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1895-1995 – The Century
of X-Rays

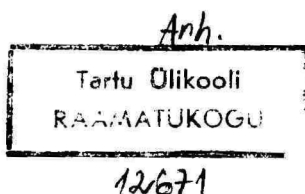
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WILHELM CONRAD RÖNTGEN

P R E F A C E

The present situation of Estonian radiology can be characterized by the same kind of crisis that exists in all fields of development in Estonia: with Estonian independence was lost 50 years of progress, such that the level of training in radiology is low and radiological equipment is far behind the newest technology. The first step in finding a way out of these problems was agreed on between the Baltic countries two years ago. Representatives of Estonia, Latvia and Lithuania signed an agreement which outlines numerous important topics, guaranteeing cooperation in improving Baltic radiological training. Meanwhile, this plan for improving radiological training in the Baltics has been implemented, but only partially - the unstable financial system has prevented the plan from moving faster. Some Estonian radiologists have been fortunate enough to study abroad for a short time. The University of Helsinki has been a great help in making this possible. Also, radiologists' training has changed drastically. During the Soviet period, 5 months training was enough after receiving a diploma to begin work as radiologist. Now, 5 years training is required after receiving a diploma: two years general internship and three years

radiological general residency. In addition, it is possible to study interventional ultrasound or angiology as well as CT or MRI for one more year. Two years ago the Radiology and Oncology Clinic was founded at Tartu University as a center for radiological training and research, having its base of training at medical treatment and diagnostic institutions in Tartu and Tallinn.

The Estonian Radiological Research Project was activated, by which cooperative research agreements with other countries have been compiled. The First Baltic States' Oncological and Radiological Congress will take place in October 1994 in Tallinn, in which we hope many colleagues from abroad will participate. Secondly, a yet more important project is to bring radiological equipment -- radio-diagnostic as well as therapy equipment -- up to date. With few exceptions, all equipment is obsolete and must be replaced. As Estonian financial resources are very limited, we have created joint projects with the United States, Finland, Sweden and Germany. Especially active is the Estonian American Fund for Economic Education INC. (EAF). Two years ago EAF gave the clinic of the University of Tartu a CT-scanner, the first in Tartu. In summer 1993 two engineers traveled to the United States to dismantle a gift of one CT-scanner DR3 and five complete sets of x-ray equipment. A CT-scanner was also bought inexpensively for Tallinn and MRI Tartu University clinics.

The greatest necessity is ordinary, universal X-ray diagnostic equipment. We hope to exchange in the above-mentioned ways approximately 200 X-ray apparatus in

the coming years, apparatus which have been in use already for five to ten years and which will continue to be used until the Estonian Republic is able to buy new apparatus. Radiotherapy apparatus must be replaced as well.

Two years ago the Estonian-Finnish Radiation Protection Project was founded. The goal of this project is to organize work in radiation protection until we have integrated our radiation protection work into the European radiation protection system. As the publication of this Tartu University journal coincides with the 100-year anniversary of the invention of the X-ray, we have dedicated a large part of this book to Estonian radiologists of Tartu University, thanks to whom radiology in the Estonian Republic has achieved excellent results.

Erich Kuus

WILHELM CONRAD RÖNTGEN AND HIS RAYS

Sven KRUUP, Erich KUUS

Clinic of Radiology and Oncology

On February 19, 1896, a representative of the state of New Jersey, United States of America, tried to push through a bill about "banning the use of X-rays in opera glasses" in the local government (2). At the same time a prestigious London newspaper advertised underwear which could protect against X-rays (1).

These examples reflect the comical aspects of one of the greatest discoveries in physics in the 19th century. The discovery of X-rays on November 8, 1895, by W.C. Röntgen laid the foundations of contemporary medical science and all previous development could be expressed in one sentence : X-rays had not been used before.

50 years before that event, on March 27, 1845, a baby boy was born in Lennep am Rhein who was named Wilhelm Conrad. The boy spent his younger years in Holland as his mother was Dutch. He received primary education at home and partly at Utrecht. His ability at school was estimated as satisfactory. Due to a conflict between him and a teacher in higher forms, he was expelled from school. He did not even succeed in graduating the school as an "extern", for the same teacher happened to be in the examination board. This teacher simply failed the boy (2). In 1865, without having this certificate of maturity, Röntgen entered the Zürich technical high school; in

1868, he graduated from the school as a mechanical engineer. He also defended his Ph.d. degree there. After that he worked as an assistant to a then widely known experimental physicist, A.Kundt, in Zürich and Würzburg. In Würzburg he lived through the first disappointment of his career, for Würzburg university refused him a professorship, as he did not have a certificate of classical high education. Soon he went to Strassburg with his assistant, where he was lucky to receive a private docentship in 1874. A year later, at the age of 30, he became a full professor of physics and mathematics at the Hohenheim Academy of Agriculture.

In 1876, at the request of Kundt, Röntgen came back to Strassburg to work as second physicist. He wrote a number of works there. In 1879, Röntgen was offered a professorship at Giessen University, which he accepted.

In autumn, 1888, he received the chair of physics at Würzburg University, succeeding Kohlrausch. At Würzburg he broadened his research and wrote a number of scientific articles that made him more widely known among the physicists of the most progressive schools.

In 1895, when Röntgen was already 50, he was impressed by works of other famous physicists (Hertz, Lenard, Hittorf, Cookes) and began to research the phenomena caused by electric current in vacuum tubes. Röntgen was working with Hittorf's tube, which was covered by black cardboard. He noticed that some crystals that were near the tube began to luminesce at the moment high-voltage current was passed through the tube. This finding on October 8, 1895 led to an

important discovery. Over a period of eight weeks Röntgen noticed a number of strange qualities of X-rays. On december 28, 1895, he gave a thesis of his work "About A New Type of Rays" to the chairman of the Physical-Medical Society at Würzburg University. It was first published in departmental gazettes and soon as a separate edition (3). It was a classic scientific work consisting of seventeen short, well-founded theses in a few short pages. A few weeks later this brochure was published in English, French, Italian, and Russian (2).

On January 23, 1896, Röntgen made a report with demonstrations in the same society. A röntgenogram made of professor A. Kölliker's hand (fig.) at the assembly was a great success and caused an outburst of enthusiasm. Kölliker, professor of anatomy, made a speech there, calling attention to the discovery and stressing its importance. He named these rays "Röntgen rays" for the first time (3).

Another scientific work followed on March 9, 1896. It appeared in the same gazette and was published later on separately under the same heading "About A New Type of Rays", theses 18-91.

A third scientific work by Röntgen "Addition to the Observations of the Qualities of X-rays", published on March 10, 1897, is also connected with the previous two, and consists of eleven points, proved with correct scientific method (2). In the above-mentioned works Röntgen has determined precisely the manifold qualities of the new rays.

Despite the thoroughness of Röntgen's research, questions about the

qualities of Röntgen rays still remained unanswered (3).



The news about Röntgen's discovery spread quickly all over the world through the medium of a telegraph agency. The name of the scientist was unfortunately misspelled "Rutgen". The information

about the discovery reached London by indirect route via Vienna: Röntgen had sent a letter to professor Eksner, a fellow-student of Röntgen's on Zürich. The first persons to learn about Röntgen's discovery were his close friend Bovery, a zoologist, and Röntgen's wife Bertha. He wrote to Bovery a few days after the discovery: "I have detected something interesting, but I do not know yet, whether my findings are precise or not" (2). His wife Bertha once made a scene because he had not praised the excellent supper she had made especially for him. Röntgen then, without saying a word took his wife by the hand and led her to the lab one floor down where he demonstrated to her the illuminating effect of X-rays (2).

Nowadays there is no doubt that there were a number of Röntgen's contemporaries who detected X-rays while carrying out research with vacuum tubes. Lenard, a physicist, was extremely close to the discovery of a new kind of ray, and he pretentiously named them after himself (2). At the same time it was Röntgen who scientifically researched them and gave a systematic survey of their qualities, so that up to the year 1908 nobody could add anything important to his works (5).

According to contemporary understanding, X-rays come into being when electrons are slowed down in matter and the rays can be qualified as electromagnetic waves of frequency $100-0.1\text{\AA}$ ($1\text{\AA}=10^{-10}\text{m}$). These rays can be produced artificially by means of special Röntgen tubes, to the electrodes of which high-voltage current (about 50,000-200,000 V)

is applied and from its cathode the emitting electrons, thrusting against the anode, produce Röntgen rays.

Röntgen rays are capable of penetrating different materials which are impenetrable to visible light. Similarly to electromagnetic waves, they do not deflect from any electric or magnetic fields and their deflection is minimal when passing from one medium to another. The rays' absorption in different materials is varied, depending on their chemical components: heavy elements (lead, for example) would absorb X-rays more intensely, lighter elements would absorb the rays less intensely.

These qualities of the Röntgen rays make it possible to get a depiction of different tissues and organs either on a screen (röntgenoscopy) or on photographic film (röntgenography). And also the damaging qualities of X-ray therapy of malignant tumors (4).

Now let us go back to our exciting excursion through history.

In 1872, W.C. Röntgen married Bertha Ludwig, a daughter of restaurant keeper. He worked in Würzburg then as an assistant professor. In Zürich, during his university studies, he met his wife in her father's restaurant "The Green Goblet". At the end of 1895, Röntgen was busy with X-ray research work and had moved one floor down to his laboratory, asking his wife to serve his meals there. Bertha wrote to her relatives that she was worried about her husband's health and that something very unusual was happening to him. Röntgen returned to normal life after the publication of his first work about X-rays; he took his

leave only after the publication of the second work, yielding to the constant demands of his wife. The Röntgens went on holiday to Italy, carefully concealing their family name (2). It was necessary, because the name was already famous all over the Europe.

According to his contemporaries, Röntgen was very modest; he refused to accept any praise and to the very end of his life he spoke about these rays as X-rays. He adamantly refused to patent his invention and to participate in projects connected with it. Due the above-mentioned facts, the rapid spread of röntgen technique and the wide use of röntgen apparatus, especially in medicine, became possible (röntgen defectometry) (2).

W.C. Röntgen's discovery also caused excitement in Estonia, as can be seen in articles that appeared in the press. On February 17, 1896, "Postimees" (Postman) imparts the following: "The experiment that was carried out in the laboratory of physics in the University of Jurjev (Tartu) to make a picture of man's hand, using cathod rays, lasted at least half an hour and the amount of electric power which had to be used was as much as a dynamo, attached to an engine of 2 1/2 horsepower, would have produced." The persons who carried out the experiment were A. Sadovski, professor of physics, and his assistant M. Kossatch. Röntgen rays were first used for medical purposes in Tartu in March, 1896. The physicists made a photo of a young man's hand, on which there was a bullet to be seen between the first and the second knuckle-bone. The young man had been shot 10

years before. "Postimees" (Postman) announced on March 21, that copies of this röntgenogram were on sale at the newsagency and in local book shops. W. Peterson was the first to use Röntgen rays on April 12, 1896. Peterson, director of the Realgymnasium in Tallinn, had procured a special apparatus for that purpose from Berlin. He gave a review of his experiment in "Revalische Zeitung" on April 13. Thus Röntgen rays were put to use for medical purposes in Estonia's most important scientific centres - Tartu and Tallinn - only a few weeks later than elsewhere in Europe (6).

