyobi shinbun keieisha," *Taiyō* 16:1 (February 1, 1910), 39.

[339] For instance, the *Ōsaka Asahi* more than doubled the advertising revenue it earned in the five years between 1905 and 1910. For more on the burgeoning business enterprise that journalism was growing into during the first two decades of the twentieth century see Huffner, *Creating a Public*, especially Chapter 10, "Leading a Public".

gradual appearance of X-rays in the lineup of medical services offered by private medical establishments.

These newspaper advertisements provide a fascinating avenue into examining the establishment of private medical practices by doctors newly trained in modern Western medicine during Meiji and Taisho Japan. Not all these practices were new, and some had relatively distinguished pedigrees. The Rakuzandō hospital in Asakusa, for instance, had opened in 1887 to serve the poor of that district, and its founder, Uno Hogara, was a distinguished pioneer of surgery and dermatology of Tokyo Imperial University pedigree.[340] A 1915 advertisement in the *Asahi* shows that Rakuzandō had added X-ray diagnosis to the list of its services, the large size of the font a striking reminder of the newness and relative scarcity of this medical technology at the time. (Figure 5-1)

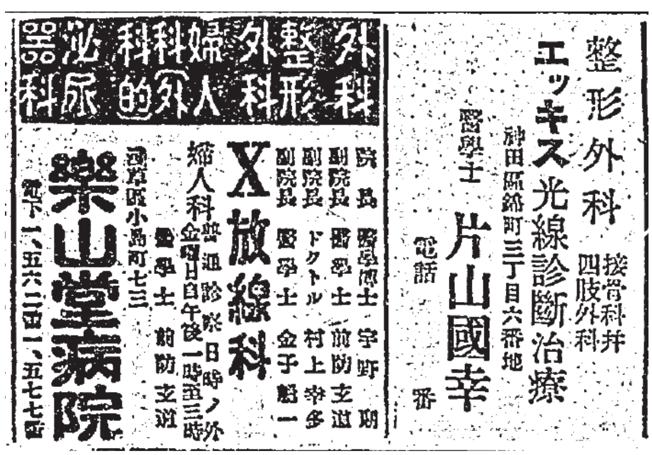

Figure 5-1. Advertisements for X-ray screenings at Rakuzandō Hospital (left) and a one-doctor clinic (right) *Asahi Shimbun*, 1915.[341]

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[340] On Uno Hogara see Doi Keizō, "Uno Hogara sensei den," *Hifu byō baidoku sanroku*, ed. Doi Keizō (Tokyo: Nanzandō, 1911), 335-336; also the entry on the official website of Mishima City, Shizuoka, "(Dai 122-gō) ~Mishima shuku no ike nidai~ Uno Tōmin, Hogara fushi to 'seisō jiraku'", http://www.city.mishima.shizuoka.jp/ipn000111.html (accessed March 3, 2015).

[341] *Asahi shimbun*, August 12 1915, 7.

In comparison, the *Yomiuri* over the same period carried almost no sorts of these medical advertisements. This suggests that the *Asahi* was viewed as a better medium for advertising to potential clients of these establishments. Both newspapers, however, carried advertisements for medical instruments aimed at both individual and corporate consumers. By the 1920s, *rentogen* were fixtures of military medicine within the Imperial Army, but modern medicine had also acquired a flourishing private sector, an indicator of which is furnished by the advertisements that hospitals and manufacturers sometimes placed in newspapers, to attract potential patients and purchasers.[342] Medical establishments which boasted *rentogen* and radium facilities or machines took care to highlight this fact.

Owing to cost, such machines and facilities were still a relative rarity in this period, even after the Kyoto-based Shimazu Corporation built the first domestically made *rentogen* apparatus in 1909.[343] A 1915 dispatch from France penned by Shimazaki Tōson, one of twentieth-century Japan's most influential poets and novelists, suggests that Japanese X-ray machines were not yet, in the 1910s, up to European standards.[344] Tōson, interested in public health and modern hygiene, toured the modern facilities at the Paris branch of the Japan Red Cross hospital, an establishment that served as Japan's contribution to aiding the Allies in World War I.[345] There Tōson described viewing a freshly developed radiograph of a broken bone, and noted a remark by Dr. Shiota, the

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[342] See e.g. an article on the request of the Imperial Army hospital for government funds to acquire rentogen machines for 40 of its branch hospitals over 6 years. "Rentogen secchihi yōkyu rikugun tsuika yosan ni," *Asahi shimbun*, April 6 1924, 2.

[343] Installed in the Kōnodai Garrison Hospital, Chiba Prefecture. See Nihon Hōshasen Gijutsu Gakkai, *Nihon hōshasen gijutsu shi*, 344.

[344] For a study of Tōson's work in the context of modern Japanese history and nationalism see Michael K. Bourdaghs, *The Dawn That Never Comes: Shimazaki Tōson and Japanese Nationalism* (New York: Columbia University Press, 2003).

[345] See the discussion of Tōson's 1906 novel *The Broken Commandment* (*Hakai*) in ibid., 47-76.

surgeon who took his around, that "*aside from the X-ray machine* there was nothing that they were not able to bring from Japan". [italics added][346] Japanese manufacture of the machines for medical use did not take off until after WWI, so the news coverage of X-ray machine parts and machines up to the late 1920s, as discussed in Chapter 2, reported for the most part on overseas innovations, such as the Coolidge tubes patented by William D. Coolidge of the General Electric corporation in 1913, and the licensing of patents by Japanese manufacturers.[347]

Contraptions and Commodities: 1920s

From 1895 to the end of the 1910s, then, X-rays and radium had already become established as news-generating topics in the newspapers here surveyed. This trend grew even stronger in the 1920s and 1930s, with scientific and technological topics making ever more frequent appearances in serial publications. Building on the trend of advertisements for X-ray screenings noted in the previous paragraph, radium and X-rays, as technologies of medical care, continued providing avenues for new clinics opened by Western-trained doctors to broaden the reach of their practice. The supposed medical benefits of radium and X-rays prompted some enterprising manufacturers to market implements whose names recalled those things, and which promised to deliver therapeutic benefits to their owners in the comfort of their own domiciles. A few enterprising firms manufactured health-promoting devices such as the "Violet Ray

[346] Tōson's French sojourn was a self-imposed exile from 1913 to 1916 after an affair with his niece came to light, a scandal which put no damper on his literary activities, judging from the serialized essays about his experiences published in the *Asahi shimbun*. See Araki Eiko's fascinating study of nurses and the Japanese medical efforts in World War I. Araki Eiko, "Ōshū ni haken sareta 'onna no gunjin-san' -- nisseki kyūgohan to dai ichiji sekai taisen," *Jinbun kenkyū Ōsaka shiritsu daigaku daigakuin bungaku kenkyūka kiyō*, Vol. 64 (2013), 5-35. Shimazaki Tōson, "Tokushi kangofu ni," *Asahi shimbun*, June 17 1915, 6.

[347] "Denkyu ni kansuru tokkyoken," *Asahi shimbun*, December 23 1913, 4; "Naigai gakujutsukai," *Asahi shimbun*, February 14 1921, 6.

Treatment Machine", a portable contraption that manifested in 1922. Allegedly used by the Imperial Army, it claimed to deliver treatment via the production of violet rays that could cure every health problem from acne to rheumatism and "women's ailments" (*fujin byō*).[348] A pamphlet distributed by its manufacturers, the Kawakita Laboratory, clarified that violet and ultraviolet light were excellent choices for light therapy, as X-rays were potentially too potent, rays of other colors like blue and red not potent enough, and termed the machine "the only family doctor" that its purchasers required.[349]

Another remarkable instance of such a machine was the "German F.L.M Style Ozone-rentogen," a kind of "natural therapy machine" sold by the Tokyo-based Sankyō Company (*Sankyō kyōkai*). Sankyō ran a total of thirty-one advertisements for their product in *Asahi* from 1925 to 1926. Figure 5-2 shows a comparatively large and eye-catching example of these advertisements: this particular one occupied the full breadth of a newspaper sheet, and which contains multiple clues to the kinds of messages that its manufacturers wished to sell. The key phrase is probably the one right in the middle of the smallest circle in the center of the advertisement: "a single course of treatment [has] The Power of Science (in bigger font) [equivalent] to a hundred courses of medicine". The vertical text on the far right refers to the revival of the German medical industry in the wake of the Great War [i.e. World War I] and claims Germany as the source of the Ozone-rentogen machine.

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[348] *Yomiuri shimbun*, August 28 1921, 1.

[349] Kawakita Kenkyūshō, *Viōrā: shikōsen denpa chiryōki* (Tokyo: Kawakita kenkyūshō tokubaiten, 1922). Available from the Kindai Digital Library, http://kindai.ndl.go.jp/info:ndljp/pid/913789 (accessed March 7, 2015).

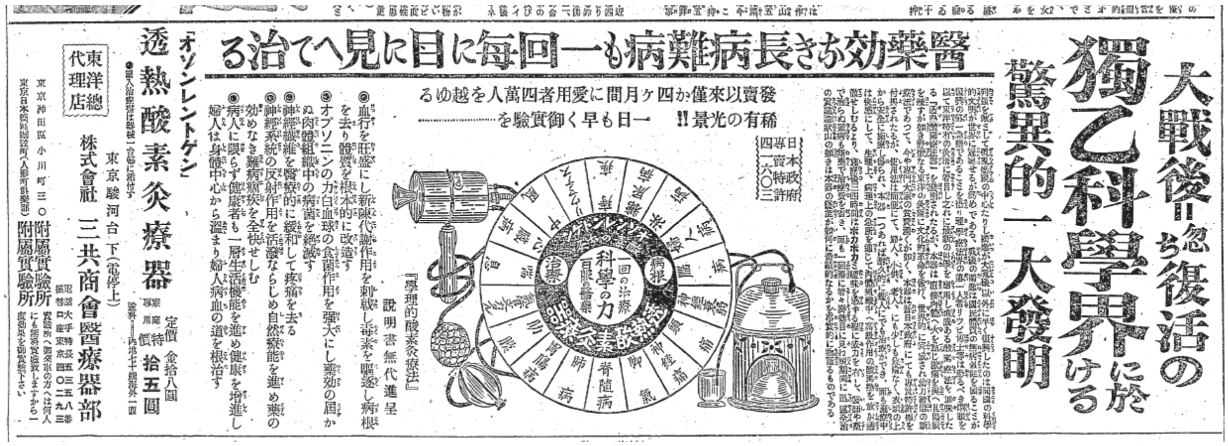

Figure 5-2. Sankyō Company's "Ozone-rentogen", *Asahi Shimbun*, 1925.[350]

A pamphlet issued by the firm further assured potential buyers of the Ozone-rentogen's many virtues: it simply aided its users' bodies in activating their in-built capacities for self-healing, and thus was not only better for health over the long term but also cheaper than taking medicine; it could heal a bewildering range of ailments, both chronic and acute; furthermore, unlike electrical devices, its portable frame needed only a match to be activated. The final segment of the pamphlet contained a variety of testimonials to the machine's efficacy, penned by satisfied customers from all over Japan whose names and addresses were included at the end of their letters.

