Early X-Ray Therapy Machines

Colin G. Orton, Ph.D.
Professor Emeritus,
Wayne State University,
Detroit, Michigan, USA

The discovery that started it all

November 1895: Roentgen discovers x rays

1st use for cancer therapy

- 29th January 1896: Emile Grubbé, a medical student in Chicago, who had established a small business making x-ray tubes, initiated a course of treatment on Mrs. Rose Lee, who had breast cancer
- He delivered 18 daily “one-hour” treatments with the breast in contact with the x-ray tube

Why 18 treatments?

- Treatments were terminated when the patient developed excessive skin damage
- This patient died within one month due to systemic disease before local control could be studied

Early medical x-ray therapy

Within a few years after the discovery of x rays by Roentgen, they were used for the cure of practically all ailments

Afflictions amenable to x-ray therapy according to Kassabian (1907)

Cutaneous affections:
- Lupus erythematosus
- Lupus vulgaris
- Naevus
- Alopecia areata
- Hypertrichosis
- Favus and tinea tonsurans
- Eczema
- Acne
- Sycosis
- Pruritis ani and pruritis vulvae
- Xeroderma pigmentosum
- Psorias
- Senile leg ulcers
- Varicose veins
- Hyperidrosis
- Kraurosis vulvae
- Leprosy

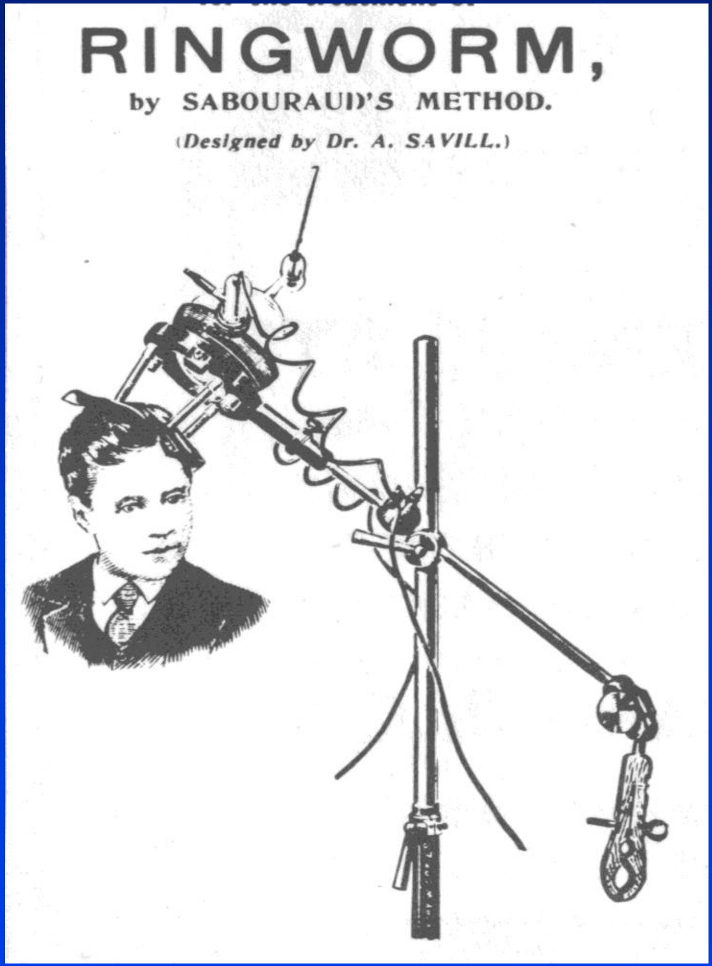
Constitutional diseases:
- Tuberculosis
- Leukaemia

Malignant growths:
- Epithelioma
- Carcinoma
  - Breast
  - Sternum
  - Oesophagus
  - Larynx
  - Stomach and bowels
  - Uterus
- Sarcoma

Miscellaneous affections:
- Trachoma
- Keloid
- Exophthalmic goitre
- Hypertrophied prostate
- Analgesic actions of the rays
- Neuralgia
- Migraine
- Epilepsy

You could use x rays to remove hair

Later studies showed that the radiation caused a significant increase in thyroid cancer and behavioral abnormalities



Often with tragic consequences

This is a 75 year old lady who was treated to remove excessive hair on her back when she was five

She never again grew hair on her back but the soft-tissue damage was horrendous

Sometimes more than one patient was treated in the room simultaneously

Note that the controls are in the room and there is no shielding of staff or other patients