A number of universities tried to attract Röntgen to their institutions after his discovery of X-rays. In 1900 he accepted the invitation to Munich, where he dedicated most of his time to administrative work, while still active in scientific research. There is also a story from that period which is characteristic of Röntgen. The incident took place at a museum in Munich, where the chief of the department of physics worked. The chief, having shown Kaiser Wilhelm II and Röntgen around in his department and "with the custom of exchanging compliments" the party went on to the department of artillery, Röntgen interrupted the kaiser by saying that he had learned nothing new from the conversation and that it had not been of any use to him. Needless to say, the kaiser took offence at his remark and became a lifelong enemy to the famous scientist (2).

The Nobel Prize was given for the first time in 1901. It was given to Röntgen, a physicist.

In spring 1920, Röntgen retired from teaching, asking to be allowed to use two rooms at the research institute. He worked there almost until his death. Röntgen died of cancer at the age of 78, on February 10, 1923, after suffering for a short time. At his request, he was buried at his family cemetery at Giessen.

Is it possible for the successors of Röntgen to underestimate Röntgen's discovery and over-estimate Röntgen himself? All the epithets praising Röntgen and his discovery to the superlative degree seem to be in place. It is indeed unbelievable and awe-inspiring to learn that 80% of diagnoses are made by means of Röntgen rays.

To end our journey, we shall let the main character speak - an interview which Röntgen gave to an American newspaperman just after his great discovery.

The story of Röntgen's momentous discovery was reported in an American magazine by a man who interviewed him at the time. He wrote:

"Now, professor, will you tell me the history of the discovery?"

"This is no history," Röntgen replied. "I have been for a long time interested in the problem of the cathode rays from a vacuum tube, as studied by Hertz and Lenard. I had followed theirs and other researchers with great interest, and determined, as soon as I had time, to make some researches of my own. I had been at work for some days when I discovered something new."

"What was the date?"

"The 8 of November."

"And what was the discovery?"

"I was working with a Crookes tube covered by a shield of black cardboard. A piece of barium platinocyanide paper lay on the bench there. I had been passing a current through the tube, and I noticed a peculiar black line across the paper."

"What of it ?"

"The effect was one which could only be produced, in ordinary parlance, by the passing of light. No light could come from the tube, because the shield which covered it was impervious to any light known, even that of the electric arc."

"And what did you think ?"

"I did not think; I investigated. I assumed that the effect must have come from the tube, since its character indicated that it could come from nowhere else. I tested it. In a few minutes there was no doubt about it. Rays were coming from the tube which had a luminous effect upon the paper. I tried it at greater and greater distances, even at two metres. It seemed at first a new kind of invisible light. It was clearly something new; something unrecorded."

"Is it light ?"

"No."

"Is it electricity ?"

"Not in any known form."

"What is it ?"

"I don't know."

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JÜRI HALDRE (5.MAY 1896-3.FEB.1949)

IN MEMORIAM

BY VELLO VIIRSALU AND ERICH KUUS
CLINIC OF RADIOLOGY AND ONCOLOGY

Jüri Haldre, professor at the University of Tartu, was one of the most outstanding radiologists of the former Estonian Republic. As the current University of Tartu Publications are dedicated to radiology, a short biography of Jüri Haldre (born Grünthal (1)), a founder of the Tartu school of radiology as well as radiology hospitals in Tartu, is hereby given. This article is based on archival documents and memories, and may therefore be of interest to researchers in the history of medicine.

J.Haldre was born on the 5th of May, 1896 in Järvamaa, in the commune of Koigi, village of Sigapusma (now named Sõrando), farm of Kubja. His parents were Johannes and Anna Grünthal. He had a sister, Anette, and three brothers Joosep, Rudolf and Johannes. When Jüri was 12, his father died, and from then on his mother had to manage on the farm. For that reason it became more difficult for the children to get an education. At that time there was one worker on the farm, 60 hectares of land, three horses, six cows, and ten sheep. J.Haldre studied at Koigi Elementary School 1905-1908, at Paide High School 1908-1913 and Pskov Teachers' Seminar 1914-1917 (2;3).

He started his career as a teacher

in 1917: on the 1st of July he became a teacher in the Järva-Jaani Higher Elementary School and in September 1917 he became the director of that school. In 1918 he went to Paide and continued his career as a teacher of mathematics and physics at Paide Boys' High School (2). In the fall of 1919 he entered the faculty of mathematics and natural sciences at the University of Tartu. In 1920 he was transferred to the medical faculty of the same university. Being a student was not easy for him as he had to earn living, working as a teacher at the same time. From the 1st of August 1920 to 31st of July 1922 he worked as a teacher of mathematics at Tartu's Hugo Treffner Secondary School; during this period he edited six textbooks for elementary schools, he also translated and adapted three textbooks for high school (2;4). During the summers of 1922 and 1923 he worked at the Women's Clinic, and in the spring term of 1924 he worked as a subassistant at the Dermatology Polyclinic. In 1923 he was awarded first prize for his student paper "Folk-medicine in Estonia - Pediatrics, Gynecology and Childbirth" (2).

J.Haldre graduated cum laude from the University of Tartu in 1924 (3). He had been a very hardworking and talented student, and for that reason was sent abroad for training in the field of radiology after his graduation. On the 1st of January 1926 J.Haldre started to work as a radiologist at the Tartu University Women's Clinic (2).

The following year he became a post-

graduate student after successfully passing the exams. At that time one had to take eight exams to become a postgraduate student. On Saturday, May 23, 1931, at 12:00 p.m. he successfully defended his thesis "Experimental Research about the Effect of X-rays on the Follicles in Ovaries". His thesis was 264 pages long in German and Estonian. On the 29th of May, 1931, J.Haldre was given the degree of doctor of medicine (5).

On the 15th of October 1931 he applied for a job as a private docent of roentgenology. To qualify for this job, he had to give a lecture, which took place on the 7th of December 1931, entitled "Der Comptoneffekt und seine Bedeutung für die Tiefentherapie". His lecture was a success and he was elected a private docent of roentgenology by the council of the medical faculty of the University of Tartu (6). In the spring term of 1932 he gave the first lectures in the history of the University of Tartu for medical students about general roentgenology. After the spring term of 1933 the course of roentgenology became obligatory for medical students (7).

J.Haldre was eager to learn and took every opportunity for training. In the years 1925 to 1939 he went abroad several times, visiting West-European and Nordic countries (Germany, Austria, Czechoslovakia, France, Belgium, Holland, Denmark, Sweden, and Finland), learn different medical systems and work principles of hospitals. He took special interest in the construction of medical apparatus and appliances, planning units for diagnostic

and treatment purposes, introducing new methods and organization of the work process, and systems of teaching radiology. Upon his return he always wrote thorough reviews, adding his own proposals, to the administration of the university (8) and he wrote travel articles for "Eesti Arst" (9;10;11), that were read with great interest. It may be interesting to know, that if the existence of a diagnostic centre is being doubted at the moment, it was clear for J.Haldre in 1935, that "a central establishment can succeed better, using less workmen at the same time..." and that "the principle of economy is being used", that "a central establishment produces high level specialists". At the same time he was concerned how the Estonian Republic could afford the 40,000 shillings needed for the purchase of one roentgenology machine and according to his idea, it "would be possible for us to construct the same kind of equipment at much less cost". When visiting the Siemens exhibition, he was asked "How does your apparatus work". He said that the difference, as he saw it, was that the Siemens apparatus were easier to handle (9). Of course, the mechanical parts of the Siemens apparatuses were more completely finished, as they were made at a factory by special drafts, but in Tartu these were handmade. What is most important, is that the roentgenologic display was of the same quality.

The first appliance for radiotherapy, constructed in 1929 by a university technician named Jaan Kersna-Muuga based

on the ideas of J.Haldre, was the result of one of his trips abroad (10).

In April 1940, when the professorship in roentgenology was announced, J.Haldre applied for it (7). On the 2nd of Sept. 1940 the council of medical faculty elected him to this post (12).

In 1939-1940 J.Haldre founded the Radiology Institute and Clinic. In 1947 he founded Tartu Oncology Dispensary. During the chaotic period after the war he acted energetically as the chief roentgenologist of the Estonian Soviet Republic, organizing the Tartu Republican Roentgenology Station, being elected the foreman of the medical council at the Health Ministry, and organizing the first training courses for laboratory technicians in roentgenology, as there was a severe lack of those specialists (13).

At the beginning of the 1940s J.Haldre developed leucopenia, that evidently was caused by long-term exposure to radiation sources. He had treatment for that for 2.5 months (14). In 1948 he was diagnosed with bone sarcoma, which was considered to be of the same origin. Shortly after that, metastases were discovered in his neck and hip region. Jüri Haldre died on the 3rd of February 1949. He is buried in the cemetery of Raadi (13).

J.Haldre's death slowed down the development of radiology in Estonia for decades. In 1949 the radiology department at the University of Tartu was closed down. It was only in 1980 that the department of radiology and oncology at the university was re-opened and in 1992 that

the Clinic of Radiology and Oncology was re-established on the place of the former Oncology Dispensary. J.Haldre's bust-relief was placed on the wall of the foyer of this hospital in 1990.

It is interesting to mention that there is a correlation between J.Haldre's progressing disease and the beginning of the destruction of the former Estonian Republic's medical system. Both these events occurred fifty years ago. Now that the Estonian Republic has regained its independence, and we have been able to re-establish the Tartu University Radiology and Oncology Clinic, initiate fellowship in radiology, and hope to get up-to-date medical equipment, there is hope that we can start a new period in the history of radiology in the Estonian Republic, which was initiated by J.Haldre about sixty years ago.

J.Haldre has written approximately fifty scientific and travel articles (7;13). In 1941 his monography "Radium and Radioactivity" and in 1948 "Radiology" were published. "Radiology" was written with such a perspective that it is used as the only Estonian language radiology handbook up to the present time.

J.Haldre was extremely talented, hardworking, determined and an optimistic person. He was the pioneer of radiology in the former Estonian Republic. His good command of foreign languages enabled him to bring new ideas and materials to his homeland and make contacts with specialists in his field. As a result, he managed to create the school of radiology in

Estonia, stressing the importance of training in radiology. His personality and what he accomplished will serve as a good example for future generations of radiologists in Estonia.