From the contents of this marketing tract, the Ozone-rentogen had no actual relationship with X-ray generating devices of any sort, and claimed to work via "heat-conducting oxygen" that traveled through the nervous system of patients' bodies. Nonetheless, its manufacturers clearly wished to borrow some of the reputation that X-rays had built by the 1920s, and the burnish of a reputedly German pedigree in its design – a claim that carried no real support other than the presence of a portrait of a Caucasian gentleman, sporting a handlebar mustache, in the

[350] Image of advertisement taken from the *Asahi shimbun*, March 22 1925, 5.

company's advertisements.[351] Another advertisement that alluded to *rentogen* in name only was placed in the *Asahi* by a laboratory calling for applicants to undertake a training program for "drugless therapists" (*muyaku no chiryōshi*). These therapists would work with ozone-rentogen, and were promised an independent and lucrative career on finishing. That this laboratory never advertised again in the newspaper suggests it never succeeded in obtaining applicants, or that those it did were less than satisfied with the training they received.[352] Another company, which advertised a "radioactive medicine" called "Radiokalk" (presumably 'radioactive chalk' in German) that promised to be a machine-free treatment even more effective than radium therapy, ran two advertisements before disappearing from the newspaper's circuit.[353]

The appearance of such devices and the ways in which they were advertised suggest, again, the growing presence of an educated middle class that had disposable income at their means to purchase such items, and who bought or subscribed to newspapers and periodicals. The rise of a bourgeoisie who participated in mass consumer culture and an urban white-collar population that had been created during the economic upturn (and later crash) induced by World War I constituted a phenomenon recognized by the central government of Japan, who initiated a movement aimed at the reform of "living issues" (*seikatsu mondai*) for this new, growing class.[354] Taishō Japan evokes comparisons to F. Scott Fitzgerald's Jazz Age in America. It was a lively period colored by the appearance of new cultural forms and liberal, modernist ideologies

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[351] Sankyō shōkai, *Doitsu F.L.M. shiki Ozonrentogen jikken rei tsuki setsumeisho* (Tokyo: Sanykō shōkai iryōki bu). The pamphlet is not dated, but is likely to be from the 1920s to the 1930s given the relative spike in interest and media coverage of X-rays in that period.

[352] Tokyo muyaku ryōhō kenkyūsho, "Muyaku no chiryōshi seiyō jitaku dokushūsei dai boshū," *Asahi shimbun*, October 17 1925, 7.

[353] Hirao bussan kabushiki kaisha, "Rajiokaruku shōkai rajiokaruku," *Asahi shimbun*, September 28 1926, 3.

[354] Jordan Sand, *House and Home in Modern Japan* (Cambridge, MA: Harvard University Press, 2003), 162-202.

that produced the fashionable "Modern Boys and Modern Girls" (or, as the Marxists of the time might have preferred, "Marx Boys" and "Engels Girls").[355] It is likely that this same class could also afford to seek out the latest medical treatments from the clinics who advertised in the newspapers. *Rentogen*, after all, were what a *Yomiuri* piece termed "Knowledge for Modern People" (*Gendaijin no chishiki*): information that people in the 1920s *ought* to be equipped with about their modern, cultured world.[356]

In part this was due to the Western origins and mysterious newness of X-rays, which lent them an air of modern sophistication and also provided opportunities for enterprising souls to profit, as described above with the home therapy devices advertised in the 1920s. Indeed, merchandising items for leisure consumption that involved X-rays was fairly common – an indicator that the readers of the *Asahi* and *Yomiuri*, and perhaps of newspapers in general, were expected to have incomes generous enough to accommodate the consumption of luxury goods (in the sense of economics). A good example of this is how, as early as 1896, the first X-ray photographs taken in Japan by the physicists Yamaguchi Einosuke and Mizuno Toshinojō at the Tokyo First Higher School (incorporated into the Komaba campus of the University of Tokyo from 1949) were commodified some months later by being bound together in an album and sold under the auspices of the Maruzen publishing company.[357] Advertisements appeared in newspapers and magazines for pharmaceutical products, as they did in America and Europe, for things such as "X-ray soap," which an 1896 advertisement placed in the *Asahi* claimed would not

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[355] For an analysis of the "modern girl" in Japan see Miriam Silverberg, *Erotic grotesque nonsense: the mass culture of Japanese modern times* (Berkeley, CA: University of California Press, 2006), 51-69. For discussion of the "modern boy" see the Introduction to Hsiao-yen Peng, *Dandyism and transcultural modernity: the dandy, the flaneur, and the translator in 1930s Shanghai, Tokyo, and Paris* (New York: Routledge, 2010), 1-21.

[356] "Gendai jin no chishiki rentogen sen wa byōki ni dō riyō sareru ka," *Yomiuri shimbun*, July 19 1927, 3.

[357] "Rentogen tōei shashin chō," *Asahi shimbun*, June 9 1896, 6.

penetrate one's body, but which would – unlike regular soap – cleanse your skin without a squeaky noise or sensation (Figure 5-3).[358]

Figure 5-3. "X-Ray Soap," *Asahi shimbun*

Accidents and Experts: 1920s – 1930s

From the 1920s onwards, there is evidence of a growing awareness that *rentogen* were sources of danger as well as medical treatment. The occasional big accident broke out, such as a 1921fire at a medical instruments factory located in front of the 'red gate' of the Tokyo Imperial University. The conflagration was apparently sparked by a mishap in the "*rentogen* manufacturing process" – the details are unclear from the report, but it is possible it was an electrical fire caused by high-voltage equipment. No human casualties were reported, but the blaze completely incinerated eighteen domiciles to the ground, badly damaged another ten, and occasioned complaints of the young and careless workers employed at the unlucky factory.[359]

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[358] "X kōsen sekken," *Asahi Shimbun*, May 28 1896, 7.

[359] "Teidai akamon mae no asa kaji de daikonran Tōkyō igaku denki kōjō kara hakka shi zenhan shō nijūhachi to gen'in wa rentogen seizō," *Asahi shimbun*, March 24 1921, 2.

Two years later, in 1923, the Red Cross hospital in Akita Prefecture, northeastern Japan, also fell victim to an electrical fire that started in the X-ray room.[360]

Other reports mentioned the potential danger that X-ray screenings could cause, such as a 1930 piece which commemorated the death of a radiology technician employed at the Red Cross hospital in Nagano from a painful bout of "*rentogen* cancer". Even before his internal organs were afflicted, in his career of over two decades he had suffered prolonged injuries to his skin and the fingers, three of the latter requiring amputation.[361] These were by no means the first reports that X-rays could potentially harm their users: there had been isolated reports of doctors, scientists, and tinkerers in the West who had suffered grievously from X-radiation as early as 1896.[362] Marie Curie's untimely death in 1934 was also widely eulogized as a life sacrificed on the altar of science, as in a *Yomiuri* editorial penned by the eminent physicist Nishina Yoshio. The appearance of casualties on home ground surely made the danger more imminent and real, relatively speaking. But this danger was overshadowed by reports of advances in the domestic manufacture of *rentogen* machines, and the portrayal of the moving, powerful significance of lives sacrificed in the name of science – a theme that will recur in the following chapter's study of the radiologist Nagai Takashi.[363]

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[360] "Akita sekijūji byōin kasai geka shujutsushitsu yaku," *Asahi shimbun*, February 18 1923, 2.

[361] "Kenkyū kara giseishi Nagano sekijūji byōin no Kobayashi Toraichi shi hansei ni kagayaku iseki," *Asahi shimbun*, April 15 1930, 7.

[362] See for instance the two articles side-by-side on "The Harms of X-scatter radiation" ("X hōsansen no gai") and "Burns [caused] by X-scatter radiation" ("X hōsansen no nenshō") in *Taiyō* 2:14 (November 20, 1896), 136.

[363] An example of reporting on the domestic manufacture of *rentogen* machinery appears in "Doitsu seihin wo shinogu rentogen keikōban kansei su Tōkyō Denki no wakaki Izawa shi ga go nenkan kushin no kesshō," *Asahi shimbun*, January 17 1933, 11. Nishina's eiulogy appears in Nishina Yoshio, "Ko Kyurī fujin wa donna hito? 2 do mo Nōberu shō wo eta kenkyūnetsu no gonge," *Yomiuri shimbun*, July 6 1934, 4.

The awareness of potential danger in over-exposure to X-rays was by no means widespread amongst the public. But there was one case, reported in the *Asahi* in June 1925, of an X-rayed patient seeking damages of 6,800 yen from a private hospital in Tokyo. The plaintiff, a rice merchant, had had his ankle X-rayed for athlete's foot, resulting in inflammation and pain. On receiving the diagnosis that it was *rentogen* dermatitis, he pressed charges against the hospital and its head doctor for the prolonged loss of ambulatory powers following treatment.[364] As expected, medical and scientific communities that worked with X-rays had a better sense of the potential damages that could accrue to the operators of X-ray apparatus, even if they did not always spare the same consideration for those operated on. One manifestation of this is a 1935 advertisement for *rentogen* machines manufactured by Tokyo Denki and sold through the Nihon Iryō Denki (Japan Medico-Electrical Equipment) company, which is likely to have been targeted at professionals who wished to purchase such machines for their practice. The advertisement's headline asked, rhetorically, "Are *Rentogen* Dangerous?" (レントゲンは危険か？) before informing the reader that its medical, dental and industrial-use machines were outfitted with anti-electric shock protection.[365]

At the same time, individual scientists and doctors wrote increasingly for the newspapers to educate the public about how *rentogen* could be used medically and scientifically. For instance, a three-part series on the scope of using *rentogen* to induce temporary sterility contraceptive purposes, written by an M.D., ran in the *Asahi* in November 1930 under the column of "Science for the Masses" (*Taishū kagaku*). The essay was a response to the question

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[364] "Byōin chō wo aite ni songaikin wo uttau chiryō wo ayamatta tote roku sen happyaku en no seikyū soshō," *Asahi shimbun*, June 4 1925, 7.