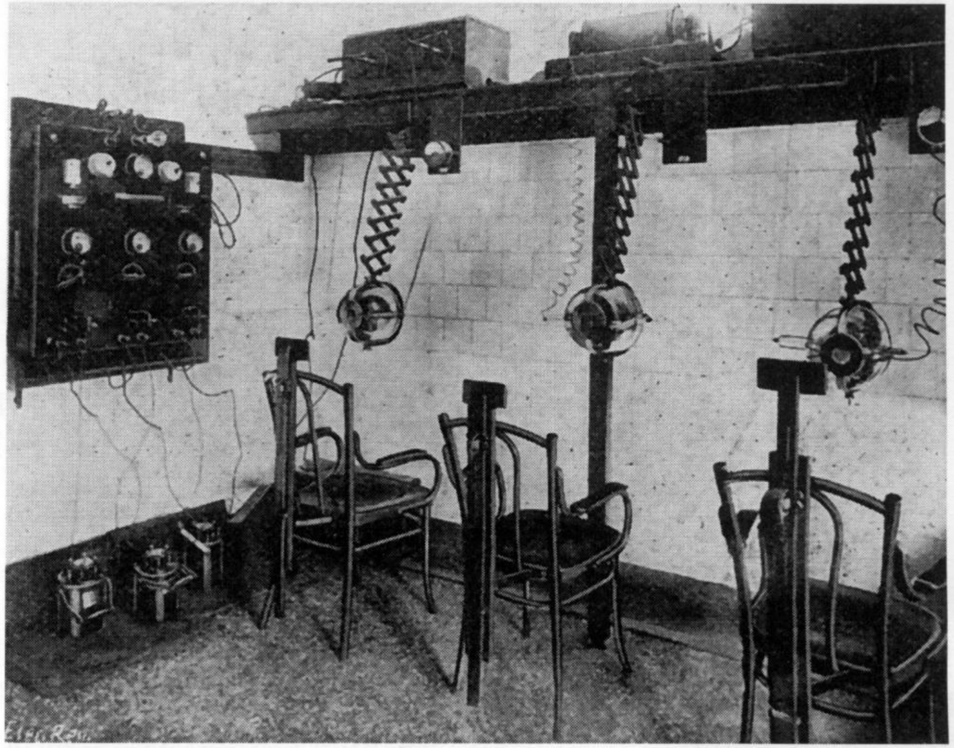
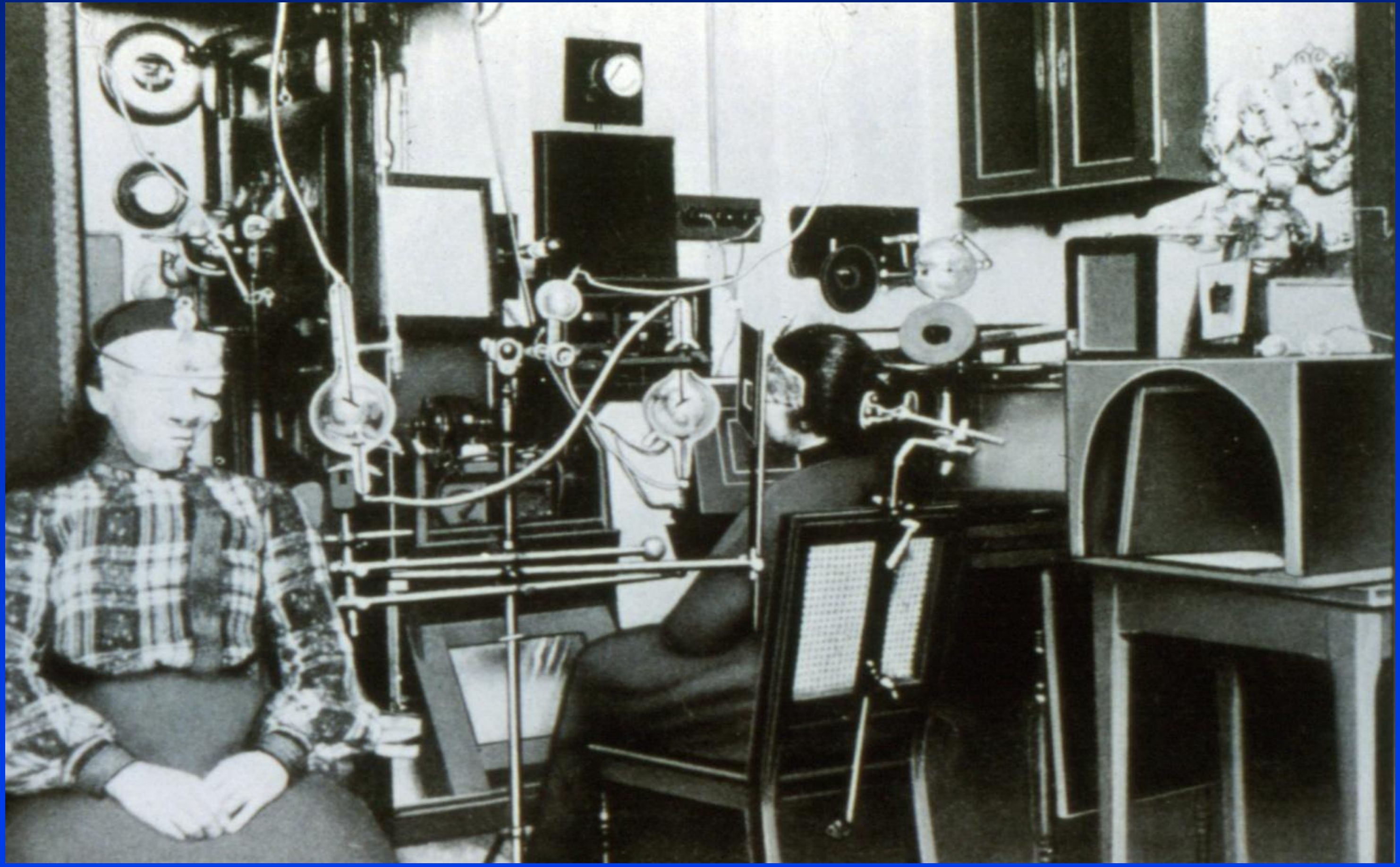


Fig. 6. The Roentgen Therapy room at the London Hospital in about 1905. Note that the x-ray tubes are unshielded and several patients could be treated simultaneously. Reproduced from Sequeira and Morton (1905; with permission).