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CELEBRATION OF THE 70TH YEAR OF RADIOTHERAPY AT THE UNIVERSITY OF TARTU

V.VIIRSALU, R.OLE
TARTU CLINIC OF ONCOLOGY AND RADIOLOGY

Systematic X-ray therapy began in Tartu in 1922, but there are a few references to the earlier use of X-ray treatment. It is said that in Tartu (known as Jurjev in writings in Russian) whooping-cough was treated with X-ray in 1904 (1). Also there was a legend in medical circles, told by professor Artur Linkberg, that at the beginning of the century the medical leaders of Tartu (professors Vanach or Zoege von Manteuffel) owned the preparation of radium, that was kept in a stove in surgical hospital and was used for curing the cancer of the lower lip of the door-keeper (2, 3).

Continuous X-ray therapy has been practised in Tartu for 70 years now, at first in the clinics situated on Toome hill, and since the year 1974, in Vallikraavi Street. The first X-ray surgery began its work on the 10th of January, 1922, in the Women's Clinic of Tartu University, the first patient was a woman with uterine fibromyoma. Jüri Haldre-Grünthal gave 10 years later the following description of that event (4): "We consider it the beginning of the X-ray therapy. There was installed the most modern machinery for inside therapy of this time - "Intensiv-Reform" from Veifa factory". The X-ray surgery was founded

in 1921 by later professor of otopathy Ernst Saareste-Saaberg (5), the military doctor Sergei Veretennikof came there from Tallinn to work as a roentgenologist. Later Konstantin Sööt worked in the X-ray surgery and from the 1st of January 1926 there was Jüri Haldre-Grünthal (4).

Already in the year 1926 the X-ray apparatus used was so outdated that there was a need for a new and more modern one. This so-called "cannon of Holfelder" was built by Jaan Muuga, the engineer of the university in 1929 (4). This apparatus worked till the year 1958 (2, 3). It is also important to say that all the time Jüri Haldre took care of the maintenance of home-made machinery and other economical problems. The apparatus built in Tartu was many times cheaper than one bought from abroad and there were no differences in quality (4, 6).

In the Women's Clinic there were rooms only for women, now the X-ray therapy was made for both men and women. Because of that, in February 1930 in the women's hospital a room for men with 6 beds was opened (4).

The idea of beginning to teach X-ray therapy and radiology in Tartu University was important for all the doctors in Estonia. In May 1931 J.Haldre defended his doctoral dissertation and on the 15th of December that same year, the council of Tartu University declared J.Haldre to be elected to the post of private-docent of roentgenology and in the spring semester of 1932 he began to read the course of roentgenology (7).

In searching for new methods and possibilities of therapy they dwelled upon the radium therapy. Already in 1926

the managing committee of Women's Clinic of the university made a proposal to the Government of the University to found a radium fund to procure radium, although the decision about purchasing radium was made only in 1934. There are some interesting details to be remembered in connection with the beginning of radium treatment. Jüri Haldre wrote in 1934 in "Eesti Arst" (Estonian Doctor) about purchasing radium for the university that Estonia needed 1 to 1.5 grams of radium (Sweden had 8 grams then) and it must be situated in the university, not in different places all over the Estonia. He brought out three essential reasons that sound very up-to-date even today (8):

- 1) university as an **educational institution** could not be behind the times, it had to be able to prepare young up-to-date doctors;
- 2) university as a **medical establishment** must be equipped with first-rate and modern apparatus
- 3) there are always higher aims connected with the name of university - namely the **development of science**. Without equipment there could scarcely be any talk about scientific work.

That is why the university was obliged to purchased radium.

Radium was bought from Canada and on the 17th of October 1935 the financial committee of Tartu University accepted the cabinet with 146 milligrams of radium. The radium cost 29,635 kroons, in addition 550.50 kroons were spent on the cabinet (9). There were two more years needed for preparatory work before the radium treatment could begin. Jüri Haldre made the first session of radium treatment on the 25th of September 1937

together with Meeta Haldre-Vassil (2, 3, 10).

The next step was to begin exploring the possibilities of X-ray therapy inside cavities. According to the reminiscences of Laos Koskvee, the X-ray mechanic Rudolf Sibold built an X-ray therapy apparatus with water-cooling (Schaefer-Witte) for treatment inside cavities in 1938 (3).

Radiology got on very well under the protection of Women's Clinic, therefore the question of founding the separate medical establishment came on the agenda. The resolution of University Government from 5th of May 1939 predicated to found an Institute and Clinic of Radiology under the medical department, giving the following motivations:

1) the establishing doesn't need any special expenses (it is the transformation of the department of roentgenology under the women hospital to a separate institute and clinic); 2) the founding of the Institute and Clinic of Radiology is needed both for better organization of studies and for developing the speciality.

The new clinic got separate medical establishment on the 1st of April 1940. The accommodation (8 rooms altogether, of them 3 hospital rooms with 12 beds) was in the Women's Clinic in the wing near Lossi Street. In the beginning of 1941 the staff consisted of a director, the physician who was chief of the hospital, two doctors, two nurses, two hospital attendants, two laboratory assistants, three hospital assistants and an X-ray technician (11). After the war, the

Institute and Clinic of Radiology opened again on the 8th of January 1945 (2, 3).

In the new, changed situation, when also oncology was being developed, Jüri Haldre began to look for a "house of their own". Although it would have been possible to redesign the ruined house of the former Supreme Court for the needs of radiology and oncology (see the end of this article), but this was not realistic. For improving the working conditions of the radiology hospital they looked for other possibilities. Temporarily, in addition to the rooms the Institute and Clinic of Radiology had in the Women's Clinic, it was given the third floor in 17 Lossi Street, and so it had 75 beds altogether. On the 1st of August 1949, two departments were opened - the department of oncology with 45 beds and the department of radiological therapy of tuberculosis with 30 beds. The heads of the departments were Elmar Jõgar and Elmar Haldre (2, 3).

In addition to that the hospital of oncology was opened in Tartu in 1946 and the dispensary of oncology in 1947; they were united in 1948. Thus at the end of the 1940s there were two medical institutions in Tartu dealing with therapy of oncological diseases, and the more viable of them was the clinic of radiology. But soon the following development of radiology was influenced by the illness of professor Jüri Haldre and his early death on the 3rd of February 1949. Therefore they had to close the department of radiology in autumn 1949, and later, also the clinic. After the death of Jüri Haldre the

position of head physician was occupied by Laos Koskvee (2, 3).

The history of the independent Hospital of Radiology was finished on the 1st of March 1951, when the establishment, meanwhile being under the Clinical Hospital, was liquidated. Of parts added to the dispensary of oncology, the separate department of radiology was formed with 15 beds, of 48 former employees, 16 were transferred. Elmar Haldre stayed as a head of department until 1955, afterwards Henno Alari took his place until 1962 and Hilja Sibul from 1962 to 1964 (2, 3, 12).

As radium therapy was forbidden in the Women's Clinic from the year 1961, the department of radiology moved to 19 Lossi Street, where work began on the 4th of January 1962 (2, 3), and where it is situated now.

We add also some other important dates:

February 15, 1958 : the gamma-treatment apparatus GUT-Co-400 began to work in the basement of the Hospital of Internal Diseases in 17 Lossi Street;

in 1974 the annex in Vallikraavi 10 was finished. Mihhail Potasenkov, Rein Ole and Paul Alapuu have been working there as heads of department;

July 22, 1975 : the first session of gamma-ray treatment in the new annex with new and more apparatus AGAT-S (made in Narva in the plant "Baltijets");

April 3, 1979 - the first session of intracavitary afterloading gammatherapy apparatus AGAT-V (also made in "Baltijets");

January 1984 : radium therapy becomes forbidden in the hospital on Toome hill;

November 10, 1987 : the first session with the new and modern tele-gamma apparatus of rotatory type AGAT-R1 (made in "Baltijets").

As for teaching students the important dates are as follows:

September 1, 1955 : Kaljo Villako begins again to teach roentgenology and radiology under the department of internal diseases;

September 1, 1980 : reopening of the department of radiology and oncology, the teaching of those branches were again united into one department. In the years 1980-1990 the head of the department was professor Kaljo Villako, from the year 1990, professor Erich Kuus.

Searching for a house of our own

The dream of "our own house" was with Jüri Haldre all his working years. Before the war the Institute and Clinic of Radiology got independence in 1940, but remained in the house of Women's Clinic. After the war professor Jüri Haldre began to look for new rooms for the clinic - at first only for the clinic of radiology, later for the hospital of radiology and oncology. There were discussions about building up the ruins of the former Supreme Court and Mellin's hospital (2, 3, 10, 12).

In choosing the territory, two aspects were kept in mind: "The Institute, being in very close connection with scientific work, needs its location to be near to Tartu University, but on the other hand, as a medical establishment,

it needs a quiet, green and secluded territory." According to that we have the design project by Arnold Matteus, dated April 30, 1946, for building up the ruins of the former Supreme Court into medical establishment for the Institute and Clinic of Radiology with 120 beds (13).

The next preserved project by Arnold Matteus is a preliminary project of the clinic of radiology and oncology, dated August 22, 1946. Then it was planned to built on the territory of two ha between the streets Pepleri, Tiigi and Aia a hospital with 214 beds. The main entrance and the main building were planned to face the renovated park near Tiigi Street; the wings along Tiigi Street and the present Akadeemia Street (on the first floor the therapy rooms for the Institute and Clinic of Radiology and the boardinghouse, the second and third floor for the patients of radiology). There were planned 94 beds for radiology, 108 for oncology patients and 12 for the boardinghouse (14). In the same district, squares named after Curie and Röntgen were planned (10).

Finally the Government of Clinics decided to build the complex of radiology and oncology on the plain of Maarjamõisa. So the first serious attempt of getting its own hospital of radiology and oncology failed (2, 3).

In the intermediate years, even the idea of building a separate clinic of radiology died out. Under those circumstances we had to be satisfied with the annex in 10 Vallikraavi Street, where there were two variants: a tower building at the side of the Art Museum or a two-

storied wing along Senf's staircase (2, 12). Finally it was decided for the variant closer to the center and the two-storied wing was finished in the summer of 1974. There was a room for tele-gamma-ray therapy and two rooms for X-ray therapy.

But the need for getting all the radiological medical establishments together in one center remained and the colloquium of the Estonian Ministry of Health decided on the 30th of October 1980 that in the near future the planning and later the building of the new centralized department of radiology would begin (15).

Planning began in 1988 (architect Roman Smuskin) and the first buckets of soil were removed from the territory near the Viljandi road on December 4, 1991, but even this building was stopped because of a lack of money.

The Radiologists of Tartu - the Head Physicians

In the medical establishments of Tartu there have worked besides Jüri Haldre (see the biography in this publication) as head physicians also radiologists Laos Koskvee, Elmar Haldre and Hilja Sibul. We give a short description of them too - based on their own data.

LAOS KOSKVEE (till 1938 Leo-Roland Kosenkranius) was born on the 28th of November 1909 in Kuldiga, Latvia, in the family of a teacher and died on the 10th of May 1991 in Tartu in his own home, and was buried in Raadi cemetery.