[365] *Asahi shimbun*, March 8 1935, 2.

of a woman from Chiba asking if *rentogen* contraception was safe. The doctor's reply asserted that, despite some risks, it was perfectly fine to use *rentogen* as a method of birth control for both men and women.[366] Commemorations of distinguished researchers in the field also continued to appear: an eulogy to Guido Holzknecht, a pioneering Austrian radiologist, appeared a few months after his death in 1931, for instance, or the long-time head of a sanatorium serving patients with Hansen's disease who had, late in his career, acquired a medical doctorate in radiology.[367]

Public Health Campaigns: 1940-1944

The last few years of the pre-war period, prior to the atomic bombings, was marked by the privations of war amongst those on the home front. During the same period, *rentogen* gained significant public exposure through the implementation of mandatory mass screenings for tuberculosis instituted by the 1940s, and which carried on for the first decade or so after WWII. X-rays had been part of anti-tuberculosis screenings for some time; a 1929 article reported that the city government of Tokyo had begun to implement *rentogen* screenings as part of their annual Tuberculosis Prevention Day (an event instituted since 1925).[368] Screenings that took place by itinerant medicals staff, though, became commonplace in the 1940s. Portable X-ray machines installed in small vans traveled to residential neighborhoods, schools and workplaces in order to take chest X-rays of civilians. The hope was that making early diagnoses of the

366 "[Taishū kagaku] Rentogen hinin wa kōka ga aru ka," *Asahi shimbun*, November 27-29 1930.

367 "Horutsukunehito no gyōseki sekai rentogen gaku no taito," *Asahi shimbun*, December 9 1931, 9; "Fugū no kanja to nijū nen 'gakui' ni hikaru kenkyū," *Asahi shimbun*, October 16 1933, 11.

368 "Kekkaku yobō dē nijūnana nichi shi eisei shikenshō de muryō de sōki shindan," *Asahi shimbun*, April 25 1929, 7.

disease would help to control its spread. A newspaper report from the Tokyo *Asahi shimbun* in 1940 introduced the appearance of a "*rentogen* car" outfitted with an "excellent *rentogen* photography device". The vehicle had been generously funded by a gift of 30,000 yen from the Manchurian Emperor (who, the paper said, had always supported the public health works of the Japan Anti-Tuberculosis Association). A follow-up report made in January of the following year added that, based on the German experience, the completed vehicle was expected to handle the health screenings of thirty thousand people in a month.[369]

Newspapers and periodicals in the 1940s devoted much of their space to covering the war that intensified after Japan's bombing of Pearl Harbor in December 1941 and America's subsequent entry into the conflict. Mentions of *rentogen* in this period thus concentrated on its role in public health, as a tool to combat the spread of tuberculosis and national health campaigns. A key way in which *rentogen* served this function was via the medical vans that traveled the imperial metropolis to screen its denizens. "Walk, get used to wearing fewer clothes; the *rentogen* van is also playing a part!" declared the somewhat oblique headline of an article exhorting Japan's subjects to participate in a ten-day long health promotion campaign organized by the Ministry of Welfare that included a *rentogen* van making inspection rounds in Tokyo.[370] Workers were advised to get *rentogen* screenings to ensure they were tuberculosis-free, advice framed in terms of a self-strengthening regimen ideally taken before one undertook manual labor.[371] The *Yomiuri* newspaper even sponsored five medical teams to travel across the country,

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[369] "Hashiru rentogen kashikin de kekkaku zanmetsu," *Asahi shimbun*, August 29 1940, 2; "Machi ni kuridasu 'X sen sha' tonarigumi to mo kyōryoku shi no kekkaku bokumetsu jin," *Asahi shimbun*, January 25 1941, 2.

[370] "Aruke, usugi ni nare rentogen jidōsha mo ichiyaku kenkō zōshin undō," *Yomiuri shimbun*, April 27 1941.

[371] "Tengyō e no karada wo tsukuru kinrō kunrensho e hairu chūi mazu kekkaku hannō kensa wo se yo," *Yomiuri shimbun*, March 24 1941.

starting with its eastern regions, in all-purpose medical vans outfitted with *rentogen* apparatus and other therapeutic devices.[372]

Magic, Science and Pseudoscience

What passed for "scientific journalism" in the newspapers of the day would not always have lived up to expert standards about the enlightenment of the masses. There were columns with basic information about X-rays, such as a 1927 *Asahi* column on "Family Science" which clarified for its readers that *rentogen*, *renchen* and *ekkisu sen* referred to the same thing, and listed various medical applications of X-rays.[373] But it is difficult to imagine, for instance, that Professor Gotō would have approved of a 1932 *Yomiuri* column about "hand radiation" which urged its readers to prepare food with (clean) hands instead of consuming machine-prepared dishes. Researchers in the United States, its author reported, had apparently found that the hands emitted rays which interacted with ingredients to make food taste better, and which could also ward off digestive ailments. Thus this piece primarily underscored the value of culinary labor, and since the author was a woman named Kitahara Misako, it is likely that she was addressing women in particular to cook for their families – a duty that would have slotted neatly into the sociopolitical framework of being a "good wife and wise mother" (*ryōsai kenbo*).[374] Another piece in a 1936 issue of *Kagaku gahō* praised one Francis Mildred Davis, a young American woman who worked as an X-ray technician in Los Angeles. Ms. Davis also practiced

[372] "Muryō junkai iryō hōkoku Yomiuri iryō hōkōtai wo hensei," *Yomiuri shimbun*, June 2 1941, 1.

[373] "Katei no igaku rentogen", *Asahi shimbun*, December 21 1927, 8.

[374] Kitahara Misako, "Hōshasen no te?" *Yomiuri shimbun*, 6 July 1932, 9. On the pre- and postwar origins and continuities of *ryōsai kenbo* see e.g. Kathleen S. Uno, "The Death of the 'Good Wife, Wise Mother'?" *Postwar Japan as History*, ed. Andrew Gordon (Berkeley: University of California Press, 1993), 293-322.

photography, and had taken several eye-catching radiographs of flowers. The author noted the potential usefulness of her radiographs for the field of plant biology, and praised her for being a rare specimen of scientific womanhood he thought sadly lacking amongst the ladies of Japan.[375] The term *kenkyū*, or research, when applied, lent a sheen of scientific authority to activities and reportage which did not always fit that framework.[376]

Japanese mass media coverage of radiation science and technology in the first decades of the twentieth century also showed clearly that bringing scientific enlightenment to the public at large was far from a smooth process. Media controversies over science in the 1910s and 1920s show that battles took place over what did or did not constitute actual science, and tested the credibility of scientific authorities in national institutions. Two major incidents involved experiments that sought to determine whether clairvoyance was indeed a scientific phenomenon, and the purported creation of a "radioactive human" who had ingested artificial radium produced at RIKEN, the Institute for Physical and Chemical Research in Tokyo. In both cases, scientists primarily engaged in research at prestigious national institutions became embroiled in research controversies that started out as academic affairs and eventually became public matters.[377]

But regardless whether or not the general public understood what constituted science or scientific work, popular publications did effectively communicated that X-rays were wondrous.

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[375] "Shirouto ga totta kaki no X sen shashin," *Kagaku gahō* 25 (9), 46. Photos and text almost certainly taken and adapted from an issue of the American magazine *Popular Science* – see "X-ray flowers form novel hobby," *Popular Science*, September 1936, 28.

[376] *Kenkyū*, which from the late 19th century took on the modern sense of scholarly research, was a much older term that referred in a similar sense to the deep study and contemplation of things and knowledge. *Nihon kokugo daijiten*, accessed via the JapanKnowledge database, Harvard University, http://japanknowledge.com.ezp-prod1.hul.harvard.edu/lib/display/?lid=20020161f884IPI4JEiY (accessed February 25, 2015).

[377] Nakao, "'Kagakusha no jiyū na rakuen'".

The tenor of most reportage struck notes of curious admiration and wonderment over the massive strides that science and technology were making, along with occasional dashes of prurient interest. X-rays might reveal the skeletal structures of Egyptian mummies or American baseball players to further the causes of archeology or sports medicine.[378] However, as in the United States, consumers also took interest in the cosmetic applications of X-rays to enhance one's appearance. X-radiation might possibly turn white hair black again, and the rays also promised to relieve the torments of hirsute ladies by eradicating the hairy symptoms of their "frigidity" or "masculine character".[379] They could also peer into the contents of a man's gift to a lady love; this last accomplishment featured in a *Yomiuri* column where X-rays were personified as a character ("Mr. X-ray") that discussed his powers of penetrative sight in the first person by "spying" on a Caucasian man and woman as they each prepared for a rendezvous (Figure 5-4).[380]

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[378] "Ejiputo miira no X sen shashin," *Yomiuri shimbun*, January 8 1932, 4; "Yakyū senshū no te hone no kenkyū ni hito anji," *Asahi shimbun*, March 28 1933, 3.

[379] "Kebukai nayami ni naku hitobito e kon chiryōhō ni futatsu aru," *Asahi shimbun*, June 3 1931, 7; "Kagakukai X kōsen ga shiragami wo naosu," *Yomiuri shimbun*, February 8 1907, 1.

[380] "Kareshi to kanojo no randebū X sen shi no hanashi," *Yomiuri shimbun*, July 15 1937, 5.

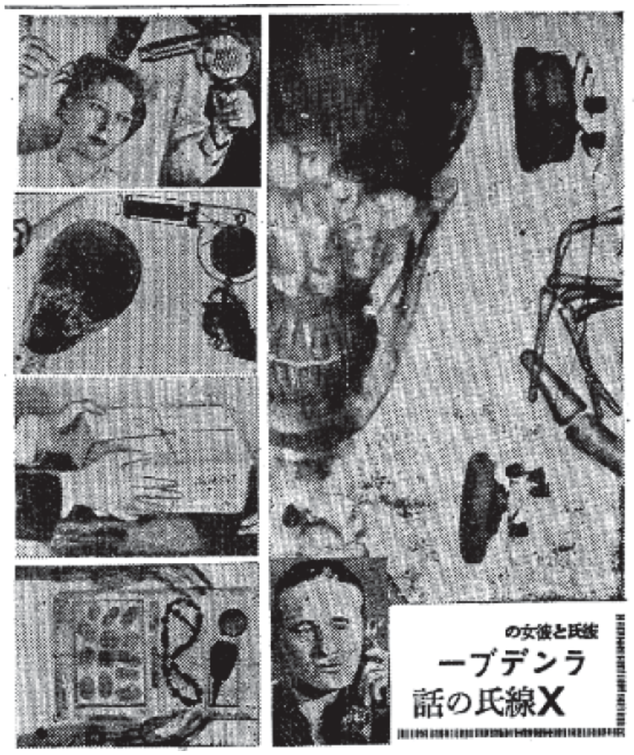

Figure 5-4. "Mr. and Ms. On a Rendezvous – the tale of Mr. X-Ray", *Yomiuri shimbun*, 1937.

The images of the Caucasian pair just mentioned also mark the essential foreignness of X-rays, which persisted into the 1930s. As mentioned earlier, a good amount of the Japanese coverage of X-ray science and technology was a re-reporting of news in America and Europe.[381] One of the *Yomiuri*'s earliest pieces, for example, presented the saga of a German-American woman's discovery, via an X-ray screening, that a small black snake-like creature had been living in her gut for years.[382] *Taiyō* readers learned, in 1896, that French scientists were using X-rays to test wine for substances that indicated a bottle's contents did not actually come from fermented grapes.[383] The *Kagaku gahō* also featured regular profiles of innovations and

[381] See the essay by Fred van Gelderen, "A Brief History of Radiology", *Understanding X-Rays: A Synopsis of Radiology* (Berlin: Springer, 2004), 598.