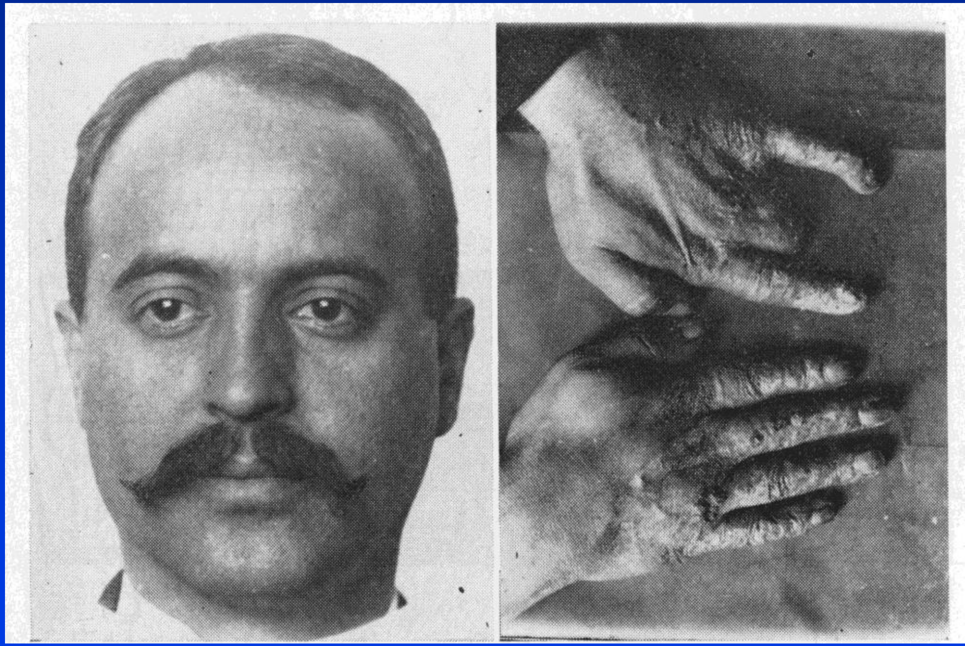
Another example

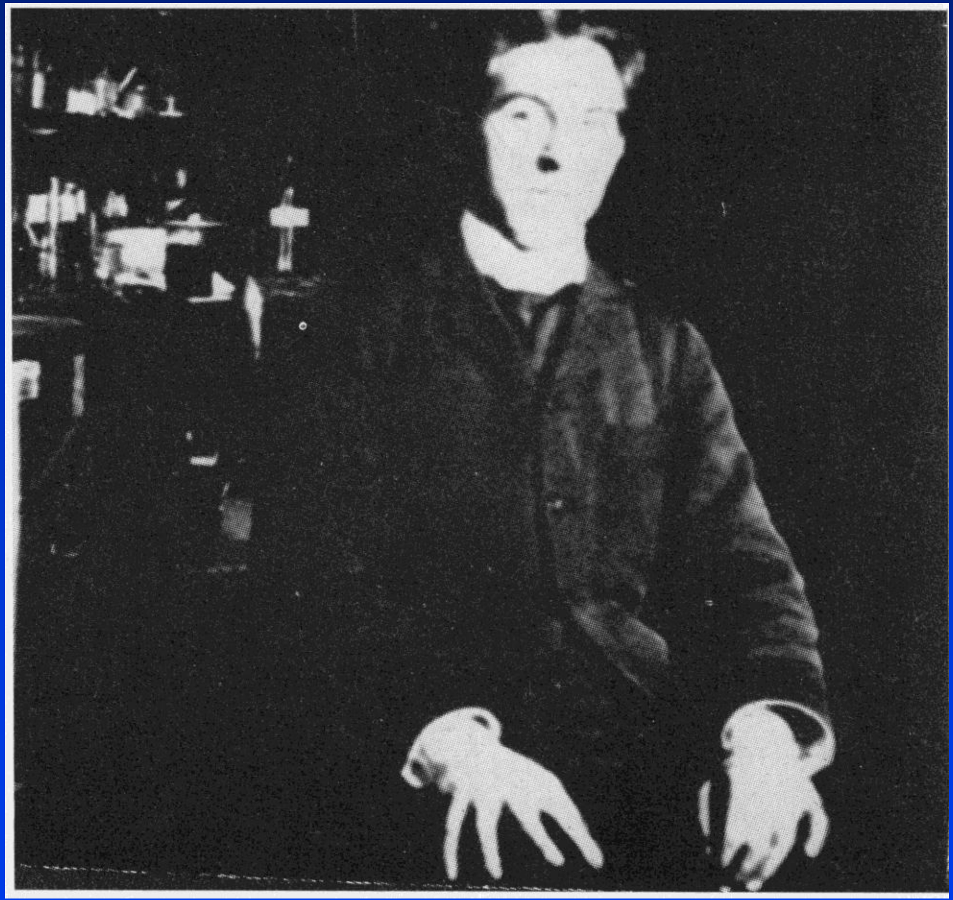


“Martyrs” of Radiology

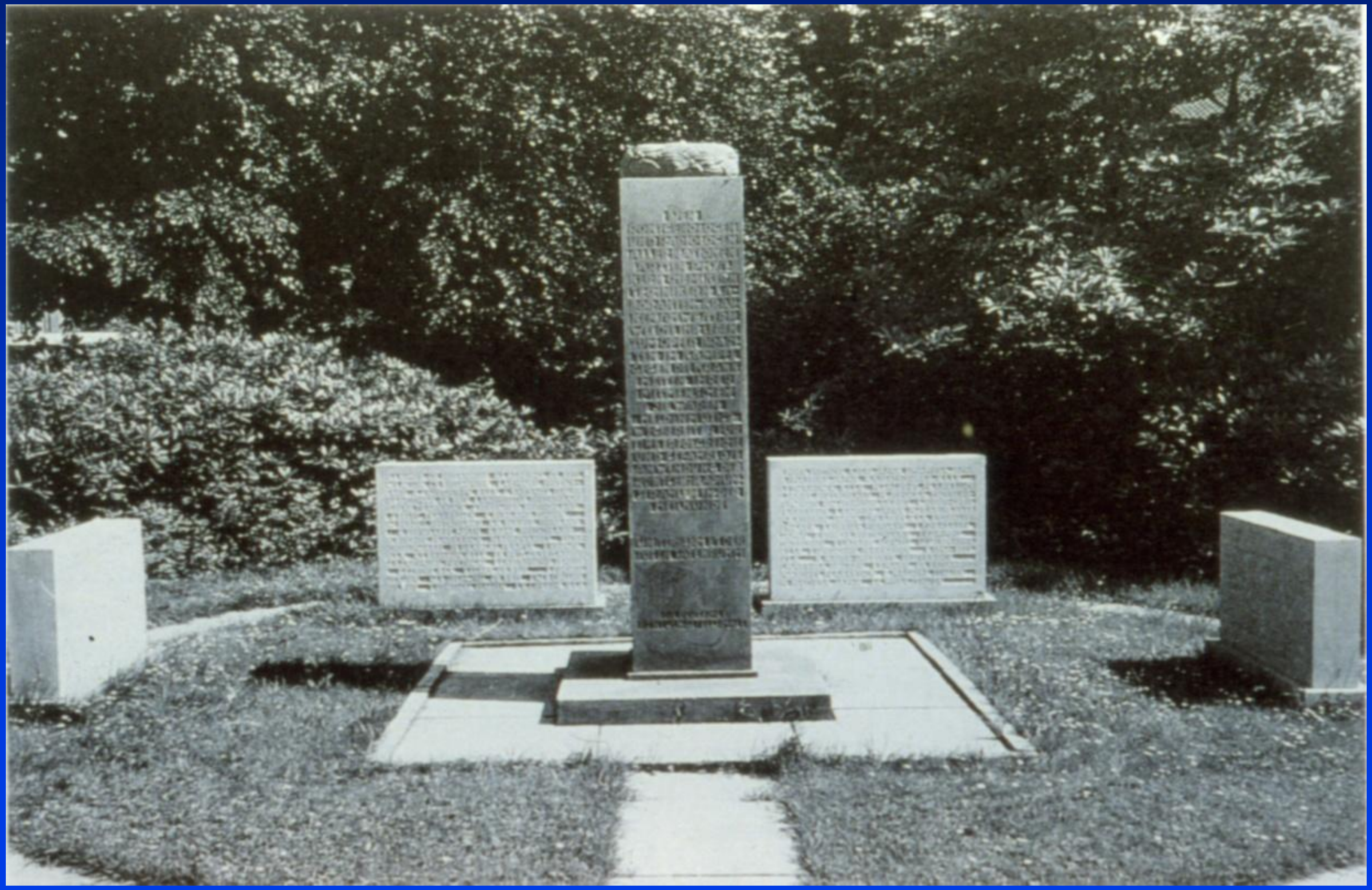
- Early pioneers developed skin cancers, especially in the hands
  - *radiologists, technicians, engineers, physicists*
- There was an increased incidence of leukemia
- About 400 known deaths

Two of the pioneers: Kassabian and Grubbé





Memorial to the "Martyrs of Radiology" in Hamburg



Why were treatments fractionated?

- Very low output
  - *to complete the treatment in one fraction would have taken hours, even days*
- Dose was unpredictable
  - *you only found out what dose had been delivered after the completion of each session*
  - *clearly, you couldn’t give the full treatment in a single, unpredictable, fraction*

Early fractionation schemes were very crude

- Many fractionation schedules were published, usually based on observation of skin reactions, such as the one of Carl Beck of New York:
- *“It is best to expose for a short time and at long intervals until the individuality of the patient is well studied.”*
- *“Some patients react soon, some after many exposures, and some do not react at all.”*

Carl Beck method (cont'd.)

- *"It should be regarded as an ion-clad rule to stop the exposures as soon as the patient feels a burning sensation in the irradiated area."*
- *"Only after symptoms of this kind have again disappeared entirely the irradiations may be repeated."*
- *"A week should elapse before a second exposure is made."*

Carl Beck method (cont'd.)

- *"If after the third exposure, made two weeks later than the first, no inflammatory signs have shown, the patient does not seem to have an unfavorable idiosyncrasy, longer exposures and shorter intervals can be attempted."*
- *"These exposures may last ten, twenty, or even forty-five minutes, and may be repeated every other day, in obstinate cases even daily."*

Carl Beck method (cont'd.)

- *"The risk of burning the patient under such powerful treatment is small."*
- *"In the treatment of malignant disease, however, this should not bear great weight."*