1927 he graduated the German Gymnasium in Pärnu, in the years 1927-1933 studied in the medical faculty of Tartu University and graduated it cum laude. After military service, in 1934, he began to work in the Women's Clinic of Tartu University as an assistant to Jüri Haldre in X-ray diagnosis and therapy and from July 1938 as a senior assistant. From the 1st of May 1941 he was an assistant to the head physician and from the 1st of January the acting head physician (during the illness of Jüri Haldre) of the Institute and clinic of Radiology. After the death of Jüri Haldre he was the head physician of the Institute and Clinic of Radiology until its liquidation (June 1, 1949 - February 28, 1951). From June 6, 1949 till October 1, 1954 he acted as a head roentgenologist of Estonia. From the 1st of March 1951 (after the liquidation of the Institute and Clinic of Radiology) till retiring on the 1st of August 1980 Laos Koskvee worked as a director and roentgenologist of the X-ray department of Tartu Clinical Hospital, being at the same time in the years 1951-1969 the radiologist of the oncology dispensary.

Although Laos Koskvee passed his doctors examinations already in 1936, he defended his doctoral dissertation only on March 28, 1952, on the subject "The factors of falling ill and curing patients with actinomycosis and the campaign against actinomycosis in Estonian SSR".

His lifework was to teach the technical assistants for X-ray laboratories for the medical

establishments in Estonia in the years 1950-1975.

ELMAR HALDRE (till 1935 Grünthal) was born on the 10th of May 1916 in Järvamaa in the county Koigi village of Sigapusma in the farm of Kubja as Jüri Haldre's nephew.

In the years 1924-1934 he studied in the elementary school in Koigi, and in a co-educational Gymnasium in Paide, Järvamaa and in the years 1934-1941 in the medical faculty of Tartu University. As a student he came to work in the Institute and Clinic of Radiology, on the 25th of April 1941 he began his work as a hospital doctor in Rakke department, although he didn't have his graduation diploma yet. He got his recognition as a doctor on the 1st of March 1942 (the second time after the war on the 29th of November 1948).

Meanwhile he was mobilized, spent some time as a prisoner of war, but from the 1st of July 1946 he came to work as a chief physician in the Institute and Clinic of Radiology of Tartu University. On June 1, 1949 he became the head of the department of tuberculosis. After the reorganizing of the Institute and Clinic of Radiology on March 1, 1951, he was the head of radiology department in the Tartu Oncological Dispensary. 1.02.1955 - 20.06.1964 he was a head physician of the Oncological Dispensary. 20.06.1964 - 19.05.1969 he was the head of radiology department in Oncological Dispensary and afterwards a radiologist in the same place. On the 1st of July 1976 he retired.

He died on the 5th of September 1990 in Hiiumaa in his summer cottage and is buried in Paulus (Ropka-Tamme) cemetery.

The merit of Elmar Haldre was to preserve and develop the department of radiology in the revolutionary years of the 1950s and 1960s. Very valuable are his memoirs of the medical history of Tartu (especially those connected with radiation therapy), that were used to compile this overview.

HILJA SIBUL (maiden name Maasiksalu) was born on September 2, 1924 in the Oudova province, Russia. In the years 1933-1945 she studied in the elementary school in Alatskivi, in the II High School for girls in Tartu and in Tartu Medical School, but in the years 1953-1959 she was a student of the medical faculty of Tartu University. H.Sibul-Maasiksalu started to work from the 1st of June 1945 without a salary in the Institute and Clinic of Radiology.

At first she worked as a nurse, then as a head nurse, later as a radiologist and head of department. Hilja Sibul was the head physician of the Tartu Oncological Dispensary from the 21st of May 1966 to the 16th of February 1974. After that she worked as a radiologist almost 20 years until her retirement on the 1st of September 1992.

Her main achievements are expanding the radiological department and building the annex for the radiological department.

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IONIZING RADIATION IN MEDICINE AND HEALTH PROTECTION

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1. Introduction

Man is continuously exposed to ionizing radiation but it is only to a limited extent that he can influence the radiation dose received. The mean annual dose obtained consists of contributions from cosmic radiation, terrestrial radioactivity and the radioactive ⁴⁰K isotope as an internal radiator in the body. Moreover, the decay products of radon may also become internal sources, mainly by the inhaled air, thus contributing to the annual radiation dose. Artificially produced radiation, produced by man himself, includes the medical use of radiation as well as contributions from fallout, radioactive waste from nuclear power plants, nuclear fuel, etc. Approximately 15-20 % of the total mean annual dose to the population of an industrialized country is due to the use of artificial radiation sources. Among the artificial sources the medical contribution dominates, and under normal conditions other artificial radiation sources are of minor importance.

From the arguments given above, it follows that the staff at a radiological department (radiologists, physicists and technicians) should have a thorough education in radiation physics and radiology: they should be able to take care of the patient in the safest way and also to carry out diagnostic and/or treatment routines effectively. At the same time, a well organized radiation

protection system must be included in the national health protection programme.

To achieve these goals an extensive programme for education, training, control and research work has to be set up. Therefore, we will discuss some details for such a programme. Furthermore, we will examine the situation in Estonia and make some comparisons to Finland. Finally, we will focus on some problems in Estonia and how they can be solved.

2. The need of education in radiology and radiation protection

2.1 Radiation risks

The interaction and influence of ionizing radiation with living tissue can be divided into three main phases. First, we have the "physical" phase, which means that radiation energy is absorbed by living tissue. This absorption process results in ionized and excited molecules and atoms, and in the production of free radicals. A free radical is a molecule or a molecular fragment with an unpaired electron and the free radical is, therefore, very reactive towards other organic compounds.

After this first phase of energy deposition comes the second phase, the "chemical" phase. That phase involves the chemical reactions in which the radiolysis products are taking part. As a final result of this phase, molecular changes in the living tissue or cell are present, also mutations might have occurred. In other words: there has been a change of the milieu for the living cells.

Then, the third phase starts, which is the "biological" phase, and it involves the evolution of the biological system after exposure to ionizing radiation. Due to the preceding "chemical" phase, biochemical changes are also now present. At first, they are not detectable, but in case of a massive irradiation, they become observable and lead to cell death, which might be the starting point for the death process of the whole organism. Furthermore, through mutations late somatic changes, like cancer and leukemia, may appear, thus affecting the further life of the organism.

On a timescale the "physical" phase is extremely short. In less than a millionth of a second (0.000 000 001 second), the energy is absorbed and the "chemical" and "biological" phases take over. Thus, the energy absorption process acts as a trigger for the other phases, and it also means that by having energy absorbed the

"point of no return" has been passed. The initial radiation effects cannot be removed and the process goes on.

A widely accepted practice is to use the multistep model of carcinogenesis. This model involves the initiation of irreversible genetic alterations and the promotion of clonal populations of initiated cells which expand and progress into malignancy. The induction depends on several factors, including environmental factors and individual characteristics. In addition to radiation dose, the radiation risk depends on such factors as genetic differences, sex, age at the time of exposure, individual radiation sensitivity, synergistic effects between radiation and carcinogenic materials. Due to these factors, and also due to uncertainties in dose determinations, application of the correct risk model, epidemiological data etc., the risk assessments include large uncertainties.

We have fairly good knowledge of what happens when man is exposed to large radiation doses. This information has been obtained from a follow up study of the victims of the atomic bomb explosions over Hiroshima and Nagasaki, from cancer patients receiving radiation treatment, and from data collected from radiation accidents and animal experiments etc.

If the absorbed radiation dose is 3-5 Gy (Gray), it is estimated that 50 % of those people exposed to that amount of radiation will be killed through bone marrow damage in one to two months. Doses in the range of 10-50 Gy will kill through gastrointestinal damage in one to two weeks. Mastodont doses of 100 Gy kill through nervous system collapse in hours or days.

It is much more difficult to predict the outcome of small radiation doses. Now one has to consider the small individual doses given to a large population and only a statistical prediction can be made. The principle is that a total dose to the population is calculated. This total dose, to which the population is exposed, is expressed in units of manSv (Sv, Sievert is the biological dose corresponding to the physical unit Gy, Gray for the absorbed dose). Furthermore, one makes the assumption that a certain amount of manSv will always have the same biological impact, regardless of the population size and the individual doses received so far as the dose to an individual can be considered as "a small dose". Therefore, a population of 10,000 individuals, each of whom has received a dose of 1 Sv (10,000 manSv to the population), will have as many cases of cancer and other harmful radiation effects as will a population of 10,000,000 people, each of

whom has received a dose of 0.001 Sv (also now we come up to 10,000 manSv for the population).

Earlier, and for a long time, the total risk factor for producing harmful stochastic effects in man was considered to be 0.0165/Sv, including the genetic risk factor for the first two generations (0.0040/Sv). Thus, the collective dose of 10,000 manSv will produce 125 cases of cancer in the population, and furthermore, 40 cases will occur with genetic harm.

Today a recalculation of the radiation milieu in Hiroshima and Nagasaki and of the protracted epidemiological studies has been performed, and it is obvious that the total radiation risk is 3-4 times higher than was earlier believed. Thus, 10,000 manSv may cause some 400-500 cancer cases. Although this number is high, it has not been possible to prove it true. The total number of cancer cases in a natural population is manyfold, due to other causes.

Such is the case when we are dealing with small radiation doses, of the same order of magnitude as the ordinary background radiation. It has been estimated that in Finland 150-200 cancer cases per year are produced due to radiological investigations (population: 5 milj.; investigations: 4 milj.; modern x-ray techniques are used). This risk number (cancer cases caused) should be balanced against the benefit of a reliable x-ray investigation, although these estimated cancer cases cannot be picked out from the large amount of new cases discovered each year in the total population. Nevertheless, it can be said that the benefit is mostly greater than the detriment in x-ray diagnostics.

However, even though the benefit is much greater than the risk involved, all efforts should still be made to further reduce the risk factors involved in the application of x-rays. To be considered acceptable, the use of radiation and practices involving exposure to radiation shall meet the following criteria:

- 1) The benefits accruing from the practice shall exceed the detriment it causes (principle of justification).
- 2) The practice shall be organized in such a way that the resulting exposure to radiation hazardous to health is kept as low as is reasonably achievable (principle of optimization);
- 3) No person's exposure to radiation shall exceed the maximum values prescribed by decree (principle of limitation)

The provisions of these criteria on the medical use of radiation apply to practice in which ionizing radiation is deliberately targeted at a human body or part of the body for the following purposes:

- 1) To examine or treat an illness
- 2) For some other medical procedure or medical research.

The maximum values for radiation exposure under this act are not applicable to the radiation exposure received by a person being examined or treated. Such exposure to radiation shall be limited so that it is no higher than is considered necessary for the examination or treatment.