[382] "X kōsen to motte jintaijū ni seisoku seru kohebi to hakken wo," *Yomiuri shimbun*, September 22 1897, 4.

[383] "X kōsen to gizōshū," *Taiyō* 2:14 (July 5), 167.

inventions related to radiological apparatuses – mostly in America, by the manufacturing powerhouses of Westinghouse and General Electric. As in the case of Francis Mildred Davis, the flower X-ray photographer, many of the *Kagaku gahō* pieces were translations of articles featured in American popular science periodicals such as *Popular Science* and *Popular Mechanics*. This was especially true of the "newsflash" entries, which were usually no more than a paragraph of text accompanied by an image; several of these entries would be bundled together into a news section that highlighted current events in the world of science and technology.

Articles that profiled the various potential applications of X-rays covered not only their medical uses, but also industrial ones. *Kagaku gahō* featured several pieces in this vein, often penned by employees who worked in the research laboratories of private and public organizations, and richly arrayed with photographs and diagrams. The prominent entomologist Yagi Masahiko, professor and researcher at the Ministry of Agriculture, for instance, contributed a piece in 1932 on how X-rays could be used to find vermin hidden in plant tissues, thus raising the quality of Japanese agricultural exports like chestnuts.[384] In another case, an engineer from the Hitachi conglomerate discussed in a 1935 issue how X-ray examinations of metals and other materials could lead to improvements in machine manufacturing.[385]

But utilitarian and nationalist conceptions of radiation science and technology were not the only things put forth. Attempts to communicate science to the public, in the periodicals of this period, actually cultivated an understanding amongst non-scientists that science was *magic* (*majutsu*), instead of a rational, empirically proven process; X-rays and radium provided two

[384] Yagi Masahiko, "X sen ōyō de mokuzai gaichū hakken," *Kagaku gahō* 19(6), 754-756.

[385] Kubo Toshihiko,"Kōgyō ni ōyōserareru saishin X sen," *Kagaku gahō* 24(4), 93-98.

especially potent manifestations of this understanding.[386] A *Yomiuri* column called "School of Inventions," devoted to introducing modern marvels of technology to the paper's readers, described X-rays as the *magic* phenomenon that could reveal how even a beautiful person would become nothing but bones.[387]

X-rays, as much as they were praised for their application, were also much feted for their capacity to render the invisible visible. This was mostly to further the cause of scientific inquiry, but also sometimes as social commentary, or just because they *could*. The author of a haiku on "*Ekkisu kōsen*", penned in 1903 and printed in a poetry contest featured in the *Asahi*, mused that if the power of this machine [the X-ray device] could be used to expose people's hearts, it would assuredly command more business than the court of the underworld.[388] The content of a 1938 "talkie" film made by the Tōhō Educational Films company primarily introduced X-ray machines, radiographs and the basics of medical radiology to its viewers; however, the focus (and headline) it received in the *Asahi* centered on the film's final segment. This featured fluoroscopic footage of a nearly-stopped heart going back to its normal pulse rate, the

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386 Nakao, *Hōshanō no tankyū*, 37-38. It is also worth noting here that this was an age in which science and pseudoscience or magic were not strictly distinguished even by scientists themselves. William Crookes, the chemist who discovered the element thallium and invented the Crookes vacuum tube, was not only a scientist but also a committed Spiritualist who believed that the dead had the ability to communicate with the living. See e.g. Janet Oppenheim, The Other World: Spiritualism and Psychical Research in England, 1850-1914 (Cambridge: Cambridge University Press, 1985), 199-392.

387 "Hatsumei gakko rentogen wa," *Yomiuri shimbun*, August 11 1927, 3.

388 "Haikai zoku ame furi sumō jō," *Asahi shimbun*, June 22 1903, 6. Literally, "more business than the court of Enma". In East Asian Buddhist cosmology, influenced by Vedic writings, the Great King Enma (Yamarāja) is ruler and judge of the underworld, who decides which souls go to Heaven or Hell on account of their deeds while alive. For a concise, comparative study of Enma's various forms in East Asian religious thought see Caroline Hirasawa, "The Inflatable, Collapsible Kingdom of Retribution: A Primer on Japanese Hell Imagery and Imagination," *Monumenta Nipponica*, 63:1(2008), 11-16.

accomplishment of these visceral acrobatics performed by a *jūdō* martial arts master from Aichi Prefecture.[389]

Radium was another nexus where ideas and images of science and magic converged. The biological metaphors often invoked in descriptions of radioactivity led the radioactive elements identified in the early twentieth century to be viewed as possessing powers to give or restore life and vitality. This proved particularly so in the case of radium, leading to a craze for that element which the American historian Henry Adams termed "physics gone stark mad in metaphysics".[390] Media coverage on radiation focused not only from X-rays, but also on radium, that most radiant of radioactive materials. Public awareness of radiation and its manifestations as cultural phenomena involved both these sources, with radium in particular reported on for its "magical" properties. The proliferation in advertisements during a "radium boom" that appeared during the Taisho era shows that radium was valued, in Japan as in America and Europe, as a cultural, cosmetic and health commodity – in the last case, particularly as a component of hot spring therapy.[391] The element's celebrated discoverers, Marie and Pierre Curie, were profiled glowingly as giants of science, with Madame Curie often singled out for achievements that far exceeded expectations of her sex. "The world's foremost female scientist," as one author described her, had her face emblazoned on the first page of articles about radium and radioactivity, far more often than her husband or Henri Becquerel, the other two in the trinity of

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[389] "Eiga shinzō ga tomattara," *Asahi shimbun*, December 16 1938, 11.

[390] Analysis of the biological aspect of radioactivity and Henry Adams's quote from Luis Campos, "The Birth of Living Radium," *Representations* 97: 1(2007), 1-27.

[391] Nakao, "Kindaika wo hōyō suru onsen".

radioactivity's discoverers.[392] Radium, in the form of hot springs, its own profusion of questionable pharmaceuticals, and was also vital as a source of images and ideas about radiation-supported health.[393]

Gendered Exposures

The manufacture and use of *rentogen* vehicles highlighted the spread of tuberculosis as a national health threat, and arguably made medical radiation into a familiar, approachable phenomenon through the coverage it received in the commercial press. In this way the Ministry of Health appears to have sought to ease the stigma around tuberculosis and the social consequences it could engender. The growing commonality of reports on tuberculosis X-ray screening, and the clinical spaces in which it was conducted, also provided avenues for *rentogen* to make occasional appearances in literature.[394] *Rentogen*, in the form of a radiograph, play a pivotal role in Hori Tatsuo's novel *The Wind Rises* (*Kaze tachinu*), written between 1936 and 1937. The protagonist is shown a radiograph of his fiancee's lungs by her physician. In contrast to the white ribs visible on the right lung, the left is covered in strange, dark lesions, and the radiograph allows him to sense for the first time that his fiancée is dying.[395]

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[392] Senō Tarō, "Sekai-ichi no jokagakusha Kyūri fujin ga ajiumu hakken zengo," *Kagaku gahō* 1(5), 499. The 1903 Nobel Prize for Physics was shared by the Curies and Becquerel. See the official website of the Nobel Prize Committee, "The 1903 Nobel Prize for Physics," http://www.nobelprize.org/nobel_prizes/physics/laureates/1903/ (accessed December 23, 2014).

[393] Nakao, "Kindaika wo hōyō suru onsen".

[394] Although never so often as the disease that *rentogen* were used to detect. Tuberculosis made frequent and important appearances in modern Japanese literature. See e.g. chapter 5 of Johnston, *The modern epidemic*, 124-159. For further theoretical analysis of the significance of tuberculosis in literature and society, see chapter 4 of Karatani Kojin, "Sickness as Meaning," trans. Yukari Kawahara and Robert Steen, *The Origins of Modern Japanese Literature*, ed. Brett de Bary (Durham: Duke University Press, 1993), 97-113.

[395] Hori Tatsuo, *Kaze tachinu* (Tokyo: Noda Shobō, 1938), 62-3.

Outside of public health inspections, there is evidence that *rentogen* screenings became an established part of the rituals of matchmaking, at least for the socio-economically privileged. Women from this class could be required by their prospective mates to produce medical proof that they were free of tuberculosis and insanity in order to be seen as a suitable match; either affliction was grounds for being refused. In a short story written in 1931 by the playwright and author Kishida Kunio, "The X-ray Room" (*X kōsen shitsu*), a young woman visits a radiologist to be screened for that very purpose. In Kishida's story, the drama unfolds in the confines of the X-ray screening room, where the protagonist, a radiologist named Kusumi Shūta, is fatally attracted to a young female patient whose chest he is asked to X-ray before her matchmaking sessions.[396] Another literary instance of this literal screening-for-marriage appears in the novel *The Makioka Sisters* (*Sasameyuki*), one of the best known works by Tanizaki Jun'ichirō, already hailed as a giant of modernist literature in his own time. The novel narrates the declining fortunes of four sisters born into a wealthy merchant family in western Japan. The family takes the third sister, Yukiko, for a chest X-ray to ensure "that there was not the faintest cloud on [her] lungs."[397] The *Yomiuri* even carried a story in 1926 of a woman divorced from her husband on the accusation of "diseased lungs" – a colloquial reference to tuberculosis – whose sad fate was rectified by the powers of *rentogen*. Her father had marched her to Tokyo Hygiene Laboratory for a very affordable X-ray screening (1 yen) carried out on its costly new machine (10,000 yen).

[396] Kishida Kunio, "X kōsen shitsu", *Kishida Kunio zenshū 8 shōsetsu*, eds. Tanaka Chikao et al. (Tokyo: Iwanami Shoten, 1990), 273-302. Originally serialized in 1931 (Showa 6) in the magazine *Wakakusa* (Young Grass), issues 1-6 of Vol. 7.

[397] Tanizaki Jun'ichirō, *The Makioka Sisters*, trans. Edward G. Seidensticker (Tokyo: Charles E.Tuttle, 1958), 49-55. The novel was written towards the end of WWII, but is set in the period from 1936 to 1941. Tanizaki, whose fame had already garnered a publication of his "Complete Works" as early as 1930, reached back to portray a world not yet torn asunder by war.

There a friendly radiologist produced a radiograph of her "excellently healthy lungs" (*rippa na kenkō no hai*) and confirmed that her paleness was due to a duodenal ulcer rather than the tubercle bacillus.[398]

X-rays, when turned onto female bodies, confirmed their suitability for marriage and motherhood by exposing their insides to the critical gaze of the (male) radiologist, her potential husband and his relatives. Here, too, medical technologies proved a means of evaluating the fitness of a body to serve an institution – in this case, that of affluent families.[399] Moreover, not only women's bodies, but also their morals were subject to judgment, a theme vividly illustrated in this 1929 image from the satirical magazine *Tokyo Puck*: (Figure 5-5)

[398] "Ochauke," *Yomiuri shimbun*, July 10 1926, 7.