William Coolidge (AAPM Honorary Member) changed all this

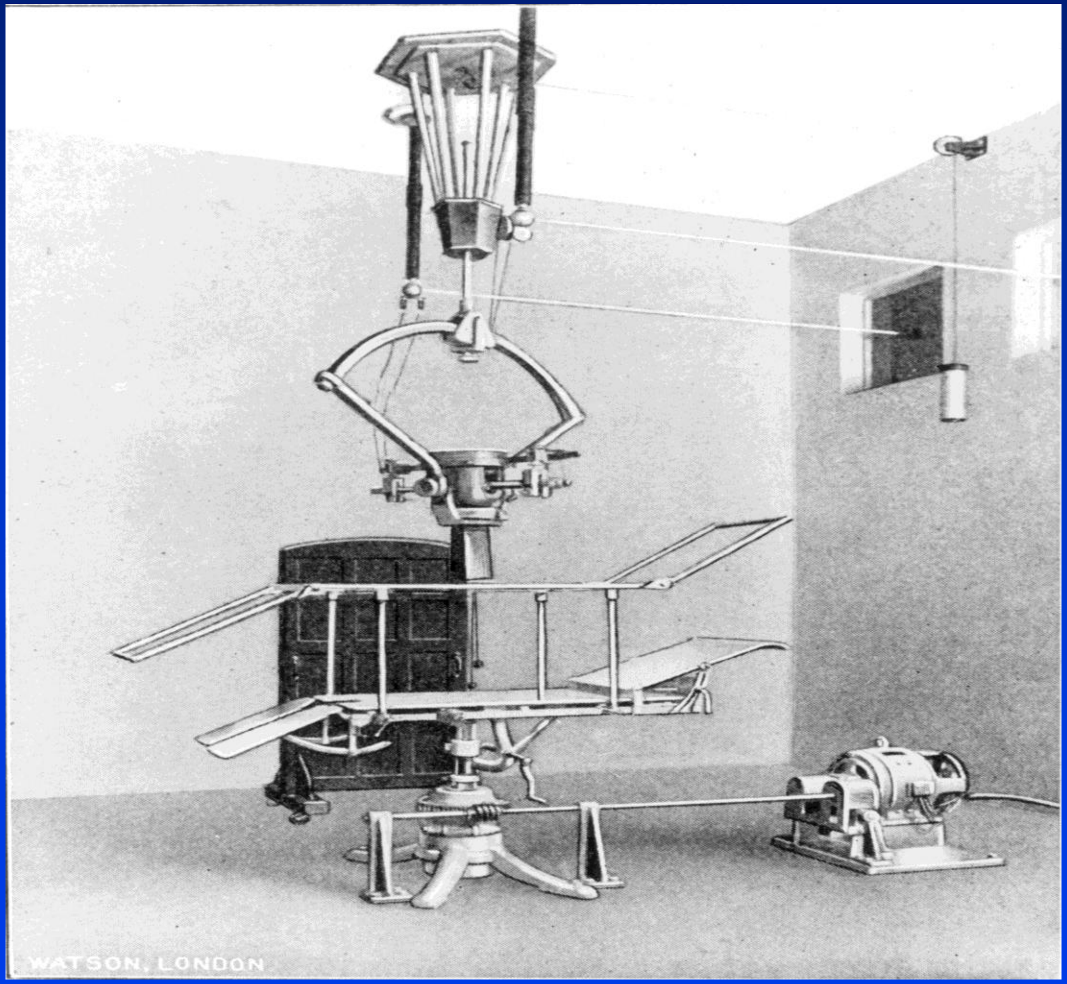
The hot-cathode X-ray unit

- It was not until 1914 with the development of the hot-cathode X-ray tube by William Coolidge that high, predictable, dose rates became possible
- Equal daily fractions delivered in a short time became possible
  - *fractionation became a “science” and it became possible to compare fractionation schemes*
- Next came the quest for higher energies

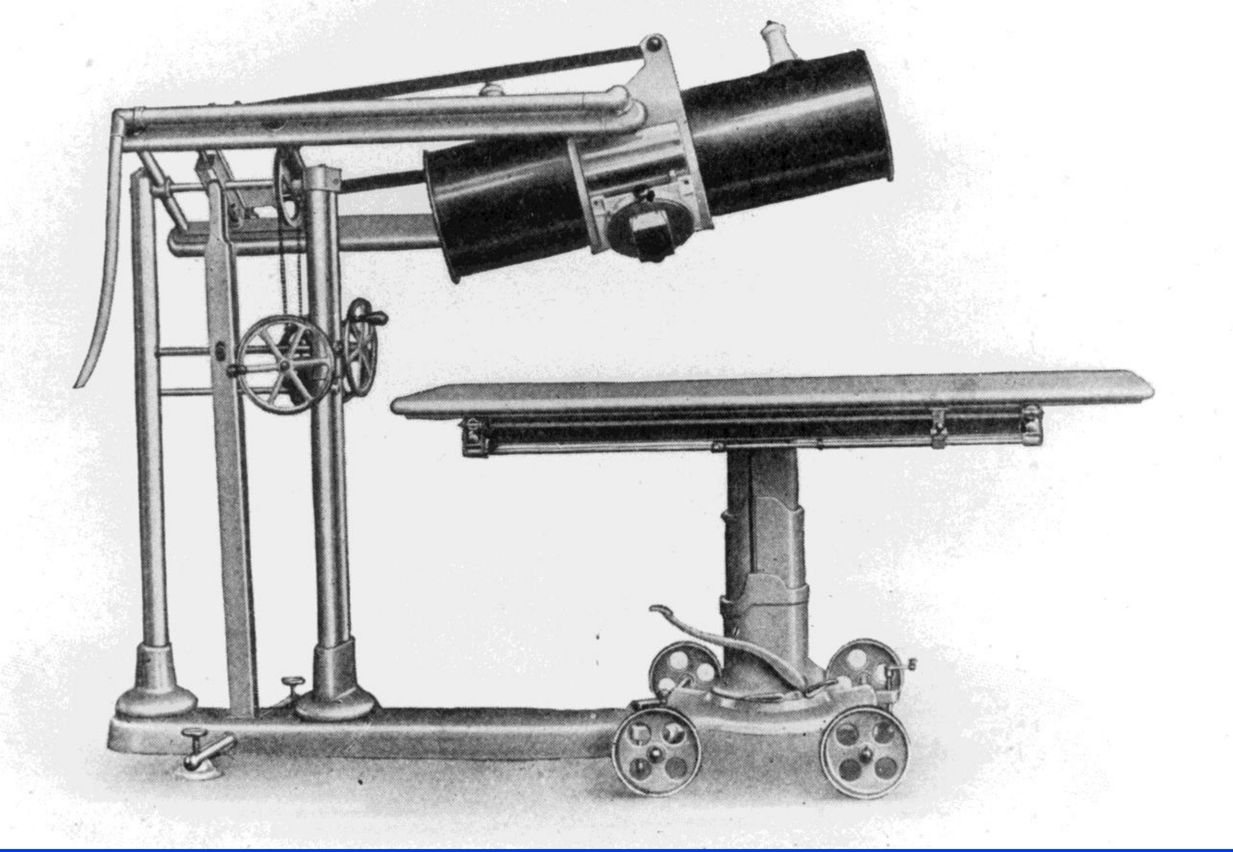
The quest for higher energies and more versatile equipment

- Higher energies
  - *better penetration*
  - *sufficient penetration to fire beams from different directions*
  - *reduced "skin" doses*
- Rotational machines
  - *isocentric units*