2.2 Education of medical students

For medical students at the University of Helsinki, during the first year of studies, a course in medical physics is given. This course includes a general part and a part in radiation physics. The general part of the course is a basic introduction to medical physics and covers the complete field of medical physics, except that of radiation physics, which is delivered separately. The textbook by Holmberg and Perkkiö is used. As most of the medical students have read the advanced course of physics in the upper secondary school and have prepared themselves for the entrance tests to the faculty of medicine (physics is one of the subjects), they are considered to have a good knowledge of physics. Therefore, the university course in medical physics starts from the level of the advanced physics course taken during the three years of upper secondary school, and takes up only medical applications. The course consists of 20 hours of lectures and 4 hours of exercises. For the exercises, problems are given beforehand to the students as homework, which is then discussed in class. The course ends with a 2 hour written examination.

The course in radiation physics starts immediately after the general course has finished. As radiation physics is considered important to all physicians, the number of hours are somewhat increased in comparison to that of the general course. Currently, we have 28 hours of lectures, 5 hours of exercises, 4 hours for a demonstration in hospital milieu, and finally 2 hours for a written examination.

The course material can be presented to the students in different ways. Although the number of lectures is not very high, the aims are to prepare the students for further studies in medicine, to show how physics can be applied to solve medical problems and to give a broad base for the understanding of new phenomena which the students/physicians may encounter in the

future. This education is delivered by the medical faculty, by teachers of physics specialized in the field of medical physics. Starting from lectures, which in many respects means a theoretical approach, one can include exercises, laboratory work and demonstrations of clinical routines. It is clear that by moving from lectures towards clinical routines, motivation among the students increases rapidly. As it is difficult to arrange demonstrations in the clinics for a large number of first year students, this problem has been partly solved in Helsinki by using videofilms. After these general studies, common to all medical students, the physician may specialize in radiology.

At the University of Tartu, the course in general medical physics delivered to first year students consists of 64 hours of lectures and 96 hours of laboratory work. Radiation physics forms a part of this course. This number of hours forms about 1-2 % of the total number of hours during the period of study in the medical faculty. The aim of the course is the same as that at the University of Helsinki, but there are some differences in realizing this aim in Tartu.

The selection process of students at the University of Tartu does not include an examination in physics and the students do not necessarily prepare themselves in this subject. Therefore, they have probably forgotten a considerable amount of knowledge in physics as they enter the university, and this must be taken into consideration in the lectures and laboratory works.

A textbook on medical physics and videofilms are also lacking in Estonian. The coursebooks available are mainly in Russian, and therefore difficult to understand. The result of this is allotting a small number of hours to the specific problems from diagnostic radiology, nuclear medicine and radiation biology in the lecture course of medical physics in Tartu as compared to the programme of radiation physics of the University of Helsinki.

In addition to the general course of medical physics, a special 14 hour lecture course to medical students in Tartu is presented. The topic of this course is radiation physics, radiation protection and dosimetry with applications to medicine. The participation in this course is voluntary, but the attendance is highly recommended to the students specializing in radiology, nuclear medicine and in various applications of x-rays and isotopes in medicine. This course was given for the first time by Peter Holmberg in spring 1992 and it is our hope that it will be repeated during the years to come and that it can be included in the curriculum for the medical

students. At the same time, it must be mentioned that this course can also be expanded to meet the demands of the physicists specializing in health physics.

The laboratory exercises for the medical students of the University of Tartu include problems from general medical physics, for example, elements of medical data handling and modelling, physical principles of audiometry, determining the coefficients of viscosity and surface tension, acquaintance with electrical measuring instruments, measuring of the electrical impedance of living tissue (plants), principles of ECG, applications of electrical impulses, low and high frequency alternating currents and electromagnetic fields in medicine, principles of optical methods of determining concentrations of various substances in solutions, etc.

Practical exercises concerning radiation physics are as follows: concepts of dosimetry and principles of dose measurements, acquaintance with a radiometer, determining the half value layer of different materials and acquaintance with a medical x-ray apparatus. The practical work is considered very important at the University of Tartu because during these practice sessions, the students have to conduct their own measurements and calculations. The number of students in a group is about 10, so discussions about the results of measurements, physical principles and medical applications can be provided individually. Of course, this requires competent teachers in the field of general medical physics.

2.3 Post-graduate training of hospital physicists in Finland

After graduating from a university or a technical university (majoring in physics or medical engineering), the candidate may continue his or her specialization and go for an exam in the field of hospital physics. The necessary knowledge in this special field of clinical physics can be obtained in different ways. The practical training takes place during a four year period of work in a hospital under the guidance of an experienced hospital physicist (chief physicist). After fulfilling this training period, the following main areas of medical physics should be familiar to the trainee: radiotherapy and radiation protection, clinical radiology and patient safety, nuclear medicine and radiation protection, clinical physiology and neurophysiology. In addition, medical data handling and computer technique can be included as a main field. During this training period the candidate thus comes into contact

with physiological measurements, patient care and computer applications in the fields mentioned above. Some administrative education is included as well. Twenty hours are needed, so when the "homework" is considered, this means that a total of one credit is completed. Additional special courses from the main fields mentioned are obligatory. The necessary amount of working hours (i.e. 60 hours, corresponding to 3 credits) can be obtained by taking part in lectures, symposia and congresses. For physicists there are several series of lectures from which to choose in the university programme. These lectures are mostly delivered by "docents" at the universities and hence given by experts, who are aware of the everyday problems which are encountered in the hospital milieu. The lectures, thus, give a deeper understanding and a broad base of clinical physics.

A special committee is appointed by the National Board of Medicolegal Affairs to organize and supervise the training and also to conduct the examinations. This committee consists of 6-7 members, one of which is a representative of the National Board of Medicolegal Affairs and one which is a medical expert. Moreover, the universities and the hospital physicist organization have their members in that committee.

After the final examinations in radiation physics and protection and clinical physics, the candidate graduates as a hospital physicist. He then has such a thorough knowledge and practical training in the field that he can work on his own in a hospital, taking over part of the routine controls and work from the radiologists. There are today some 50 hospital physicists working in Finland in the largest hospitals as chief physicists, hospital physicists and candidates specializing in this field. This number of health physics specialists gives a balance to the work of radiologists.

In Estonia, there is no post-graduate training for health physicists at all. At Oncology Centre in Tallinn there are three physicists and at Tartu University Radiology and Oncology Clinic two physicists. They are trained as physicists or electronics engineers, having had no medical training. They belong to the radiotherapy department, and their task is treatment planning and individual dosimetry of the radiation sources, which is carried out by film dosimetres. However, the films are often of poor quality and do not have constant sensitivity. As there is no CT or simulator available, we use for treatment planning a general x-ray apparatus and electroradiographical methods, which do not give

very reliable results, and the amount of radiation is too high. The post-graduate training of health physicists has, therefore, been started now in Estonia.

During the year 1992 one of us (T.M.) worked for one month at the oncological clinic of the University of Helsinki Central Hospital as a hospital physicist getting acquainted with the apparatus and methods of measurements and treatment. Then later, took part in a six week course on radiation dosimetry arranged by IAEA in Helsinki and Stockholm.

3. Radiation protection and dosimetry

Operating organization has the ultimate responsibility for radiation safety when ionizing radiation is used. Nevertheless, a national infrastructure is needed to ensure that all aspects of radiation safety are adequately dealt with. There are also some facilities and services essential for proper radiation protection and safety beyond the capabilities of a separate operating organization. Such facilities may include e.g. those for calibration and intercomparisons of radiation measuring equipment, arrangements for personnel dosimetry and dose registries for occupationally exposed persons, and environmental monitoring. These facilities may be provided either by governmental institute(s) or as a service on a privat basis. In the latter case, the national authorities in charge shall be provided with adequate information by the enterprise.

The following gives a short introduction to the radiation protection arrangements established in Finland. The present radiation protection legislation in Finland was issued in the beginning of 1992. In the contents, the 1990 Recommendations of the ICRP are taken into account. The legislation will be applied both to artificial and natural ionizing radiation and to non-ionizing radiation.

The main subjects covered in the act are the definition of the responsible authorities in charge, registration and licensing procedures for authorization of a particular practice concerning radiation sources, requirements concerning radiation sources, inspections, requirements concerning radiation work, particular requirements concerning medical use of radiation, e.g. quality assurance, course of procedures when dealing with natural

radiation, and consequences caused by the violation of the requirements. Generally, according to the act any radiation involved activity must fulfill the three basic radiation protection principles: justification, optimization and individual dose limitation.

Determination of the dose limit is the main contents of the radiation decree. Some of the procedures presented in the act are also specified more accurately in the decree.

In the radiation protection legislation, the Finnish Centre for Radiation and Nuclear Safety (STUK) is appointed to act as the Regulatory Authority. In order to stay as a competent authority, STUK issues ST-Guides which cover all the subjects of radiation protection other as nuclear power where YVL-Guides are issued. To achieve and maintain competence, STUK carries out research and development (R & D) on subject-matter. The results of the R & D are published as scientific articles in international journals or in STUK-A or STUK-B Report series. STUK also has some service activity. Personnel dosimetry service, radon measurements in dwellings, and calibration of radiation measuring equipment are examples of service. Radiological education concerning radiation safety and quality assurance aspects is also included into the STUK programme.

The national organization for the radiation protection and nuclear safety is very centralized in Finland. Except the ministries involved, there is only one regulatory authority, STUK. These arrangements are very similar to those in the other Nordic countries. The advantage of the centralized system is the possibility to benefit from resources effectively. However, centralization also has disadvantages which must be recognized. When facilities and know-how are gathered in one well-equipped institute, the influence is the same as a 'monopoly'. Universities, hospitals and enterprises are not obliged to engage in research and development on radiation protection. The more services are provided by the monopoly, the fewer service enterprises will arise. In summary, other parties do not have any interest in radiation protection aspects, and no scientific debate exists between various participants.

Other problems may arise though, caused by the very centralized regulatory authorities. The regulatory authorities must be independent of those who are authorized by the authorities to conduct the practices and to operate the sources. The regulatory authority shall, e.g. inspect that personnel dosimetry is adequately and reliably executed. If the personnel dosimetry system

performed is provided by the authorities, the dependency is obvious. "Quality Audit" has nowadays been recognized as an important part of the overall quality assurance. Quality audit has a special importance in radiation therapy. The regulatory authorities must forestall all the arrangements which would prevent the authorities from undertaking an independent review of the quality control system performed in each case. Whatever radiation protection organization is established, neither the inspections or other measures of the regulatory authorities nor the service either by the authority or other enterprise shall detract from the primary responsibility for radiation safety of the due authorized operating organization.

Health care of the staff working with radiation sources in Estonia is not yet organized. Individual dosimetry is carried out in large hospitals in Tallinn and Tartu but the results are not always reliable. A nationwide well-coordinated organization of radiation protection is missing. During the past year, University of Helsinki and STUK have cooperated with the University of Tartu and encouraged efforts to establish a radiation protection system.