[399] Women's bodies and marriage, during the late nineteenth and early twentieth century, were also mobilized in eugenic thought to benefit the Japanese race and nation-state. See Sumiko Otsubo, "The Female Body and Eugenic Thought in Meiji Japan," *Building a Modern Japan*, ed. Morris Low (New York: Palgrave Macmillan, 2005), 61-82.

Figure 5-5. Ono Saseo, "Modern Girl Under the X-Ray," *Tokyo Puck* 1929[400]

The illustration is titled "A Modern Girl Under the X-Ray", and shows an unattractive, almost grotesque modern girl. Sporting short hair and an abundance of eyeliner, she is clearly obsessed with possessing luxury and male attention, flaunting a diamond ring on her right hand and several small men falling about atop her forearm, in addition to which her mind reveals yet more jewels and money. Her stomach contains patent medicines and alcohol. The words "MODERN Ninth Generation" are inked below her stomach right above a pair of male and female fetuses. Here the X-rays are a device used to highlight the decadence of capitalism and its degenerating effects on women.[401]

[400] Ono Saseo, "X kōsen ni kakatta modan garu," *Tōkyō Pakku* 18:2 (February 1929). Ono also drew a variant of this for an insert illustration in 1949, showing contraceptives, money, alcohol and syphilis inside the body of a beautiful woman bedecked with jewels. See Ono Saseo Ten Jikkō Iinkai, ed., *Moga-on-parēdo – Ono Saseo to sono jidai* (Tokyo: Iwanami Shoten, 2012), 71, 75.

Conclusion

As Hiromi Mizuno notes, in her study of how scientific discourse promoted nationalism in modern Japan, radiation reportage in the first decades of the twentieth century often involved the "mobilization of wonder" – a concerted effort by science educators and their supporters to bring people into the scientific fold by showcasing its various marvels and curiosities.[402] The torrent of scientific discoveries that occurred in the late nineteenth century to the first decades of the twentieth was never understood – in Japan as well as in the West – simply as "science". Rather, these discoveries, or rather the images created around them, were interpreted through existing matrices of culture and ideology.[403] So newspaper and magazine accounts of X-rays and radium in this period highlighted the power of X-rays and radium to treat ailments, and above all, to *see* by means of penetrating seemingly impervious exteriors. The *Kagaku gahō* coverage of these things is also noteworthy on two points: its warnings of the potential risks of radiation, and its frequent reports on innovations in radiation science and technology overseas. Science and technology themselves were always cast as international things. Like radiation itself, news, information and images about X-rays and radium were diffuse phenomena.

Radiation, as discussed in the preceding pages, was thus presented as a news-creating and global phenomenon throughout the first decades of the twentieth century. But it was also

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[401] I am indebted to Chinghsin Wu for drawing my attention to this image and her own cogent analysis of it in the context of art history and gender theory. See Chinghsin Wu, "Reflecting and Refracting Modernity: Images of the Modern Girl in 1920s and 1930s Japan," *Japon Pluriel La modernite japonaise en perspective*, 8 (2011), 107-118, especially 116. Many Marxists saw the modern girl, with all her stereotypical characteristics, as a sexualised and decadent embodiment of capitalism's most decadent aspects. Barbara Sato, *The new Japanese woman: modernity, media, and women in interwar Japan* (Durham, N.C.: Duke University Press, 2003),76.

[402] See Part Three of Hiromi Mizuno, *Science for the Empire*: *scientific nationalism in modern Japan* (Stanford, Calif.: Stanford University Press, 2009), 143-172.

[403] John Canaday, *The Nuclear Muse: Literature, Physics and the First Atomic Bomb* (Madison, WA: The University of Wisconsin Press, 2000).

presented, in many cases, as a field in which Japan had achieved significant *national* accomplishments. Newspapers carried reports on medical and scientific meetings about *rentogen*, when the Army or the Red Cross installed X-ray machines in their hospitals, and the development of nationally produced apparatus for X-ray use, such as intensifying screens. *Rentogen*, X-rays and radium were, in these reports, invisible yet given concrete materialization in photographs of machine parts, along with portraits of the great men and women involved in their creation – Roentgen, Curie, Becquerel, of course, but coverage also of Japanese (male) scientific heroes like Nishina and Nagaoka.[404]

Newspapers and magazines not only provide a barometer of how *rentogen* were being accepted and integrated into society; they also contributed actively to people's awareness that this phenomenon existed, that modern, Western-style medicine was the new, state-sanctioned standard of medical treatment. Those who would have been able to access and afford this Western medical treatment in reality were limited to the relatively affluent, urban areas of the country. It is likely that rural dwellers would still have sought the services of Chinese medical doctors, or their local village doctor. But columns like the *Yomiuri's* monthly series "Examination Room" ("*Shindan shitsu*"), for instance, arguably provided a means for people to communicate with Western-trained medical specialists and ask about their health problems. In their replies doctors could promote new treatments and pharmaceuticals, *rentogen* screenings and treatment included.[405] These replies, along with popular texts and advertisements for medical products, may be seen as reflections and responses to broader social anxieties about health,

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[404] See e.g. in the *Asahi shimbun*: "Nigiwau igaku taikai", March 25 1923, 9; "Rentogen secchihi yōkyū rikugun tsuika yosan ni," April 6 1924, 2; "X kōsen yō no kokusan zōkanshi," September 7 1933, 3.

[405] The two pieces in this *Yomiuri shimbun* series that featured *rentogen* are: "[Shindan shitsu] Nōka suitai ni X sen," June 29 1940, and "[Shindan shitsu] Rentogen kensa wo," January 22 1941.

illness and the body.[406] The *Asahi* column about *rentogen* contraception discussed earlier, for instance, grew out of a question posed by a woman; her question, as her M.D. respondent remarks, was probably induced by a growing birth control movement in the 1920s and 1930s.[407]

As noted in Chapter 1, *rentogen* were used as a tool of the imperial Japanese state to police the health of its subjects' bodies. But *rentogen* were also used by Japanese society to police the health of young adult female bodies. The general sense that X-rays showed the future death present in any human body, through revealing the skeleton underneath flesh, acquired a particularly gendered dimension in Japanese society. This is brought into relief by many of the print media examples discussed in the preceding pages. Women, as Lisa Cartwright has argued, have not only been analyzed via X-rays; their bodies have contributed in complicated ways to establishing a popular culture around the same rays.[408]

The popularization of radiation, in the years after 1945, took very different tracks. The Nagasaki-based radiologist and *hibakusha* Nagai Takashi, in the 1940s, became a figure whose writings framed radiation and nuclear energy in very specific ways alongside the tragic specter of the atomic bombings. Moreover, film images of X-rays in the service of medicine and public health also appeared more frequently. Moving images of X-rays appeared, for instance, in a 1951 film titled *Rentogen sen to seimei* (*Roentgen rays and life*) made by the Tōhō Educational Films

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[406] On this point, Sabine Frühstück also discusses the power of capitalism in creating desires to consume medicines to boost adult male sexual potency in pre-war Japan. See Sabine Frühstück, "Male Anxieties: Nerve Force, Nation and the Power of Sexual Knowledge," *Building a Modern Japan*, ed. Morris Low (New York: Palgrave Macmillan, 2005), 50-54.

[407] For a history of birth control in Japan see Tiana Norgren, *Abortion before Birth Control: The Politics of Reproduction in Post-war Japan* (Princeton, NJ: Princeton University Press, 2001); on the pre-war movement see 25-27.

[408] Lisa Cartwright, "Women and the Public Culture of Radiography," *Screening the Body* (Minneapolis: University of Minnesota Press, 1995), 143-170.

company, the same creator of the 1938 movie earlier mentioned.[409] They also featured in local newsreels about tuberculosis screening and cancer prevention, such as those shown in Okayama Prefecture up till the early 1960s.[410] But, as suggested in Chapter 1, it is arguably Nagai's writings that made the biggest impact on the post-war Japanese imagination, by framing medical and scientific radiation in a positive light.

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[409] Tōhō Kyōiku Eiga Kabushiki Kaisha, *Rentogen sen to seimei*. Film script. 1951.

[410] Sanyō Eiga, "Okayama-ken nyusu kekkaku yobō ni iryoku ~rentogen sha~". Newsreel. November 11, 1959.

Conclusion

Understanding Radiation in Postwar Japan

> Fearing things too little or too much is easy, while fearing them justifiably is hard.
>
> – Terada Torahiko, physicist-author, on the Mt. Asama volcanic eruption of 1935[411]

Within the field of radiological medicine, *rentogen* screenings in Japan today have established a status as one of the country's most frequently used routine medical procedures. In 2014, the *Asahi Shimbun* reported that Japan now possesses one of the world's highest annual rates of CT scans and X-rays per person, to the point of being described by some observers as the "land of medical exposure". Citizen groups as well as radiological societies are advocating stricter limits on the use of radiation in medical procedures.[412] Medical professionals tend to see their role as promoting the safe use of radiation and educating the public with the "correct knowledge" on radiation risk. At the same time, increasing specialization within radiation research has shrunk the scope of an individual professional's expertise while widening the range of distinct occupations: radiologic technology, radiology nursing or nuclear medicine technology, showing the continued separation which first began to take shape in the early 20th century between radiological doctors and technicians. The Shimadzu Corporation continues to manufacture state-of-the-art radiological equipment, joined by a fleet of other companies including electronics giants like Hitachi and Toshiba. The difference is that *rentogen* machines are now joined by other techniques of medical radiation, particularly radioisotopes and

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[411] Terada Torahiko, "Shō bakuhatsu niken", *Terada Torahiko zuihitsu shū*, Vol. 5 (Tokyo: Iwanami Shoten, 1997). Accessed from the electronic reproduction on Aozora Bunko, "Terada Torahiko Shō bakuhatsu niken", http://www.aozora.gr.jp/cards/000042/files/2507_13840.html (accessed March 5, 2016).

[412] Ōiwa Yuri, "Iryō hibaku yokusei e tōitsu kijun CT, X sen kensa nado taishō", *Asahi Shimbun Digital*, April 19 2015.

computerized or positron emission tomography. The process by which this new field of nuclear medicine developed and became institutionalized is a question for future studies to explore.