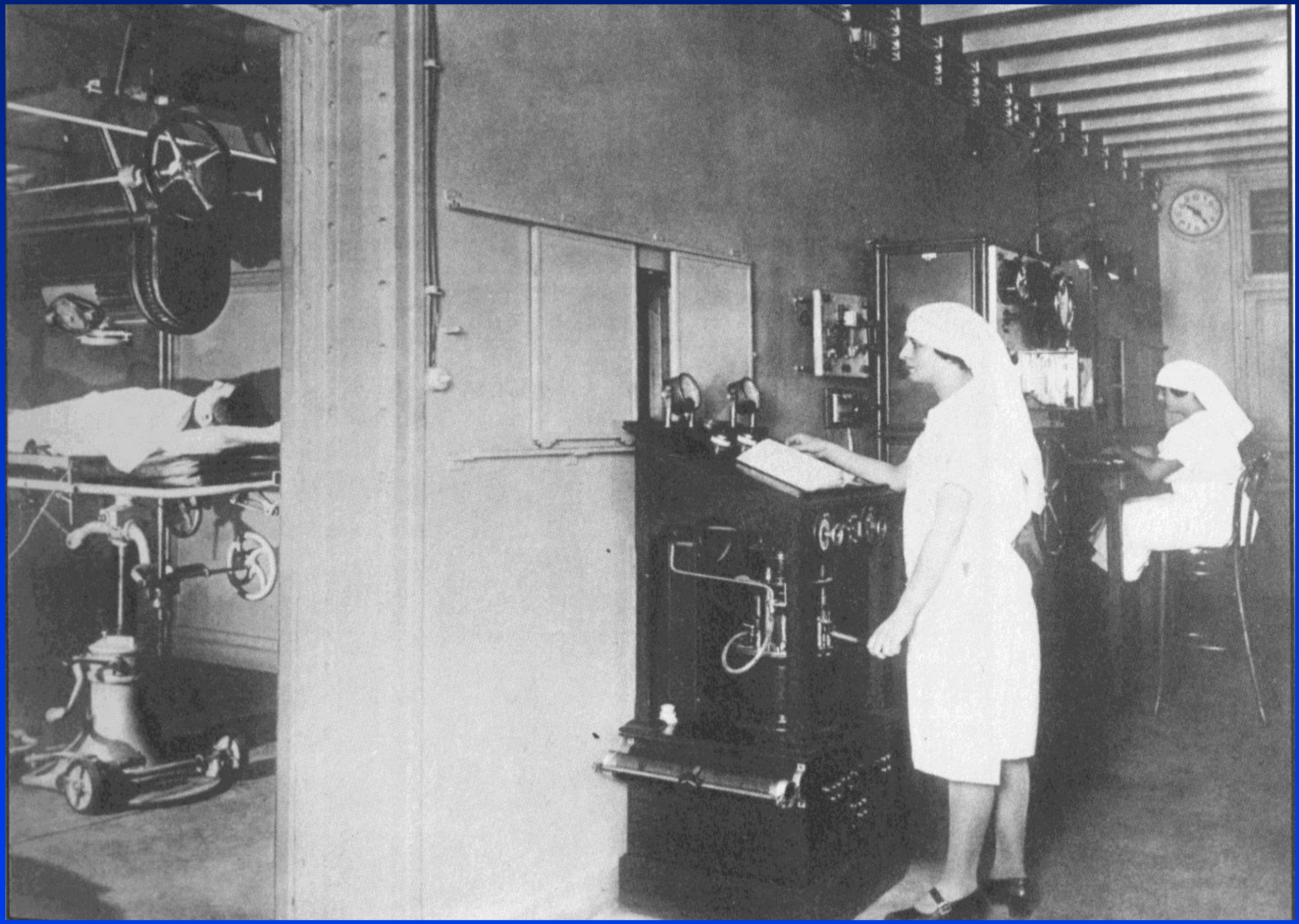
About 1930: Knox rotational unit



Deep x-ray therapy “cannon”

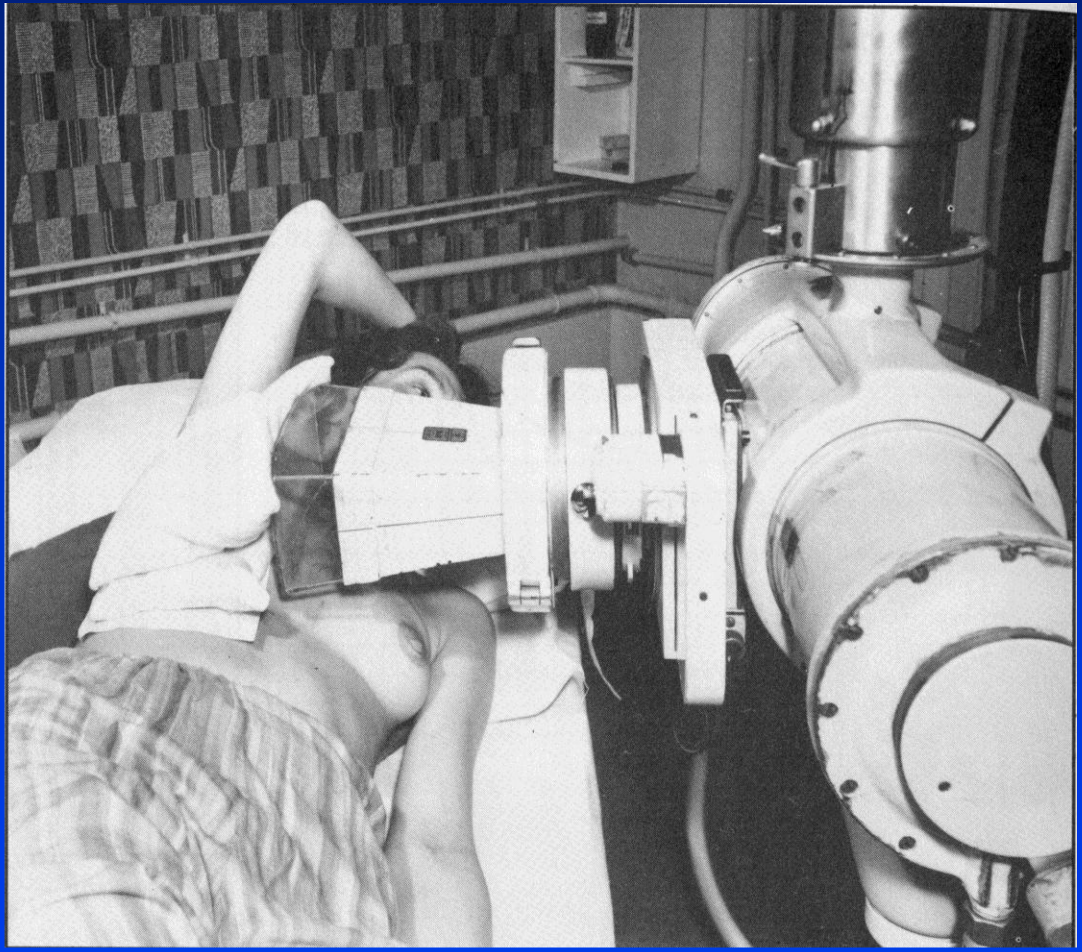


X-ray cannon in Paris (1920s)



Orthovoltage x-ray therapy machine

With energies 200-500 kVp, this was the workhorse of deep x-ray therapy from the 1930s through the 1950s until replaced by the Co-60 unit