We believe it is useful for the Estonian Republic to deepen the contacts with the Finnish counterpart. Hopefully, the cooperation would result in establishing a modern radiation protection system in Estonia, and this in turn would lead to the radiation protection legislation. It would serve as a bridge between Estonia and the rest of West-Europe and help Estonia to intergrate into the European radiation protection system.

In Finland there are many organizations devoted to medical physics and radiology. They are often further connected to larger Scandinavian, European or World organizations. Starting from several national societies, there is i.e. the Nordic Association for Clinical Physics, taking up individual members from the Nordic countries, and the International Organization for Medical Physics, a worldwide organ for national societies. Both organizations arrange symposia and congresses at regular intervals.

The Radiological Society of Finland has been an active society with several meetings, symposia and training courses each year. Together with corresponding organizations in the other Scandinavian countries, Nordic Congresses in Radiology are arranged. These are four day events with plenary lectures, scientific reports and technical exhibitions. These congresses have been arranged every year, but now after the 50th congress in Reykjavik 1992, with three Estonian participants, they will be

arranged every second year. The next meeting will take place in Oslo in 1994.

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**RADIATION SAFETY AND QUALITY ASSURANCE
IN X-RAY DIAGNOSTICS.
MEASUREMENTS IN SOME RADIOLOGICAL CLINICS
IN TARTU**

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1. INTRODUCTION

1.1 General

Man is exposed to ionizing radiation originating from many sources such as cosmic, ground, food, consumer products, nuclear fallout and radiation generating equipment. Medical radiation use is one of the most remarkable sources people are exposed to. Approximately 90% of the peaceful use of radiation is due to x-ray examinations. The patient collective effective dose equivalent due to the x-ray examinations is about 3500 manSv per year, i.e. about 0.7 mSv/capita/year¹. About 17% of occupational radiation dose in Finland is due to medical radiation use. Most of the occupational dose is received by the interventional radiologists (mean dose about 10.2 mSv) the other radiologists receiving a dose of about 1.2 mSv².

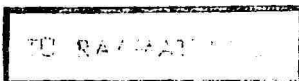
The number of exposures and patient doses vary remarkably in different x-ray examinations. The collective effective dose equivalent due to the computer tomography

examinations in England accounts for about 20% of the total dose due to x-ray examinations, but the number of examinations account for only about 2% of the total number of x-ray examinations³. In contrast the collective dose due to chest x-ray examinations account for only about 2% of the total collective dose, but about 24% of the total number of x-ray examinations³. According to the latest epidemiological data^{4,5} the radiation risk values have increased by a factor of three or more compared to the previous risk values⁶.

1.2 Performance requirements of the diagnostic x-ray units

A high quality of radiological diagnostics presupposes x-ray pictures of high quality, i.e. high quality pictures which show the specific features of each diseased condition visible in the picture and a good radiological knowledge of those examining the pictures. If the dose is increased the image quality also increases, however above a certain dose the image quality does not increase anymore, only the patient dose increases. If the dose used is too small, the quantum noise is too high, and the image quality is poor. Between these two limits there exists the optimum image quality with minimum patient dose.

The imaging chain begins from the patient's acceptance of the treatment and ends in the diagnosis. The technical quality assurance (QA) of the units is a part of the quality assurance of the whole imaging chain. The main quality criteria of the technical QA are technically high quality images with minimum dose and at reasonable costs. Many technical properties of the unit effect remarkably on both the image quality and/or patient dose, such as radiation quality, focal spot size, automatic exposure control (AEC), antiscatter grid, image receptor, imaging geometry and film processing.



Typical QA measurements carried out for diagnostic units are:

-
- High voltage (kV)
 - Exposure time (ms)
 - Focus size (mm x mm)
 - Radiation yield (mGy)
 - output (kV, mA, ms)
 - linearity (mGy/mAs)
 - repeatability (SD (%))
 - Automatic exposure timer
 - density (kV, phantom thick.) (OD)
 - repeatability (SD(%))
 - Film processing
 - base plus fog (OD)
 - contrast (ΔOD)
 - relative speed
 - Patient dose (mGy)
 - Image quality
 - contrast resolution
 - Spatial resolution (lp/mm)
-

According to the ALARA principle a reasonably good image quality should be achieved with the minimum patient dose. In Appendix 1 an example is given of the performance recommendations given by the European Community.

The following requirements can be set for the performance and operation of diagnostic units.

The power of the x-ray generator should be high enough to make the exposures needed with the shortest exposure times.

The x-ray spectrum should be optimized in respect to image quality and patient dose. This is obtained with the proper choice of high voltage and total filtration.

The focal spot size should be small in order to get a high spatial resolution. The spatial resolution is inversely proportional to the focal spot size.

The antiscatter grid should eliminate the scattered radiation effectively, and on the other hand absorb primary beam radiation a little.

The image receptor should be sensitive and have a good spatial and contrast resolution.

Automatic exposure control should produce the film density within certain limits independent of the patient size and have a good repeatability.

Film processing should be optimized so that film speed and contrast are high enough and the base plus fog is small. The increase of the developing time and developer temperature decrease the patient dose and increase the image contrast.

Radiation output of the x-ray generator should be linear to tube current. The radiation yield, mGy/mAs, should be constant with a given tube voltage and the repeatability of the radiation yield should be good.

The European Community (EC) has declared its special interest in decreasing patient doses in x-ray examinations. In the patient safety standard issued by the EC the requirement for organizing quality assurance system for x-ray diagnostic units has been provided⁷. In order to promote and carry out these quality assurance measurements the EC issued quality criteria recommendations for some adult and child x-ray examinations^{8,9,10}. The quality criteria

include recommendations for radiological and technical image quality, patient dose, technical performance of the units and examination procedures.

1.3 Radiological equipment and examinations in Estonia

Tables 1 and 2 show the statistics of radiological units and examinations in Estonia in 1991.

Table 1. Numbers of radiological units in Estonia in 1991

Unit	Number
Magnetic resonance imaging	1
Computer tomography	3
Gamma camera	2
Radiotherapy units	21
Ultrasound units	68
Mammography units	21
Fluorography units	67
Conventional x-ray units	325
Dental units	107

Table 2. Numbers of different x-ray examinations in Estonia in 1991. Also included are some other diagnostic examinations and number of radiotherapy treatments.

Examination	Number
Roentgen diagnostic examinations	1 518 000
Fluoroscopy	150 000
Radiography	1 370 000
- Fluorography	560 000
- Gastro-intestinal	175 000
- Stomach	112 000
- Angiography	60 000
- Urology	42 000
- Mammography	16 000
- Cholangiography	15 000
- Cardioangiography	12 000
- Gynecological	3 000
Isotope examinations	12 000
Ultrasound examinations	287 000
Radiotherapy treatments	35 000

The population in Estonia is some 1.5 million people so the number of x-ray examination is about 1.0/caput/year. The annual number of x-ray examinations in Finland is about 4.2 million, i.e. 0.8 examinations/caput/year.

1.4 Background for the measurements

On the basis of the agreement between Tartu University, University of Helsinki and the Finnish Centre for Radiation and Nuclear Safety (STUK), quality assurance (QA) measurements were carried out at three diagnostic

radiological departments of Tartu University Hospital. The measurements focused on the technical performance of the bucky/thorax, fluoroscopic units, image quality, patient doses and film processing. The measurements were made in co-operation with the radiologists and radiographers in the local hospitals and with physicist from Tartu University Institution of Didactics of Physics. The results, conclusions of the measurements, and recommendations for further measures are given in the following paragraphs. Measurements were made, however, only for few diagnostic units so the results are only indicative of the general situation.

2. MATERIAL AND METHODS

2.1 Hospitals and diagnostic x-ray units

Measurements were made in the hospitals listed in Table 3.

Table 3. Hospitals and x-ray units investigated.

Hospital 1:	Tartu University Hospital Vallikraavi 7 Unit 1: TUR 700/Bucky and thorax Unit 2: TUR 700/TUR DG10 General purpose unit
Hospital 2	Tartu University Hospital Vallikraavi Unit 3: EDR-750B/Bucky and thorax Unit 4: EDR-750B/General purpose unit
Hospital 3	Tartu University Hospital Maarjamoisa Unit 5:EDR 750B/Bucky and thorax /General purpose unit Unit 6: Tridoros 5S/Fluoroscopic unit

Performance measurements of the diagnostic x-ray units were focused on x-ray output, accuracy of tube voltage, exposure time, linearity and repeatability of exposures, image quality, patient dose and film processing. Exposure measurements were made with the radiation monitor MDH 1015 provided with a 10x5-6 ionization chamber for dose measurements in the primary beam and with a 10x5-180 ionization chamber to measure scattered radiation. The radiation monitors were calibrated in the Secondary Standard Laboratory of STUK. Tube voltages were measured with the Victoreen Model 07-473 kVp meter calibrated in the Laboratory of Medical Radiation of STUK. Patient doses were estimated with the output measurements of x-ray tube using the known exposure parameters in each x-ray examination. Image quality was assessed with the spatial resolution and contrast resolution test plate. Film processing was tested sensitometrically with X-Rite Model 334 sensitometer (number of steps being 21) and developing the film with the method used in the hospital. The densities of the steps were measured with the X-rite Model 331 densitometer. The contrast (gradients), base plus fog and maximum density were assessed from the density curve.

The films used in the hospitals were mainly Crema RM-1 (Russian) and Orwo (German). The cassettes used in chest examinations were manufactured by Medicor Röntgen (Hungary), the other cassettes and screens were without any label of type or manufacturer.

3. RESULTS

The results are given separately for exposure parameters, patient doses, image quality and film processing. Only some examples of the results are shown in figures. Reference values are given in Appendix 2.

3.1 Exposure parameters

Figure 1 shows the x-ray output as a function of tube voltage (Unit 3) and they are shown in Figure 2 as a function of tube current (Unit 4). The output deviates slightly from the expected values. However, that is of minor importance.

Figures 3 (Unit 1), 4 (Unit 3) and 5 (Unit 5) show the measured tube voltages as a function of pre-set values in hospitals 1 to 3. The measured values in hospital 1 are about 4–8 kV and in hospital 2 about 20 kV higher at the maximum than the pre-set values. The difference slightly exceeds the recommended value in hospital 1 and greatly in hospital 2 (Appendix 2).

Measured exposure times are given in the patient dose tables 4 and 5 for hospitals 1 and 2. The accuracy of exposure times are sufficiently good.

Figure 6 (Unit 1) shows the linearity of the x-ray output. The linearity is sufficiently good.

Repeatability of the radiation output was measured on the Unit 3. It was found to be good (SD<5%).

3.2 Patient doses

Tables 4 and 5 show the exposure values and patient surface doses for some of the commonly made x-ray examinations in hospitals 1 and 2.

Table 4. Exposure values and patient surface doses for different x-ray examinations in hospital 1.

