Russell H. Morgan, MD (1912–1986): pioneer in image quality assessment and radiological science

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Professor Russell H. Morgan, MD (Figs. 1, 2, 3) was born on March 20, 1912, in London, Ontario, Canada. He graduated from the University of Western Ontario School of Medicine. After internship and residency in pathology, he completed his residency training in radiology at the University of Chicago. His performance during and after his residency was stellar, and his contributions to radiology were milestones, as described in Memorial Tribute to Russell H. Morgan in American Journal of Roentgenology (AJR) [1] in 1986.

During his stay in Chicago, Dr. Morgan invented a photo-timer in radiographic imaging systems [2], the concept of which is commonly employed in all of modern radiologic imaging systems since that time, although many may not be aware of this major invention by Dr. Morgan in early days of radiological science and clinical radiology. Dr. Morgan received only “one dollar” from the National Institute of Health (NIH) for his invention, and thus enabling the concept of the photo-timer be utilized in all of X-ray imaging systems by all of medical imaging system manufacturers worldwide.

In 1946, Dr. Morgan was appointed as Professor and Chairman of the newly instituted Department of Radiology at the Johns Hopkins University School of Medicine and the Johns Hopkins Hospital at age of 35. He had outlined in a 10-page memo his concept of the needs for equipment, space and staff to build a top-level academic radiology department, which was then promised by President Isaiah Bowman of Johns Hopkins University. His arrival at Hopkins was about a year and a half after the end of World War II, and thus it was a time for a change.

In 1950, Dr. Morgan’s department moved into a new building with new equipment. With the support of physicist Ralph Sturm, Ph.D., Dr. Morgan continued his research on photo-timing, and began developing a concept for intensification of fluoroscopic images, which resulted in a landmark publication, one of the most-cited articles at that time, namely, “Screen intensification systems and their limitations” published in AJR [3] in 1949.

At that time, radiologic images were viewed on films recorded as static silver-halide images or with fluorescent screens for dynamic fluoroscopic images. Since the brightness of fluorescent screen was not very high, but rather quite dark, it was common for radiologists to wear dark red glasses for a while in order to improve dark adaptation of their visual system before fluoroscopic examinations of the patients. In their studies [3], for example, observers were required for one-hour dark adaptation before fluoroscopic observer studies. It was obvious in fluoroscopic observations that human visual systems do not have adequate capability in visual detection of low-contrast small details due to extremely dark fluoroscopic images.

On the other hand, radiographic images are commonly observed with use of a bright view box, thus causing no problem for human visual system. However, the number of X-ray quanta absorbed in a screen-film system producing adequate images is about the order of 10,000 per square mm, thus causing the statistical fluctuation of 1 percent per square mm. However, if details in radiologic image are of the order of 0.1 mm, and then the statistical fluctuation with only 100 quanta becomes about 10 percent, thus causing difficulty in recognizing small image details. Sturm and Morgan [3] in their paper (Figs. 4, 5) demonstrated clearly the limitation of quantum statistical fluctuations in radiological images at the time much earlier before development of modern X-ray image intensifiers, as well as flat-panel detectors and digital

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Fig. 1 Russell H. Morgan, ca. 1946, photograph #195058, Courtesy of The Alan Mason Chesney Medical Archives of The Johns Hopkins Medical Institutions

imaging systems which are commonly used in many hospitals worldwide today.

In 1971, Dr. Morgan was appointed Dean of the Medical Faculty of The Johns Hopkins School of Medicine. Two years later, he was named Vice President for the Health Division and University Professor of Medicine. In 1980, the department that he served so well for 23 years was named in his honor: “The Russel H. Morgan Department of Radiology and Radiological Science”.

Dr. Morgan was very famous worldwide due to his contribution to leading articles [2–7] published in *AJR*. In 1962, Kunio Doi started his career as an engineer at a small company called Dai Nippon Toryo, Kyokko Research Laboratories, Chigasaki, Japan, which was a manufacturer for various phosphors for TV screens, and also X-ray intensifying screens for radiography and fluorescent screens for fluoroscopy. At that time even for a young engineer, he was impressed by Dr. Morgan’s landmark paper [3] on noise limitation in X-ray imaging due to screen intensification. In fact, Dr. Morgan’s work was well known among many researchers including Shinji Takahashi, M.D. [8] in Japan,

Fig. 2 Russell H. Morgan, ca. 1965, photograph by Richard Linfield, photograph #117021, Courtesy of The Alan Mason Chesney Medical Archives of The Johns Hopkins Medical Institutions

although there was no internet at that time, and traveling from Japan to the United States was extremely difficult due to the large difference in economy in two countries.

However, Kunio Doi has met Dr. Morgan in 1966 at the University of Chicago during the International Symposium held by Dr. Robert D. Moseley, Chairman, Department of Radiology, The University of Chicago, since he was invited to present his talk on analysis of noise sources in radiography [9]. This invitation was unbelievable and ecstatic to Kunio Doi at the age of 26, since it was impossible for a young physicist in Japan to travel to the United States of America for presenting a scientific talk. However, his first visit to the United States occurred probably because of his first English paper [10] published in *AJR* in 1965 entitled “Optical transfer functions of the focal spot of X-ray tubes”. He was not aware of a potential impact of his first English paper in the United States at that time (Fig. 6).