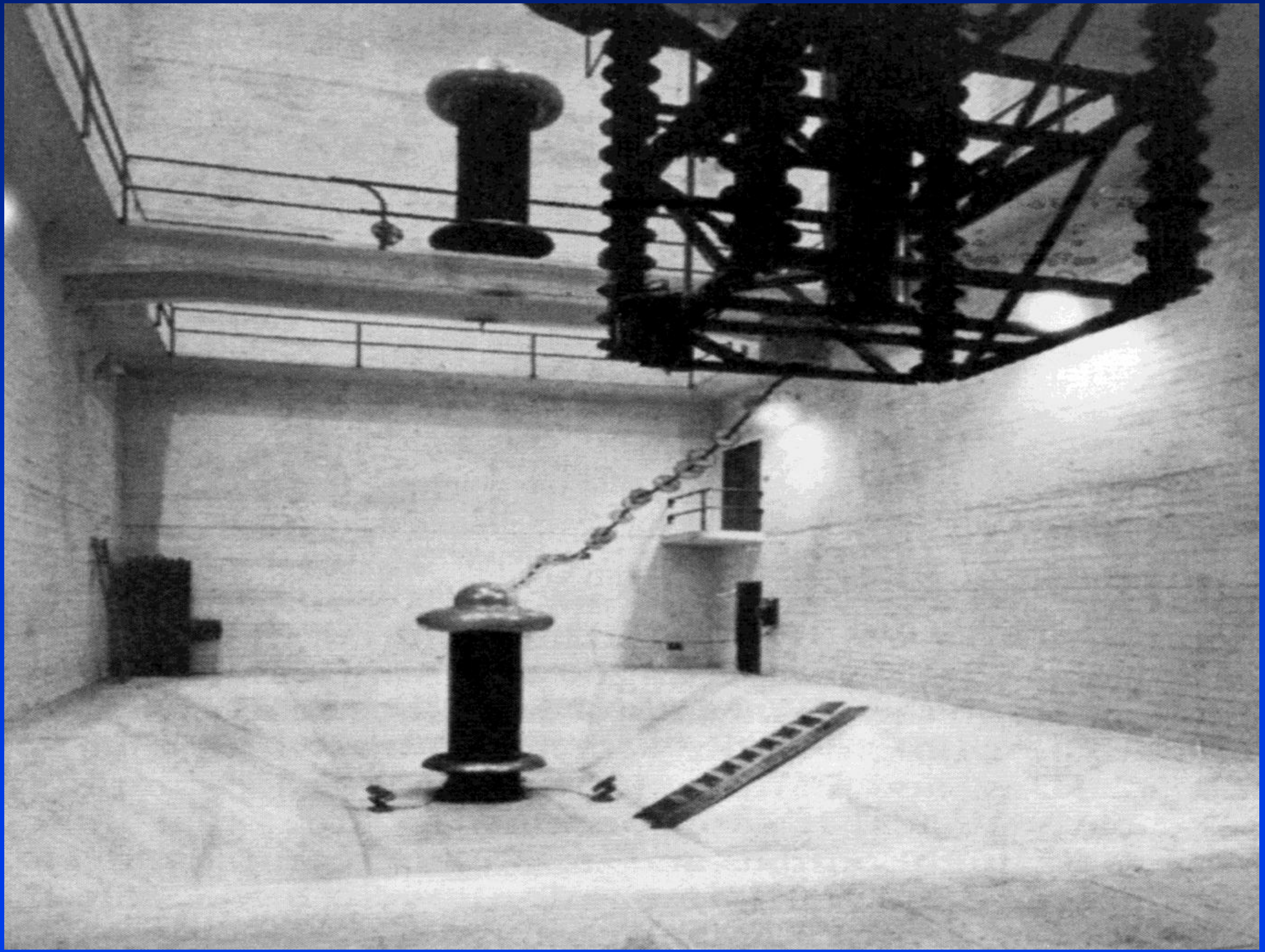
1930-1934: “Supervoltage” X-ray machines

- These included machines of:
  - *500 kVp installed at Harper Hospital, Detroit*
  - *600 kVp at Caltech*
  - *750 kVp at Memorial Hospital, New York*
  - *800 kVp at Mercy Hospital, Chicago*
  - *1,000 kVp at Swedish Hospital, Seattle and Caltech*

1933: World's 1st 1 MeV x-ray machine (Caltech)

The machine was in a vault 42 m long by 20 m wide by 15 m high

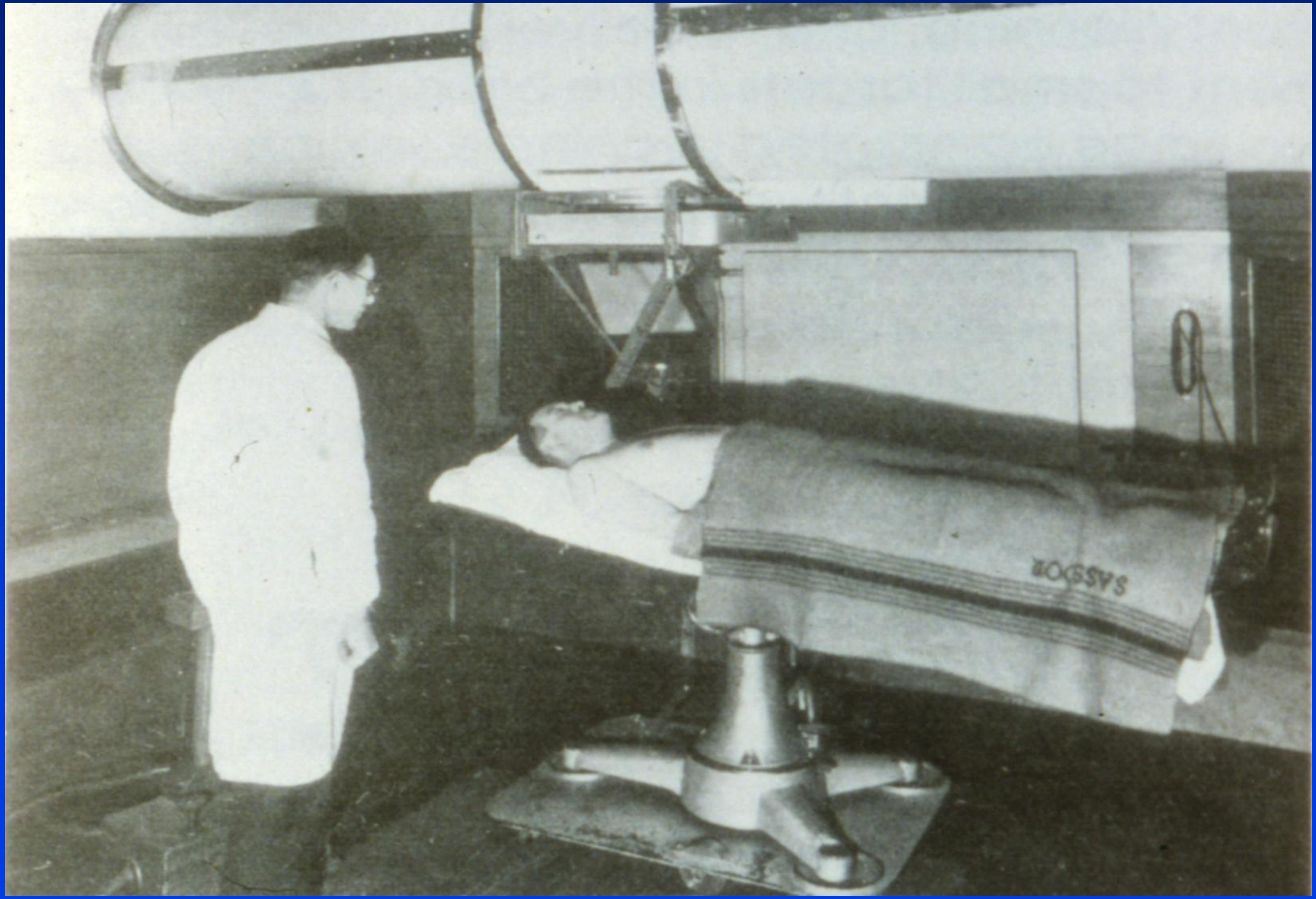
The 9 m long x-ray tube protruded through the ceiling to the treatment room above



The treatment room

Typically four patients were treated simultaneously through portals in the central tube