Examin/Proj		Exposure values			Measured values	Surface dose
		kV	mA	s	exp.time (ms)	mGy
Skull	AP	80	200	0.5	524	30.10
	Lat	70	150	0.3	273	14.30
Chest (bed)	AP	70	100	0.2	184	7.30
	Lat	80	195	0.5	554	47.80
Chest (f.s) ¹	AP	65	14	0.025	26	0.49
	Lat	80	15	0.035	28	0.86
LS-spine	AP	75	200	0.5	527	31.70
	Lat	85	230	0.7	724	61.00
Pelvis	AP	75	200	0.5	514	29.90
Femur	AP	70	150	0.35	301	14.10
Knee	AP	65	110	0.18	171	7.20
	Lat	60	110	0.18	167	5.80
Ankle	AP	55	58	0.08	9.6	2.10
	Lat	50	60	0.08		1.60
Urography	AP	77	115	0.25	204	15.30
Shoulder	AP	60	95	0.16	154	7.50
Elbow	AP	55	57	0.08		2.40
Wrist		50	60	0.08		1.70
Fingers		50	45	0.08		1.20

¹ Full size chest examination

Table 5. Exposure values and patient surface doses for different x-ray examinations in hospital 2.

Exam/Proj		Exposure values			Measured values	Surface dose
		kV	mA	s	exp.time ms	mGy
Skull	AP	80	300	0.34	358	25.10
	Lat	70	150	0.25	267	8.80
Sinus	AP	70	500	0.20	216	16.90
Chest (bed)	AP	75	500	0.2	217	12.80
	Lat	70	500	0.25	266	30.30
Sternum	AP	67	500	0.16	176	14.10
	Lat	73	500	0.20	217	26.90
LS-spine	AP	75	300	0.25	267	19.50
	Lat	75	500	0.34	356	44.80
Abdomen	AP	70	500	0.25	267	22.50
Pelvis	AP	73	300	0.2	216	15.10
Hip	AP	75	300	0.25	268	19.50
Femur	AP	70	300	0.2	217	11.10
Knee	AP	65	300	0.16	177	6.80
	Lat	60	300	0.16	177	6.10
Ankle	AP	55	50	0.08	94	0.90
	Lat	50	50	0.08	92	0.84
Urography	AP	77	500	0.25	267	26.80
Shoulder	AP	60	300	0.16	177	8.50
Elbow	AP	55	150	0.08	98	2.10
Wrist		50	50	0.08	91	0.84
Fingers		50	50	0.06	89	0.63

Patient surface dose in chest examination (70 kV, 10 ms, FSD 1.5 m) was 0.34 mGy in hospital 3 (Unit 5, bucky thorax). Measured exposure time was 31 ms.

Patient doses are 2 to 5 times higher than the corresponding mean doses measured in Finland (Appendix 2) or patient doses recommended by EC⁸.

3.3 Image quality

Table 6 shows the image quality parameters (spatial and contrast resolution) of bucky and thorax stands (Unit 1).

Table 6. Image quality parameters (spatial and contrast resolution) of bucky and thorax stands in hospital 1.

Parameter	Thorax		Abdomen	
	Local ¹	STUK ²	Local ¹	STUK ²
Spatial resolution (lp/mm)	2.0	2.5		2.5
Contrast resolution (OD)	0.07			0.09

¹ Hospital's film and screen processed in Tartu
² STUK's film and screen processed in Tartu

Table 7 shows the image quality parameters (spatial and contrast resolution) of bucky and thorax stands in hospital 2.

Table 7. Image quality parameters (spatial and contrast resolution) of bucky and thorax stands in hospital 2.

Parameter	Thorax		Abdomen	
	Local ¹	STUK ²	Local ¹	STUK ²
Spatial resolution (lp/mm)	4.0	4.0	3.0	3.0
Contrast resolution (OD)	0.12	0.16	1.10	

¹ Hospital's film and screen processed in Tartu
² STUK's film and screen processed in Tartu

The spatial resolutions are equal but the contrast resolutions are lower than the values measured with STUK's image receptor.

Dose rate on the image intensifier input surface (Unit 3, EDR 750B/UV-4) was 0.097 mGy/min, when automatic dose rate control with 16 cm thick perspex phantom was used. The recommended value in Finland is 0.048 mGy/min¹³.

Spatial resolution of image intensifier in the above mentioned unit with 75 kV and 16 cm thick perspex phantom was 1.5 lp/mm. The spatial resolution is sufficiently good.

Dose rates on image intensifier input surface (Unit 2, Tridoros 5 S fluor.), when automatic dose rate control with 16 cm thick perspex phantom and vertical x-ray tube were used, varied between 0.04–0.08 mGy/min. The

recommended upper limit value in Finland is 0.048 mGy/min¹³.

3.4 Film processing

Table 8 shows the contrasts (gradients), base plus fogs and maximum densities of the film processing in hospitals 1 to 3 using the hospitals' films (ORWO or Russian film) compared with the values measured with the STUK film (Agfa RP1).

Table 8. Film processing properties in hospitals 1 to 3.

Parameter	Hospital 1	STUK 1	Hospital 2	STUK 2	Hospital 3	STUK 3
Base & fog	0.27	0.19	0.53	0.28	0.49	0.19
Contrast 0.25-0.5	1.23	1.61	1.11	1.42	1.77	2.05
Contrast 0.5-1.5	1.37	1.86	1.28	1.50	1.88	2.25
Max. density	2.33	2.69	2.68	2.97	3.19	3.11

The figures show high base plus fog, low contrast and low maximum density in all hospitals compared to the values of the reference (STUK) film.

Figures 7,8,9 and 10 show the density curves of the film processing in each hospital. The curves clearly show the differences given in Table 8.

4. MAIN CONCLUSIONS

As a general,

1. The technical performance of diagnostic units (accuracy of exposure parameters etc.) are reasonably good.
2. Image receptors (screens, films) are insensitive.
3. Patient doses are high.
4. Spatial resolutions of fluoroscopic units are reasonably good. Technical image quality of film and screen systems are poor.
5. Film processing is mainly manual and this results in uneven density and artifacts on the film.
6. The leakage radiation in the other rooms outside the examination room is negligible.
7. No quality assurance program is yet established in Estonia.
8. Personal occupational radiation doses are not controlled.

5. SUGGESTIONS FOR IMPROVING RADIATION SAFETY AND IMAGE QUALITY IN X-RAY DIAGNOSTIC EXAMINATIONS

According to the ALARA principle a systematic quality assurance program should be established in every hospital. This presupposes:

1. A QA organisation and QA measuring system in the University hospitals should be established. This could act

as a reference institute for other x-ray diagnostic centers in Estonia.

2. The personnel should be taught to make quality assurance (QA) measurements and the availability of basic test devices (sensitometer, densitometer, radiation monitor, kV-meter, image quality test devices) for QA-measurements.
3. The first step in improving image quality and reducing patient dose should be focused on acquiring new sensitive image receptors (screens, films), film processors and processing chemicals.
4. According to ICRP recommendations and ILO agreements the control of personal occupational radiation doses should be arranged.

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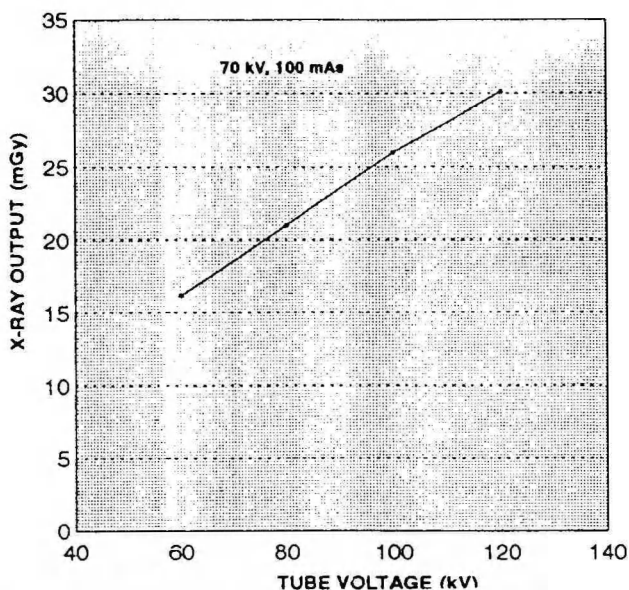


Figure 1. X-ray output (x-ray exposure/100 mAs) as a function of tube voltage.

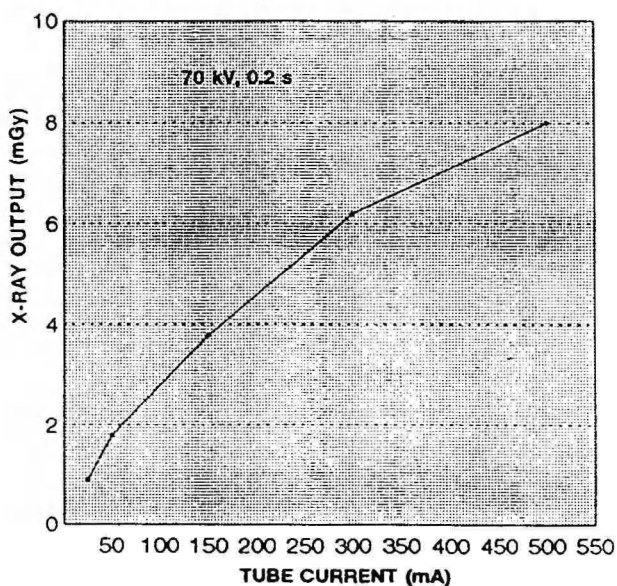


Figure 2. X-ray output as a function of tube imaging current.

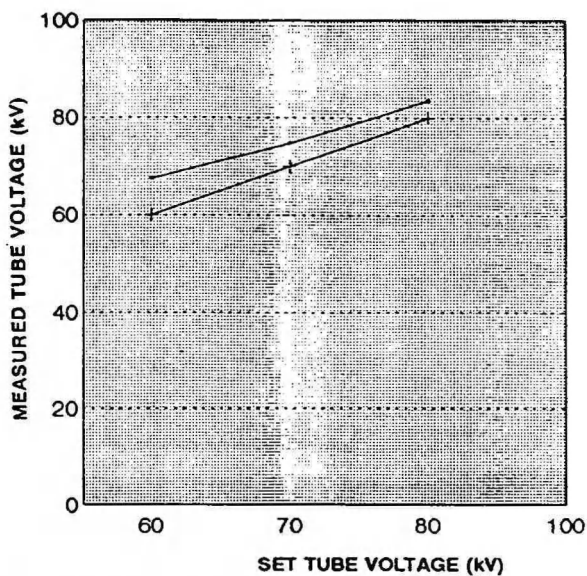


Figure 3. Measured tube voltages.