This study makes no arguments for whether radiation is ultimately “bad” or “good”. On the one hand, attempts to attribute normative characteristics to the phenomenon itself serve no substantial purpose. On the other, it cannot claim the relevant technical expertise required to evaluate the complexities of radiation’s biological effects. Indeed, even scientific evaluations of this issue are controversial amongst biomedical professionals, and there is at present a lack of hard consensus on this issue amongst researchers studying this subject today.[413] Instead, the preceding chapters have explored how the field of radiological medicine produced a new body of knowledge about the biological effects of ionizing radiation on humans. That this emergent knowledge did not get linked to the atomic bombings, was in part due to the nature of research onto the *hibakusha* of Hiroshima and Nagasaki, which took years to conduct, and which was also initially classified information. It also reflects the influence of the Atoms for Peace campaign, which promoted the “peaceful use” of nuclear energy for civilian purposes under the aegis of the United States’ sphere of influence in the Cold War. Finally, many medical and scientific professionals viewed radiation as a phenomenon whose potential harms could be managed and controlled by protection measures and safety standards, and whose potential benefits were worth risking the infliction of harms.

In this concluding chapter, the focus expands to consider the post-WWII establishment of a national and transnational infrastructure of medical radiation via the initiatives of governments and medical institutions. It also sketches an overview of how medical professionals, under

[413] For a concise and useful essay on this topic see William F. Morgan and William J. Bair, "Issues in Low Dose Radiation Biology: The Controversy Continues. A Perspective", *Radiation Research* 179:5 (2013), 501-510.

government auspices, created institutions that controlled radiation research. These institutions also played a key role in making and disseminating information about the biological effects of radiation to the Japanese public during the Cold War era of heightened nuclear fears, in the new language of health and risk.

Probing the Cave of Nature's Treasures

It is no surprise that the idea of radiation being a double-edged sword emerged most clearly from the medical world, channeling the classical dictum of toxicology that "the dose makes the poison".[414] Medical practice presented the perspective that radiation, whether in the form of *rentogen* or radium, could be harnessed to provide better medical care. Radiation would be dangerous only if *not properly controlled*. Thus, cautionary papers, articles and government regulations, all served the function, whether directly or indirectly, of facilitating radiation's ability to be used in ways deemed beneficial to society. The immense utility of *rentogen* to public health measures and the enthusiasm of the researchers and medical practitioners who worked with radiation underpinned this attitude.

Rentogen added an instrumental tool to radiation science and medicine. From the early 20th century onwards, their status as a powerful, cutting-edge medical technology also allowed professionals to relativize, justify and normalize the risk of radiation exposure as an occupational hazard. The previous chapters examined, from various aspects, the ways that medical radiation became professionalized and institutionalized in Japan. Taken as a whole, they suggest that, placed in historical perspective, the authority wielded by institutionalized medicine and its

[414] For a discussion of dose/poison see the chapter on toxicology in Marquita K. Hill, *Understanding environmental pollution* (Cambridge, UK: Cambridge University Press, 1997), 57-58.

affiliated organizations such as manufacturing companies and the Japanese state, solidified the image of radiation as positive in terms its nature and effects. The early history of how *rentogen* became associated with public health policy, anti-tuberculosis measures and medical modernity presents a crucial backdrop to understanding how, after the atomic bombings, nuclear energy could be simultaneously viewed as both boon and bane. Moreover, *rentogen* helped reconfigure the relationship of Japanese medical practitioners to their patients, as well as to medicine as a whole. Through an increasingly Westernised infrastructure of medical practice, they came into direct contact with the interiors of human bodies as a routine procedure. In addition, as distinct from the tools of medicine used by an earlier generation of doctors, *rentogen* required the networking of diverse groups of people and multiple forms of knowledge in order to exist, let alone to be used. Thus the earliest experiments with *rentogen* involved collaborations between the intellectual and material resources of physicists and manufacturers, as in the case of Muraoka Han'ichi and the elder Shimazu Genzō. The medical use of X-rays required a combination of various things: basic scientific knowledge, the maintenance of complicated instruments, and the manufacture of commodities. Their practical application in medicine involved not only doctors, nurses and patients, but also technicians, scientists, and manufacturers – and in Japan's case, the government. X-ray technology might even be understood as an early instantiation of Big Science, decades before that phenomenon reached its zenith during the Cold War.[415]

Amidst a welter of fears about nuclear weapons and the health effects of ionizing radiation, confidence in the beneficial uses of nuclear power for non-military ends – embodied so poignantly by Nagai Takashi and his writings – remained strong. Ionizing energy, although

[415] On Big Science see e.g. the essays in *Big science: the growth of large-scale research*, eds. Peter Galison and Bruce Hevly (Stanford, Calif.: Stanford University Press, 1992).

harnessed by man, was still considered the gift of nature, an idea vividly elucidated by Nagai in his history of radiology, as the following excerpt suggests:

> Nature's greatness contains any number of secret vaults. The key to opening them is human wisdom. The interiors of these vaults are stuffed with things to increase human happiness. Humanity is permitted to open them and take out their treasure to share widely with mankind. But that key is not passed to human hands for free. The larger Nature's vault, the larger the price it demands. Many excellent scientists will have to offer up their lives in exchange for it. And yet once that key is found and the vault opened, so that the treasure may be freely used by human hands, no matter how noble the price paid, it is ultimately deemed cheap. – All major discoveries and inventions are thus.[416]

Nagai's essay is striking in how it implicitly assumes the right of humans to excavate Nature for its riches, in exchange for potentially losing their own greatest treasure – that is, their lives. Furthermore, his characterization of Nature's treasures as concealed echoes how the *unknown* characterized the process by which professional scientists labored to mold radiation – a phenomena invisible to the human senses – into a quantifiable, manageable entity. Arguably, their drive to render legible something whose properties, at the turn of the century, remained fundamentally unknown and potentially hazardous, was made possible through a combination of relative ignorance and the assumption that the benefits outweighed the risks.

Medical radiation presents an obvious parallel to nuclear power in the late 20th century, not only because both cases involve the use of equipment which produces ionizing radiation, but also in how the infrastructure and networks of expertise around these technologies required the normalization of their risks. The agents that promoted both medical radiation and nuclear power assumed the existence of 1) a net positive benefit to an emergent technology riddled with unknown characteristics and 2) that this benefit would result from progressive improvements to the engineering of the equipment used in this area. In the case of Japan, there is even a third

[416] Nagai, *Seimei no kawa*, 688.

point of comparison that can be drawn between *rentogen* and nuclear power plants: that sacrifices have been made which justify the continued use of this technology and the development of each field. In the case of *rentogen*, the injuries and deaths sustained by professional doctors, nurses and technicians lent gravitas to continuing research into how their surviving colleagues could wield *rentogen* in better, safer ways. Similarly, the trauma sustained by the *hibakusha* of Hiroshima and Nagasaki were also held up, by Nagai and others, as a tragedy that gave meaning to promoting the peaceful use of nuclear energy – or, in the parlance of the U.S. Atoms for Peace campaign, to "beat swords into ploughshares".[417] The use of medical radiation in postwar Japan involved issues of justifying and managing risk. Along with scientific progress, two key ideas developed in the late 20th century also gained traction in the professional discourse on radiation: *health* (*kenkō*) and *risk* (*risuku*). As Nagai invoked Nature, so his colleagues of later years deployed these concepts to discuss the potential impact of radiation on human life and society.

Reconfiguring Radiation Exposure

More than Hiroshima and Nagasaki, the so-called "Bikini Incident" (*Bikini jiken*) formed the first instance of public panic over large-scale radiation exposure in Japan.[418] The U.S. military conducted its Castle Bravo test of a hydrogen bomb on March 1, 1954, at the Bikini Atoll in the Marshall Islands. The resulting fallout from the explosion contaminated not only Bikini, but several other inhabited atolls in the Marshall Islands, whose inhabitants had not been

[417] On the Atoms for Peace program in Japan see Chapter 1 of Nelson, *Nuclear Society*, 62-89.

[418] Taketani Mitsuo, *Gensuibaku jikken* (Tokyo: Iwanami Shoten, 1957), 15.

adequately warned or prepared to evacuate before the test.[419] The rain of radioactive debris also struck a Japanese fishing vessel, the *Lucky Dragon No. 5*, which had sailed into the fallout zone unaware of the Bravo test taking place. Although none of the *Lucky Dragon's* 23 crew members died of radiation syndrome in the end, they suffered serious injuries and required hospitalization. The Bikini incident, meanwhile, generated a Japanese mass media and consumer panic about radiation contamination of environment and fish stocks – a staple of the Japanese diet.[420] Radioactive fallout acquired the ominous soubriquet of "ashes of death" (*shi no hai*), a term also chosen for the title of an influential book of essays on the Bikini incident, aimed at a general audience, edited by the Marxist physicist (and a one-time supporter of nuclear energy) Taketani Mitsuo. The book's contributors, mostly medical doctors and physicists, discuss radiation illness, the composition of the radioactive ashes, and the future of Japan's fishing industry.[421] The radiation fears sparked by Bikini created an icon of the nuclear age, the mutant Godzilla, an ancient creature shaken awake from its deep sea slumber by hydrogen bomb testing.[422] Bikini also gave rise to a vocal anti-nuclear movement in Japan, as seen in the formation of the Japan

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[419] Takase Tsuyoshi, *Burabō: kakusareta Bikini suibaku jikken no shinjitsu* (Tokyo: Heibonsha, 2014).

[420] See n.66 of Richard G. Hewlett and Jack M. Holl, *Atoms for Peace and War, 1953-1961: Eisenhower and the Atomic Energy Commission* (Berkeley: University of California Press, 1989), 612.

[421] Taketani Mitsuo, *Shi no hai* (Tokyo: Iwanami Shoten, 1954). Taketani's initial support of nuclear energy for peaceful use is discussed in Kanō Mikiyo, *Hiroshima to Fukushima no aida jendā no shiten kara* (Tokyo: Inpakuto Shuppankai, 2013), 24-27.

[422] From the original movie made by Honda Ishirō and the Tōhō company released on November 3, 1954. See the essay by Chon A. Noriega, "Godzilla and the Japanese Nightmare: When *Them!* is U.S.", *Hibakusha Cinema: Hiroshima, Nagasaki and the Nuclear Image in Japanese Film*, ed. Mick Broderick (New York: Routledge, 2009 [1996]), 54-74.