1936: St. Bartholomew's Hospital, London, 1 MeV x-ray machine



Van der Graff generator

- In the late 1920s, Robert Jemison Van de Graaff was a Rhodes scholar at Oxford when he conceived of the idea for an electrostatic particle accelerator capable of producing very high energies
- By 1931 he was able to produce a potential difference of 1.5 MV with a machine that cost $100 to build!!!
- Van der Graff had increased this to 7 MV by 1933

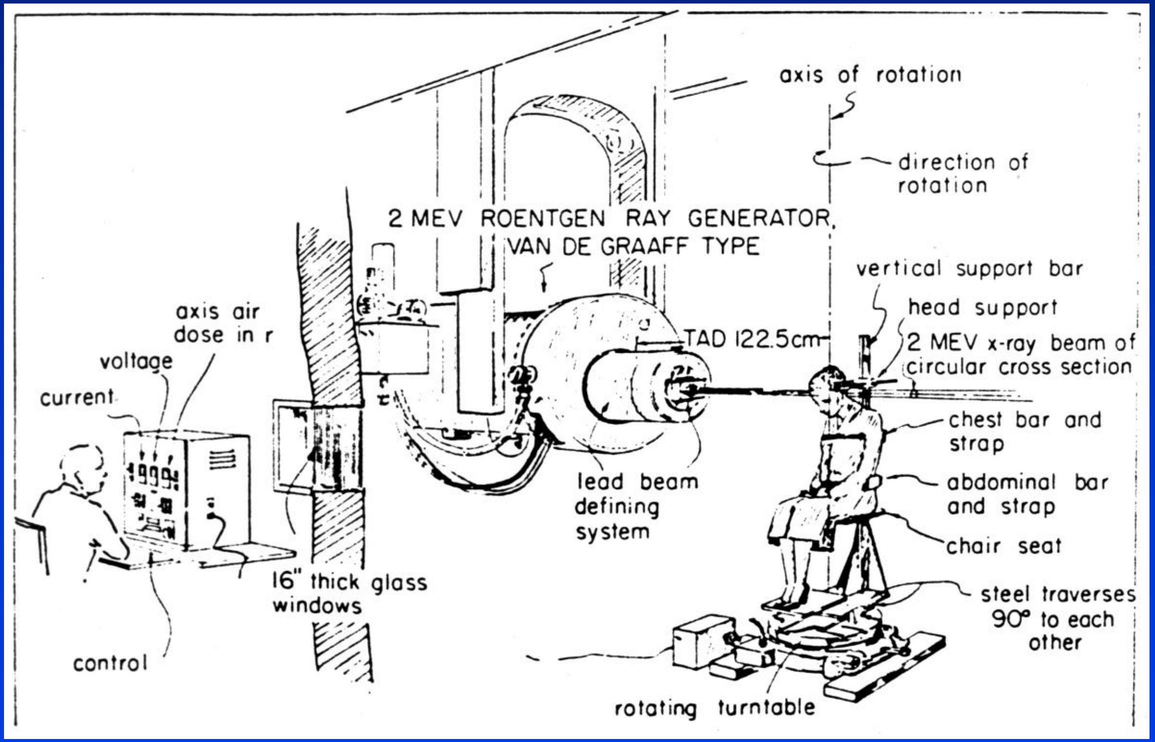
Van der Graff (1901 – 1967)

Van der Graff accelerator

1937: The first machine (1 MeV air insulated), used in radiotherapy, was installed in Boston

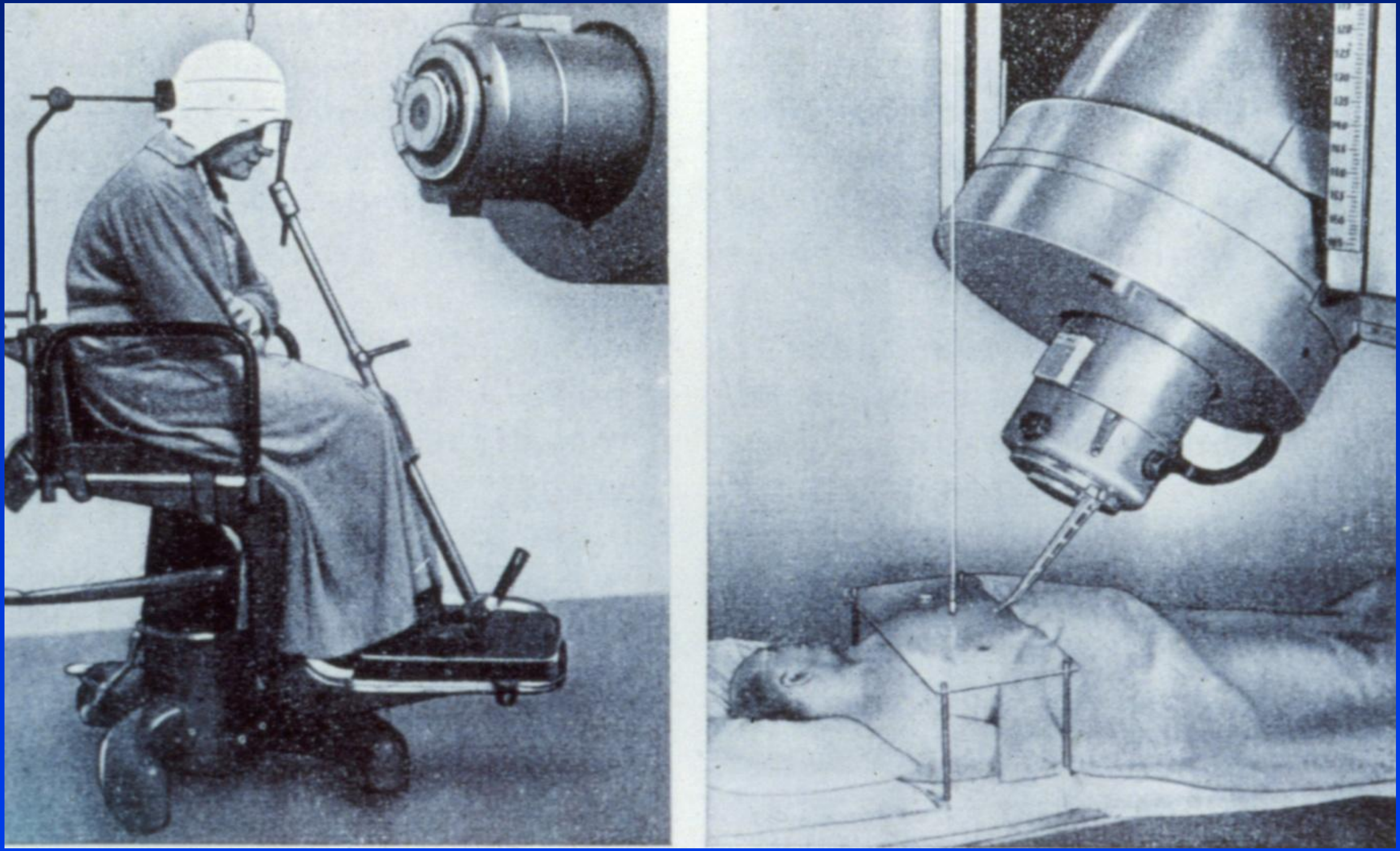
1946: High Voltage Engineering Corporation, founded by Van de Graff, began commercial production of 2-2.5 MeV machines

A total 40 such accelerators were built, until their production was discontinued in 1959



Van der Graff treatments

Rotational treatments were possible using a rotatable chair



The Betatron

- Donald Kerst built the world's first magnetic induction accelerator at the University of Illinois in 1940
- There was a competition to name it
- "*Ausserordentlichhochgeschwindigkeitelektronenentwickelndenschwerarbeitsbeigollitron*" was one of the more original entries
- Fortunately Kerst settled on “betatron”