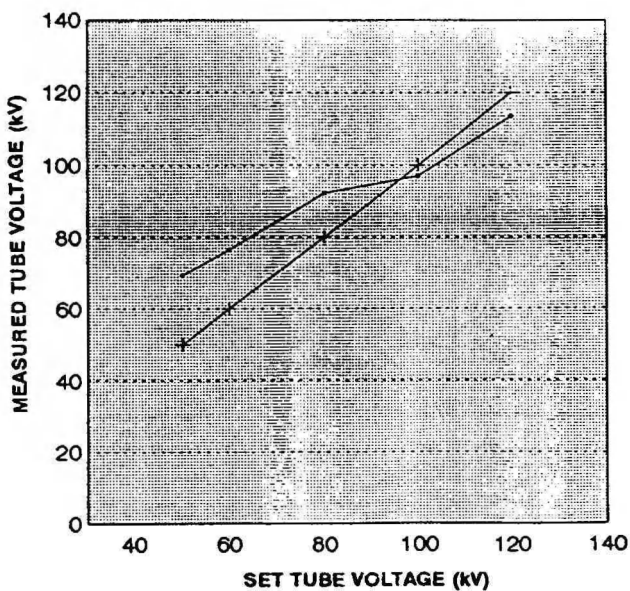


Figure 4. Measured tube voltages.

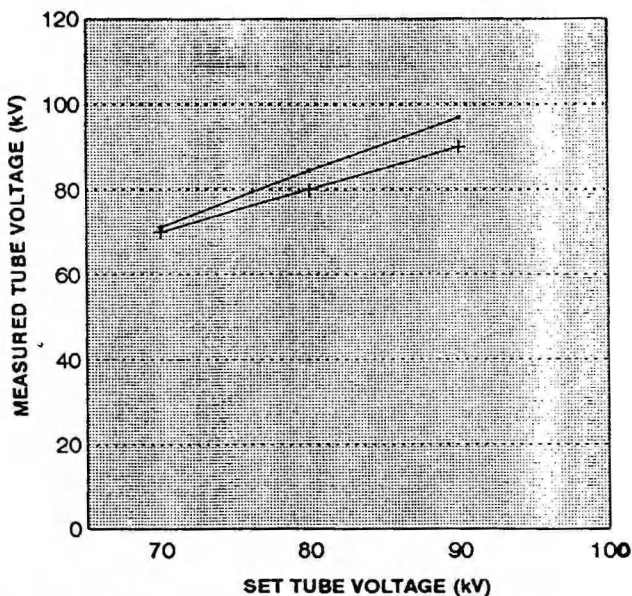


Figure 5. Measured and the expected tube voltages of the bucky-unit.

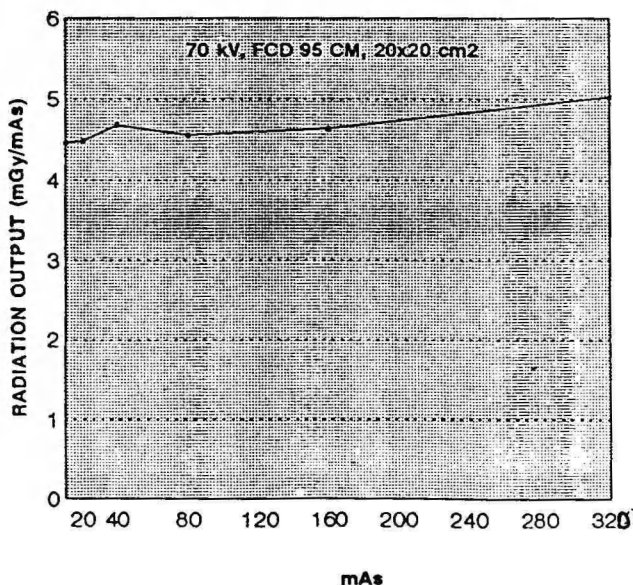


Figure 6. Linearity of x-ray output, i.e. the x-ray exposure/mAs.

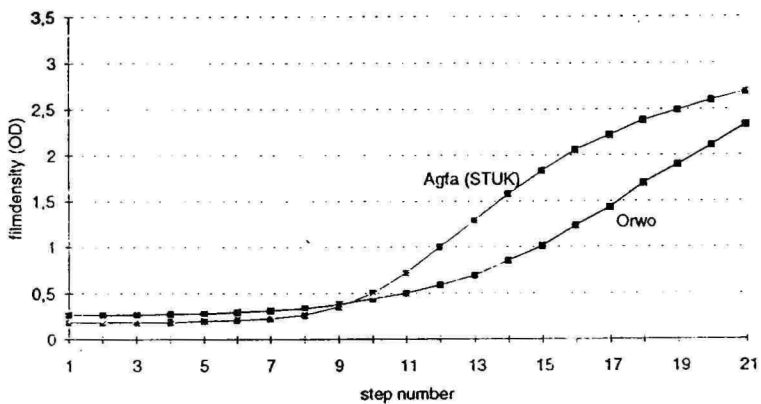


Figure 7. Sensitometric curve of the film processing in hospital 1.

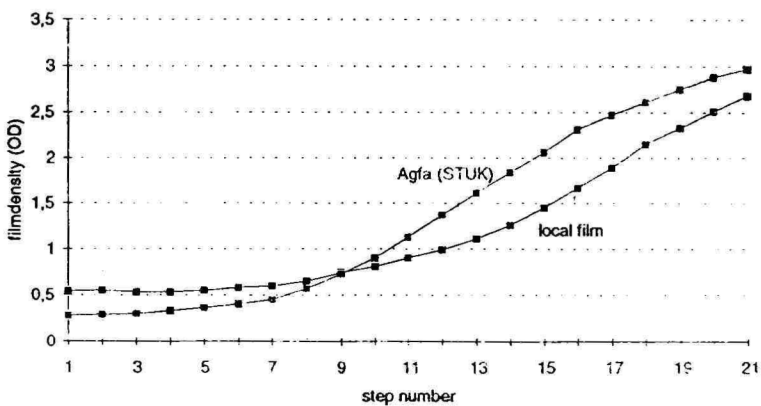


Figure 8. Sensitometric curves of the film processing in hospital 2 using Agfa and Orwo films.

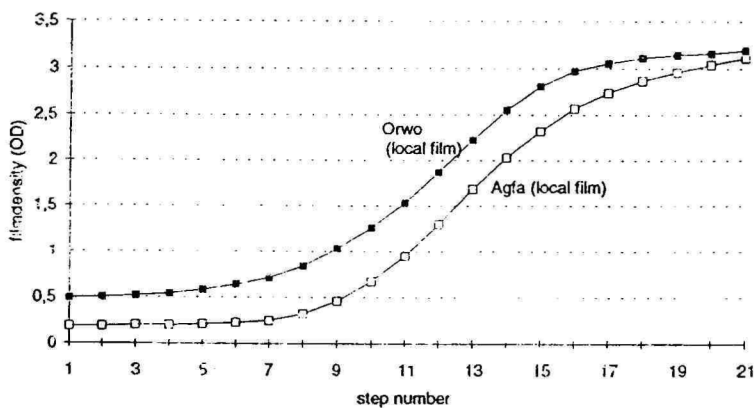


Figure 9. Sensitometric curves of the film processing (film processor) used by Agfa and Orwo films in hospital 3.

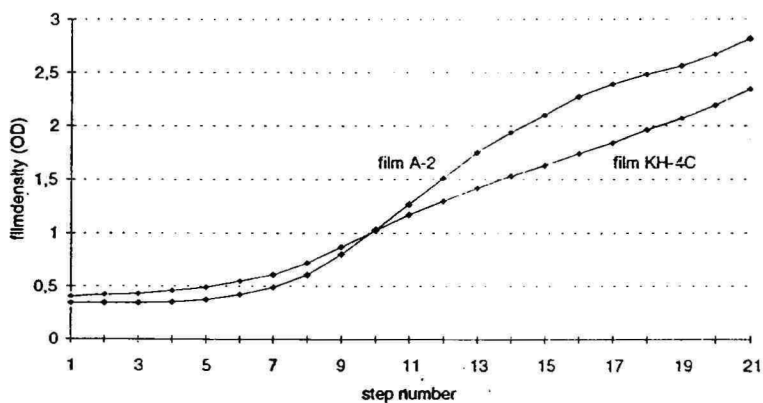


Figure 10. Density curve of cine-film processing in hospital 3.

APPENDIX 1

PA PROJECTION: CHEST (LUNGS AND HEART)

1. Diagnostic requirements

Image criteria

- 1.1 Performed at deep inspiration (as assessed by the position of the ribs above the diaphragm – either 6 anteriorly or 10 posteriorly) and with suspended respiration.
- 1.2 Symmetrical reproduction of the thorax.
- 1.3 Medial border of the scapulae to be outside the lung fields.
- 1.4 Reproduction of the whole rib cage above the diaphragm.
- 1.5 Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels.
- 1.6 Visually sharp reproduction of
 - a) the trachea and proximal bronchi, the borders of the heart and aorta
 - b) the diaphragm and costo-phrenic angles.
- 1.7 Visualization of the retrocardiac lung and the mediastinum.

2. Criteria for good imaging performance

2.1 Important image details

Small round details in the whole lung, including the retrocardiac areas:

high contrast: 0.7 mm diameter

low contrast: 2 mm diameter

Linear and reticular details out to the lung periphery:

high contrast: 0.3 mm in width

low contrast: 2 mm in width.

- 2.2 Entrance surface dose for a standard-sized patient:
0.3 mGy

3. Example of good radiographic technique

3.1 Radiographic device	vertical stand with stationary or moving
3.2 Focal spot size	≤ 1.3 mm
3.3 Total filtration	≥ 3.0 mm Al equivalent
3.4 Anti-scatter grid	$r = 12; 40/\text{cm}$
3.5 Film-screen combination	speed class 200-400
3.6 FFD	180 (140-200) cm
3.7 Radiographic voltage	100-150 kV
3.8 Automatic exposure control	chamber selected - lateral
3.9 Exposure time	<20 ms

APPENDIX 2

Table A1. Accuracy of some parameters recommended in Finland^{11,12,13}.

Parameter	Accuracy
Tube voltage (kV)	<10%
Tube current	<15%
Exposure time (ms)	<10%
Linearity (mGy/mAs)	<0.2
Repeatability (S.D.)	<0.1
Dose rate on II ¹	<0.8 μ Gy/s
Spatial resolution ¹	>0.7 lp/mm
Contrast resolution ¹	<0.5 mm Al

¹ image-intensifier-TV chain

Table A2. Mean patient surface doses and image quality parameters of some basic x-ray examinations measured in Finland¹⁴.

Examination/Proj.	Surface dose (mGy)	Spatial resolution (lp/mm)	Contrast resolution (Δ OD)
Skull	Lat 3.1 (1.1-7.7)		
Chest	PA 0.27 (0.04-0.84)	2.6 (0.85-4.2)	0.37 (0.14-0.54)
TH-spine	AP 7.9 (1.3-22)		
LS-spine	AP 8.4 (2.9-28)		
Abdomen	AP 5.2 (1.1-21) (1.1-21)	1.6 (0.85-3.5)	0.30 (0.14-0.47)