Council against Atomic and Hydrogen Bombs (*Gensuikyō*) in 1955.[423] But the members of the anti-nuclear movement were not necessarily against all forms of radiation, as powerfully articulated in the following statement by Taketani during a symposium convened by the Science Council of Japan:

> What we call radiation, no matter how small the quantity, has adverse effects on human bodies. However, on the other hand, using it can be beneficial, and moreover we are compelled to its use. As an example, take *rentogen* screening: it is a procedure that may cause some adverse effects, but at the same time it also provides the ability to detect tuberculosis early. Here we must balance the goods derived in exchange for harms, and that is what we call the tolerance dose - it is a "dose of how much harm we are able to endure". In other words, the tolerance dose is a social concept that balances benefits and disbenefits.[424]

The "tolerance dose", as discussed in Chapter 4, presumed that an individual person could receive a maximum amount of radiation without suffering long-lasting harm. Taketani disagreed with this understanding, and had already introduced his perspective in an earlier work on atomic and hydrogen bomb testing. To better suit the Japanese context, he proposed calling it the "*gaman* (endurance)" rather than a "tolerance" dose. He explained the appropriateness of this moniker in terms of how it highlighted the tolerance dose's actual character: instead of a scientific concept that specified unambiguous guidelines for safety, it was a social concept that is decided from comparing the benefits and conveniences of radiation use against the harms and risks its users are exposed to.[425]

As Taketani's argument foreshadowed, such a perspective would indeed be implemented – although more from the perspective of medical, scientific and government organizations rather

[423] On Gensuikyō and its members' subsequent split, over support for the USSR, to form the other groups known as Gensuikin and Kakkin Kaigi following the Partial Test Ban Treaty of 1963, see Thomas R.H. Havens, *Fire across the sea: the Vietnam War and Japan, 1965-1975* (Princeton, N.J.: Princeton University Press, 1987), 11.

[424] As cited in Chapter 8 of Taketani Mitsuo, ed., *Anzensei no kangaekata* (Tokyo: Iwanami Shoten, 1967), 123.

[425] Taketani, *Gensuibaku jikken*, 28-31.

than amongst Japanese citizens. The earlier focus on radiation as viewed in terms of nuclear war and radiation illness would subtly shift to just such a balancing of benefits and harms in the next few decades. As seen in the literature on radiation exposure, Japanese institutions of the late 20th century understand this phenomenon primarily in terms of *health*, via what is now known as radiation risk assessment. An instructive instance of the way that "health" is deployed as a basic concept related to radiation exposure can be found in a brochure created by the Radiation Effects Research Foundation (RERF). First published in 2008, this pamphlet endeavors to explain basic knowledge about radiation and health risks from radiation exposure to the public. Titled "The Science of Radiation and Health Simply Explained", it addresses the issues of the potential health effects (*kenkō eikyō*) that radiation exposure can induce in humans. The term "health effects" addresses social concerns about safety and illness more directly than its more scientific counterpart, "biological effects". This term thus became standard usage in epidemiological research as well as, in Japan, public relations material printed by organizations involved with radiation science and technology, including RERF.

Texts produced on radiation often reference the early history of radiology and radiation medicine to frame current events, a strategy that legitimizes current scientific knowledge by contextualizing in a string of discoveries and achievements. RERF's 2008 brochure, for instance, begins its explanation of what radiation is by outlining the research conducted by three of the Nobel Prize-winning scientists who worked with radioactivity in the early 20th century - Roentgen, Curie and Becquerel. Radiation's discovery, this section concludes, "birthed new science” (*atarashii kagaku wa umaretekita*).[426] The introduction of specific personalities and historical figures, including Albert Einstein, Linus Pauling, and Nagai Takashi, is also linked to the scientist-led movement for world peace and nuclear disarmament.[427]

Another notable feature of these public-relations texts, which take great pains to present information about radiation in easily digestible and well-illustrated form, is their frequent emphasis on the presence of radiation in the natural environment, including granite, food, and cosmic rays from outer space. Listing the sources of natural radiation that humans are exposed to in everyday life, through common activities like air travel or having a CT scan, helps to normalize radiation as an everyday phenomenon that is only dangerous in certain conditions. In other words, these texts discuss the *risk* that radiation presents from a wide variety of sources, including medical care. The RERF brochure devotes a section to evaluating radiation risk and safety standards. It contains information about the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and notes that Japan follows the committee's latest guidelines on setting limits for occupational and civilian exposure – 50 millisieverts per year in the former case and 1 millisievert per year in the latter.[428] However, these texts do not usually discuss the scientific dispute over the risks of low doses of radiation in the long term, and the accurate model to use in understanding the relationship between radiation exposure and health

[426] Hōshasen Eikyō Kenkyūsho (Radiation Effects Research Foundation), *Wakariyasui hōshasen to kenkō no kagaku* (Hiroshima and Nagasaki: Hōshasen Eikyō Kenkyūsho, 2013 [2008]). Available from the organization’s website at http://www.rerf.or.jp/shared/basicg/basicg_j.pdf (accessed March 11, 2013).

[427] Ibid., 12.

[428] Ibid., 11. The Sievert (Sv) is an SI unit denoting radiation absorption by the human body, brought into use in 1979 to replace its older unit, the radiation equivalent man (rem). See Timothy J. Horgensen, *Strange Glow: The Story of Radiation* (Princeton, New Jersey: Princeton University Press, 2016), 108.

risk.[429] In its most basic form, the controversy surrounds whether or not the health effects of radiation are directly proportional to radiation exposure; in scientific parlance, the applicability to radiation risk of what is called the Linear No-Threshold (LNT) model. [430] This debate stems from the first report authored in 1972 by the Committee on the Biological Effects of Ionizing Radiation (BEIR I), a group of US-based researchers under an arm of the National Academy of Sciences; the ICRP adopted these findings in their 1977 report as the appropriate model to use for radiation protection standards, rather than the dose-based model traditionally applied.[431]

UNSCEAR and BEIR have their origins and counterparts in the ICRP and the professional societies around radiology and radiation science that emerged in the first half of the 20th century. Scientific committees and institutions continued to play increasingly prominent roles in setting international standards to frame the understanding of radiation and to guide its applications. Some of the key official organs that govern radiation science and medicine in Japan today are introduced in the following section.

New Institutions of Radiation Research

Tracing the institutions that established radiation medicine as a new specialty in Japan illuminates the vast amounts of government and academic resources devoted to this area since

[429] Edward J. Calabrese, ed., *Biological Effects of Low Level Exposures Dose-Response Relationships* (Boca Raton: CRC Press, 1994).

[430] The LNT model debate has spanned much scientific literature since its appearance. For two perspectives that argue for and against it respectively, see John W. Gofman, *Radiation-induced cancer from low-dose exposure: an independent analysis* (San Francisco, Calif.: Committee for Nuclear Responsibility, 1990) and Charles L. Sanders, *Radiation Hormesis and the Linear-No-Threshold Assumption* (Berlin: Springer-Verlag, 2010), 3-12. For a brief overview of the LNT's significance see Kate-Louise D. Gottfried and Gary Penn, eds., *Radiation in Medicine: A Need for Regulatory Reform* (Washington, D.C.: National Academy Press, 1996), 115-116.

[431] International Commission on Radiological Protection, *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 26, Annals of the ICRP 1:3 (New York: Pergamon Press, 1977). On BEIR and an informative history of the LNT see Gottfried and Penn, eds., *Radiation in Medicine*, 284-289.

1945. Two years after Hiroshima and Nagasaki, in 1947, U.S. President Harry Truman authorized the National Academy of Sciences to conduct research on the long-term health effects of exposures from the atomic bombings. This resulted in the formation of the ABCC that same year; in 1975 it was reorganized as the RERF and jointly funded by both Japanese and American governments, with its Japanese centers in Hiroshima and Nagasaki.[432] In 1950, the ABCC began conducting a long-term study on the mortality of 120,000 people, both male and female, and of all ages. This project was called the Life Span Study (LSS). Based on national census information, the LSS included the greatest possible number of *hibakusha* survivors who were within 10 kilometers of the bombs' hypocenters. In 1958, a bi-annually conducted clinical examination program known as the Adult Health Study (AHS) began gathering data on a subsample of about 20,000 members of the LSS. Following this, follow-up research was conducted on the mortality of about 77,000 offspring of atomic bomb survivors, born from 1946 to 1984. In 1958, cancer registries were formed in Hiroshima and Nagasaki, the first of their kind in Japan, to document the incidence of cancer among atomic bomb survivors and their offspring.

Under the auspices of ABCC-RERF, the LSS, AHS and offspring studies are still in progress, and worldwide have been the primary basis for estimating the health risks engendered by exposure to radiation.[433] Another bastion of how health and radiation have become entwined in postwar Japan is the National Institute of Radiological Sciences (NIRS). Established in 1957,

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432 On RERF see Lindee, "Survivors and scientists."

433 The LSS's initial group consisted of *hibakusha* within 2.5 km of the hypocenter, and a random subsample, matched on age and sex, of the much larger numbers who had been between 2.5 and 10 km from the hypocenter. It also included about 26,000 who were not in the cities at the time of the bombing but resided there from 1950 onwards. See George D. Kerr, "Development of A-Bomb Survivor Dosimetry", *Effects of Ionizing Radiation: atomic bomb survivors and their children (1945-1995)*, eds. Leif E. Peterson and Seymour Abrahamson (Washington, D.C.: Joseph Henry Press, 1997), 3-30.

it is the sole institute in Japan that focuses exclusively on scientifically researching radiation and health via laboratories, a hospital specializing in radiotherapy, and education programs in radiation science and technology as well as emergency responses to radiation accidents or disasters. The NIRS also investigates the impact of radiation exposure on human health and natural environments, and the necessary protection measures thereof.[434] Its work is complemented by the import of radioisotopes for medical use in the 1950s and the establishment of research institutes for radiation biology and medicine at the prefectural universities of Hiroshima and Nagasaki. Table 3 lists these official organs in chronological order:

Table 3. Major institutes of radiation medicine and science research in Japan today

Year established	Institution Name
1947	Atomic Bomb Casualty Commission (ABCC)
1951	Japan Radioisotopes Association
1956	National Institute for Radiological Sciences (NIRS)
1958	Research Institute for Radiation Biology and Medicine, Hiroshima University
1962	Atomic Bomb Disease Institute, Nagasaki University
1975	Radiation Effects Research Foundation (RERF) [successor to the Atomic Bomb Casualty Commission]
1992	Nagasaki Association for Hibakushas' Medical Care (NASHIM)

Along with the medical departments in universities that established radiology departments in the early 20th century, these relatively newcomers of research institutes have been the primary sources of postwar Japan's experts in radiation medicine and science. This new generation of professionals, whose work is contextualized by the exposures of the atomic bombings and the global population to atmospheric fallout, have a far more complicated

[434] National Institute of Radiological Sciences, "About NIRS | National Institute of Radiological Sciences", http://www.nirs.go.jp/ENG/about/index.shtml (accessed March 10, 2016).

relationship to public perceptions of radiation than their predecessors. Here it is worth highlighting the case of Nagasaki University's Atomic Bomb Disease Institute, whose name invokes the spirit of Nagai Takashi and his struggle with the syndrome he thus christened. It is also worth clarifying what relationship medical radiation bears to the emergence of civilian *hibakusha* in the age of nuclear energy and nuclear weapons testing. Radiological medicine (*hōshasen igaku*), examined in this study via *rentogen*, now constitutes a different field from what is today known in Japan as radiation exposure medicine, or simply radiation medicine (*hibaku iryō*). This distinction is an important one in the Japanese context: in a disaster involving radiation exposure, it is not usually the radiologists who are called to the frontlines of response. The role of providing critical care and medical responses falls to their colleagues in a new specialty called radiation emergency medicine, which involves knowledge of radiation medicine rather than radiology, and which has seen a greater influx of institutional resources since the Fukushima nuclear power plant meltdown.[435]

Radiation after Fukushima

Few phenomena are as imbued with normativity as radiation. To refer to it is to invoke a dyad of fantasy and fear about its potential and actual impact.[436] It historically connotes both the

[435] For an overview of radiation emergency medicine see Mayo Ojino and Masami Ishii, "Reconstruction of the Radiation Emergency Medical System From the Acute to the Sub-acute Phases After the Fukushima Nuclear Power Plant Crisis", *Japan Medical Association Journal* 57:1(2014), 40-48. See also the Hirosaki University Radiation Emergency Medicine website, http://www.hs.hirosaki-u.ac.jp/~hibaku-pro/rem/ (accessed February 29, 2016).