Fig. 3 Russell H. Morgan by Herbert E. Abrams, 1982, oil on canvas, Courtesy of The Alan Mason Chesney Medical Archives of The Johns Hopkins Medical Institutions

After the International Symposium in Chicago, Kunio Doi visited a number of cities in the United States including Cleveland, Rochester, New York, Baltimore, Washington, D.C. and San Francisco in 13 days in order to gain knowledge about people and research in the United States as much as possible, because this was an important valuable chance for a young physicist from Japan at that time. In Baltimore, he visited Dr. Morgan's lab and met with Dr. Lloyd Bates, since Dr. Morgan was out of town, who showed him research facilities including a long solid bench for X-ray sensitometry in Dr. Morgan's lab, after many years later Kunio Doi had recognized, which was very similar to the equipment built in the Kurt Rossmann Lab at the University of Chicago [11, 12] in Fig. 7. Kunio Doi can only imagine at present in 2021 that Dr. Morgan and Dr. Rossmann might have communicated each other in building such an X-ray sensitometry system in their labs, since such device did not exist anywhere around the world at that time.

After the meeting in Chicago, Kunio Doi wanted to come to the United States for continuation of his research, and thus obtained his Ph.D. degree from Waseda University in 1969. Subsequently he decided to join the research group by Kurt Rossmann, Ph.D. at the University of Chicago, when Dr. Rossmann was able to secure research fund from the NIH, just before the ending of Vietnam War. Kurt Rossmann, Ph.D. [11] was Professor and Director of the

Fig. 4 Photograph of some members attended the Symposium held at the University of Chicago in 1966, including Dale Trout, PhD (Univ of Washington), Herbert Schober, MD, PhD (Univ of Munich), Eric Zieler, PhD (Philips), Waler Kuhl, PhD (Philips), from left in front row; Eric Ingelstam, PhD (Karolinska Institute), Olle Olson, MD

(Univ of Lund), Kurt Rossmann, PhD (Eastman Kodak), Russell Morgan, MD (Johns Hopkins Univ), in mid row; Kazuo Sayanagi, PhD (Canon), and Kunio Doi, BS in back row. Reprinted from Kunio Doi (2012), Message to the Future, INNERVISION, 27-5, p. 120–121, with permission from INNERVISION Co., Ltd

Fig. 5 Graphic illustration of photon densities during fluoroscopic process including stage 1: the number of X-ray photons projected by X-ray tube toward each square mm of screen surface per second; stage 2: the number of projected photons remaining after absorption by anatomical tissues; stage 3: the number of X-ray photons absorbed by fluoroscopic screen; stage 4: the number of useful light photons produced on screen surface each second by each square mm; stage 5: the number of photons entered the eye; stage 6: the number of photons stimulate the retina. Curves A, B, and C correspond to fluoroscopy of the chest, and antero-posterior and lateral view of the abdomen, respectively. Reprinted from [3] with permission from American Roentgen Ray Society

Fig. 6 Experimental visual performance data obtained under fluoroscopic conditions equivalent to A. fluoroscopy of the chest; B. antero-posterior fluoroscopy of the abdomen; C. lateral abdominal fluoroscopy. Reprinted from [3] with permission from American Roentgen Ray Society

Section of Radiological Sciences in the Department of Radiology at the University of Chicago from 1965 to 1977, after his pioneer work [13–17] on radiographic image quality at Eastman Kodak Company. Dr. Rossmann was well known for his work on the MTF and image quality studies on radiography. Dr. Morgan had known Dr. Rossmann at Kodak and also at the University of Chicago very well because of the overlap of their research interests in image quality in radiology.

In 1976, Dr. Morgan received honorary Doctor of Science degree from the University of Chicago. During his visit to Chicago, Dr. Rossmann asked Kunio Doi to spend his time with Dr. Morgan for about half an hour, which was a pleasant surprise to me in speaking with Dr. Morgan directly about my research. Therefore, I have spoken with him about my latest findings on the effect of radiologic magnification technique on reduction of radiographic noise, thus improving detail visibility of radiological images, which was subsequently published in Radiology [18]. This conversation was very pleasant for me. Dr. Morgan congratulated me for my research work, which made me very happy.

Another occasion when I have met with Dr. Morgan in 1977 was at a special study section meeting at the NIH for review of a research grant proposal submitted by a prominent radiologist in the United States. At the start of the special study section meeting, Dr. Morgan as chair of the group stated to a small number of reviewers that we, most of us, have known very well personally and professionally the principal investigator of this proposal, and therefore we must try to be very objective and do a good job in review of this proposal in order to be helpful to the investigator. This statement by the chair was very useful for me and probably for the group in critical review of the proposal, subsequently all agreeing in rejecting the proposal for funding unfortunately. However, this project was revised carefully and significantly even with a change in the principal investigator as well as Kunio Doi to be included as consultant to the project, and resubmitted to the NIH with major revision. The revised project was subsequently funded successfully, after the site visit by another independent NIH review panel.

Fig. 7 X-ray sensitometer at the University of Chicago for determination of characteristic curves for screen-film systems. Reprinted from [11]

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