[436] An observation credited to Sheila Jasanoff, notes from a conversation held on October 25 2015 at the Center for the Environment, Harvard University.

power to harm, but also to heal, as well as death and life.[437] The social imaginaries that sprang up around the infrastructure of the production and use of manmade radiation, especially in the form of nuclear energy, spread across the world in the late twentieth century, following Hiroshima and Nagasaki. In Japan, these social imaginaries peaked in force with the Lucky Dragon incident, and most recently, the Fukushima disaster.[438] In the pre-war period Japan occupied a position of relative obscurity in the international community of radiological professionals, and its scientific and medical experts depended heavily on receiving new knowledge about radiation from the research their foreign colleagues conducted. After Hiroshima and Nagasaki, however, Japan became a producer of data about the long-term effects of radiation on a population exposed to atomic bombing.[439] It continues to occupy this status following the meltdown of March 11, 2011 (3.11) at the Fukushima Daiichi nuclear power plant. A prominent issue that connects these events, as discussed in the previous section, is the impact of nuclear disasters on human health.

As mentioned in the introduction, the start of a period popularly designated as the "atomic age" is often marked by the Ground Zeroes of detonated weapons. Many of the actors mentioned in the preceding chapters of this study worked in a universalistic frame – that is, they saw "science" and "technology" as universally applicable phenomena. Yet it is often considered

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[437] For an analysis of historical interconnections between the early radioactive sciences and the sciences of heredity, see Luis Campos, *Radium and the secret of life* (Chicago: University of Chicago Press, 2015).

[438] On social imaginaries see Sheila Jasanoff, "Future Imperfect: Science, Technology, and the Imaginations of Modernity", *Dreamscapes of modernity: sociotechnical imaginaries and the fabrication of power*, eds. Sheila Jasanoff and Sang-Hyun Kim (Chicago: The University of Chicago Press, 2015). Kindle version.

[439] Soraya Boudia, "From threshold to risk: exposure to low doses of radiation and its effects on toxicants regulation", *Toxicants, health and regulation since 1945*, eds. Soraya Boudia and Nathalie Jas (London: Pickering & Chatto, 2013). Kindle version.

that there is a particularly Japanese experience of nuclear disaster and radiation exposure, an idea encapsulated in the phrase “the only A-bombed country in the world” (*sekai de yuiitsu no hibakukoku*), which emphasizes the narrative of a nationally oriented trauma originating in Japan’s status as a victim of nuclear war.[440] Nuclear missiles are undoubtedly grave milestones that carved out a new era of global fears and arms races. But post-Fukushima, it is clear that a singular focus on weapons ignores the effects of the nuclear energy industry in terms of environmental and human costs - including the *hibakusha* bodies of its laborers and local residents caught in the fallout after accidents happen. It is equally clear that the scope of these problems cannot be confined to the local or even the national scale, since the diffuse nature of radiation makes its impact transnational.[441]

Fukushima continues to be a disaster in the present progressive tense, with ongoing problems of environmental contamination and municipal recovery, not to mention concerns over the chronic health risks of mental stress and economic hardship on residents who have chosen not to, or who could not leave, their homes. Radiation fears in Japan today are well illustrated by, for instance, the social stigma that attached to the *hibakusha* of Hiroshima and Nagasaki, and now of Fukushima.[442] After 3.11, one contemporary Japanese observer, Koide Hiroaki, framed his discussion of the damage that ionizing radiation inflicts on biological tissue with the evocative phrase “Madame Curie also died of radiation exposure”. Here Koide, a professor of

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[440] Orr, *The Victim as Hero*.

[441] See e.g. Eugene H. Buck, Harold F. Upton and Peter Folger, *Effects of Radiation from Fukushima Daiichi on the U.S. Marine Environment* (Washington, D.C: Congressional Research Service, 2011).

[442] For a recent study of social phobia to survivors of nuclear events see the report by Menachem Ben-Ezra et al., "From Hiroshima to Fukushima: PTSD symptoms and radiation stigma across regions in Japan", *Journal of Psychiatric Research* 60 (2015), 185-186.

nuclear engineering and anti-nuclear activist based at Kyoto University, references the widespread trend in radiation-caused injuries amongst doctors, technicians, patients and scientists in the late nineteenth and early twentieth century – but without the positive connotations of self-sacrifice and martyrdom so often invoked in discussions of these victims, as demonstrated in the case of Nagai Takashi.[443] This prompts the question of how and why such a shift in perceptions could occur. Japan's pre-Hiroshima experiences of radiation in medical science and its early cases of radiation illness provide an opportunity to view current anxieties in historical perspective. By casting light on the pre-war history of how the earliest manifestations of radiation exposure and medical radiation took place, we are better positioned to examine the processes that took place in an era increasingly powered by nuclear fission. It is worth considering the ways in which our predecessors understood and articulated, in their own ways, what it meant to live with the awareness of danger in their environments. In this present age, the risk of nuclear energy-related accidents and concomitant environmental exposures remains indefinitely present.[444] Terada Torahiko's injunction, quoted in the epigraph to this essay, reminds us of how difficult it is to justifiably fearful of natural phenomena that are part of our everyday landscape, but whose effects are also unpredictable and often uncontrollable.

Risk can be understood as a fundamentally modern calculus of anticipatory suffering, where the question presumes the possibility that *someone* will suffer, to a certain extent, under certain conditions. But before the age of nuclear weapons and energy, in Japan and the rest of the world, radiation risk existed in a world underpinned by professional concerns. Risk originated in the seclusion of professional spaces. Originally the purview of scientific and medical experts, its

[443] Koide Hiroaki, *Genpatsu no uso* (Tokyo: Fusōsha, 2011), 45-47.

[444] Masco, *The Nuclear Borderlands*, 336-337.

control remained in their hands even after it ceased to be their sole concern, in a post-WWII era of global fallout fears and nuclear accidents with transnational impact. Radiation risk evolved from being a professional concern to an issue that involved state and public concerns over how to *manage* it. Yet, at the same time, its existence – as that of actual radiation contamination – continued to be governed by technical expertise, and the formal representations produced by that expertise, including research publications and reports issued by international expert bodies.[445] This phenomenon grew even more pronounced with the advent of chronic exposure to low-dose radiation. Radiation syndrome post-Hiroshima and Nagasaki is less clear-cut than the erythema, burns and leukemia suffered by the early generations of radiological practitioners. The question of whether chronic exposure to low-dose radiation causes cancer is still contested, although a recent French study of over 300,000 nuclear-industry workers in France finds strong evidence that even very low doses raise the risk of contracting leukemia.[446] In the pre-nuclear age of radiation science and technology, before the idea of risk structured human suffering caused by these technologies, radiological practitioners understood their trauma as a justified result of their own actions. Today, however, it is no longer a question of individual responsibility, while the individual's risk is subsumed in studies of populations. The question of who to blame is thus both far more diffuse and far harder to ascertain.

In the wake of 3.11, for a great many Japanese citizens, the legitimacy of scientific and state authorities lies in tatters. Public distrust of experts in official institutions' recommendations over the low probability of cancer induced from long-term exposure to low-dose radiation has

[445] Olga Kuchinskaya, "Twice invisible: Formal representations of radiation danger", *Social Studies of Science* 43:1 (2013), 78.

[446] Leuraud, K., et al., "Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): an international cohort study", *Lancet Haematology* 2:7(2015), e276-e281.

climbed, and attempts to wield science's putatively universal truths to pacify anxieties over radiation risk have failed to achieve that aim.[447] Fukushima shows how scientific and state institutions in late modernity view trust and credibility as goals to be manipulated in order to restore legitimacy, rather than as an opportunity for reflexively examining how these issues implicate forms of power and social control.[448] The sum of modern Japan's experiences with radiation shows the painful lack of easy answers to the question of how to calculate risk. One of the points this study makes is that attempts to resolve this modern conundrum about radiation risk require historians' tools. Lindee's study of RERF notes

> the mongrel nature of militarized and civilian sciences as they have operated in radiation risk networks since 1945. The mixture of state interests, elite science and technology, and corporate investments found in the rise of nuclear energy in Japan is implicated in many other high-risk technological systems.[449]

These are crucial insights. However, as this study shows, the "mongrel nature" of science for military and civilian use occurred even before 1945. History can draw our attention to the specific rather than, or alongside, the universal; historians seek to understand the specific interests of people and other agents that interact under specific circumstances. Understanding these specific details subsequently allows us to consider which interests have been involved in the evolution of radiation risk, and how they may be balanced in the present day.[450] And the interests at play in the present day include all those introduced in the chapters to this study, with

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447 Christopher Hobson, "Rebuilding Trust after Fukushima", Fukushima Global Communication Programme Working Paper Series Number 04 (March 2015), 1-7.

448 See the introduction by Scott Lash and Brian Wynne to the English translation of Ulrich Beck, *Risk Society: Towards a New Modernity*, translated by Mark Ritter (London: Sage Publications, 1992), 4-6.

449 Lindee, "Scientists and survivors".

450 Paraphrased from observations by Ruth Schwartz Cowan, *Heredity and hope: the case for genetic screening* (Cambridge, Mass.: Harvard University Press, 2008), 8-9.

the exception of the military: the state, scientific experts, medical practitioners, manufacturers and the public. The difference is that the portion occupied by public concern is far larger than it was before Hiroshima and Nagasaki, and the focus of the experts has shifted towards indefinitely ongoing epidemiological studies of the long-term health effects on exposed populations. While historians usually forego prognostication, this trend shows no signs of changing as long as Japan continues to possess nuclear power and reprocessing plants. The issue of how to best coexist with risk, then, is at the fore. The radiation professionals of the past, who were also radiation exposure's primary source of casualties, managed and justified that through their work; the civilians of today will need to find other reasons in a world where the technologies of risk are overwhelmingly likely to stay.

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Ikai jihō
Ika kikaigaku zasshi
Igaku chūō zasshi
Keikō
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