Donald Kerst: AAPM Honorary Member

Courtesy of the Department of Physics, University of Wisconsin

D. W. Kerst.

Donald William Kerst

November 1, 1911 — August 19, 1993

By Andrew M. Sessler and Keith R. Symon

Donald Kerst and Gail Adams work on the 22 MeV University of Illinois betatron

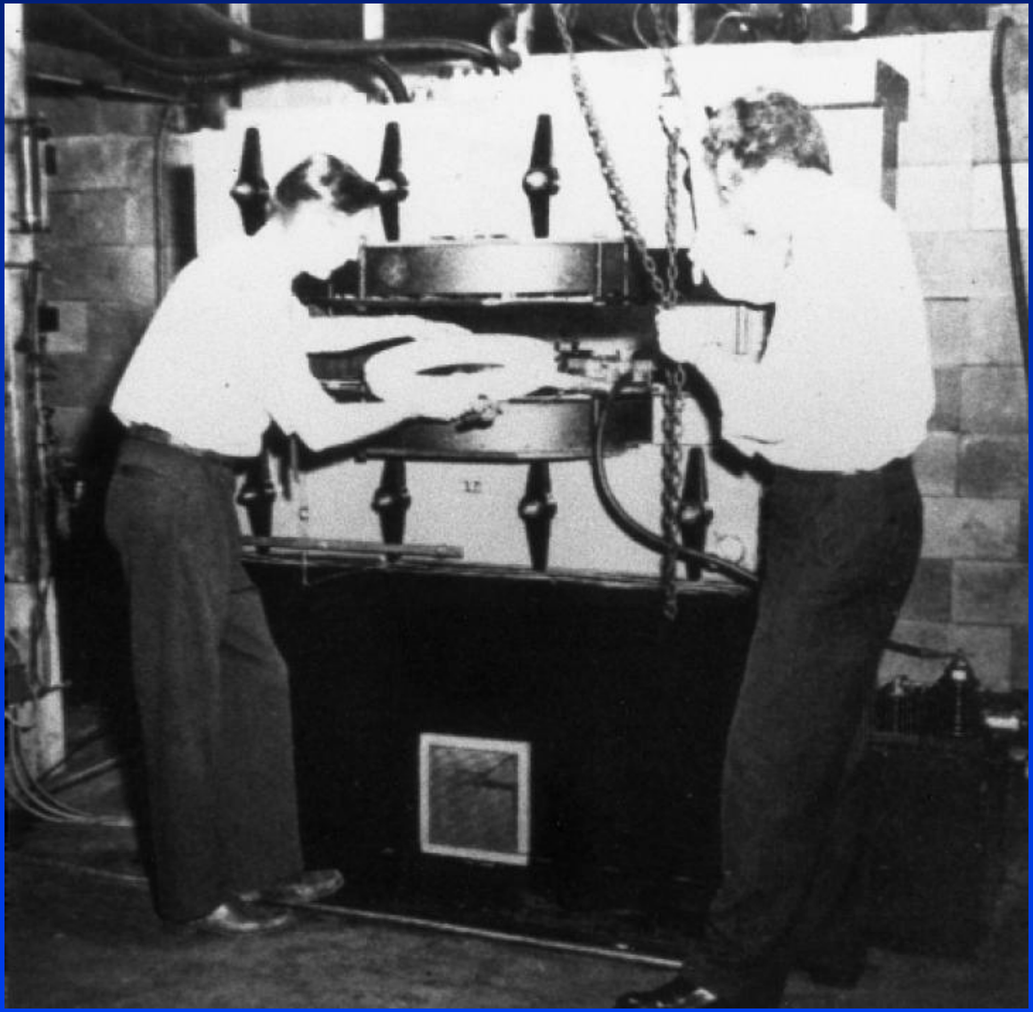
Several of our famous medical physics pioneers cut their teeth on the University of Chicago betatron

Gail Adams

Lester Skaggs

John Laughlin

Larry Lanzl



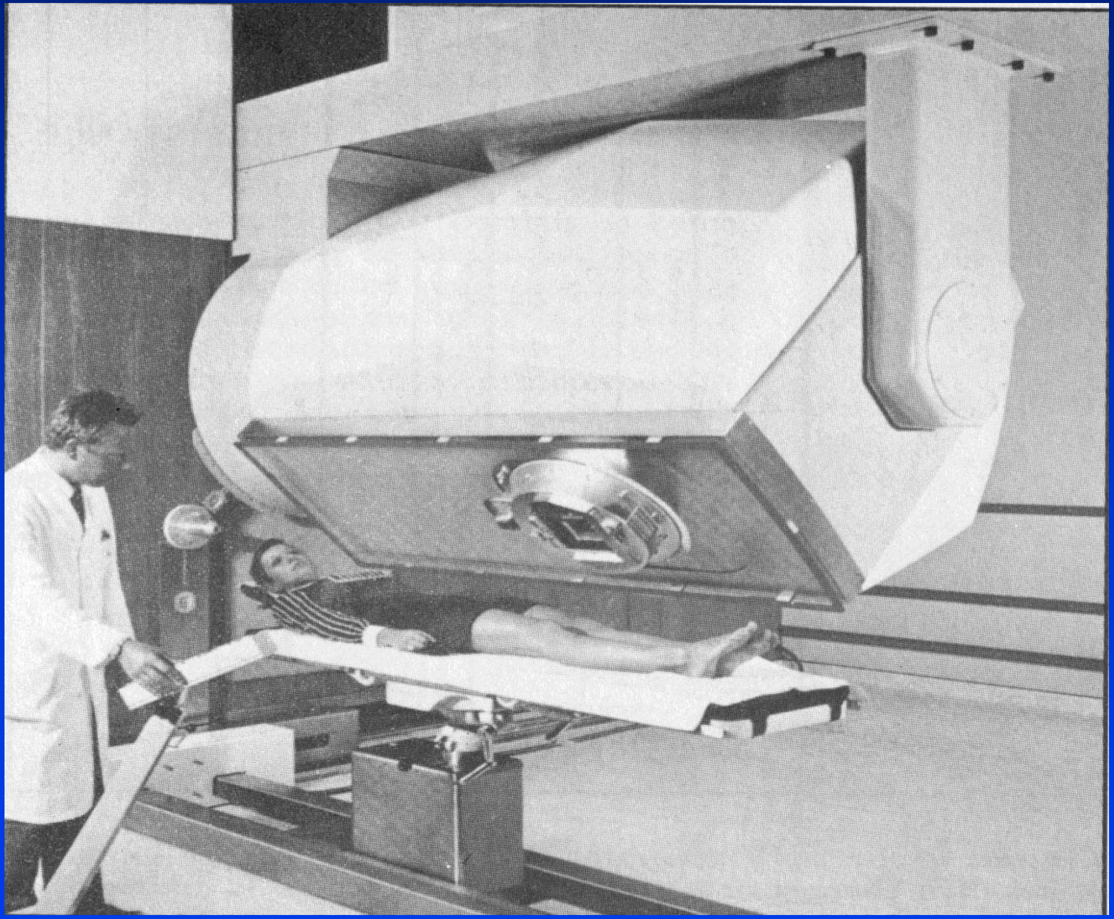
Smithsonian Institution: 1st betatron

Prof. Donald W. Kerst with the world's first betatron, built at the University of Illinois in 1940 and now in the Smithsonian Institution

1950s: The clinical betatron

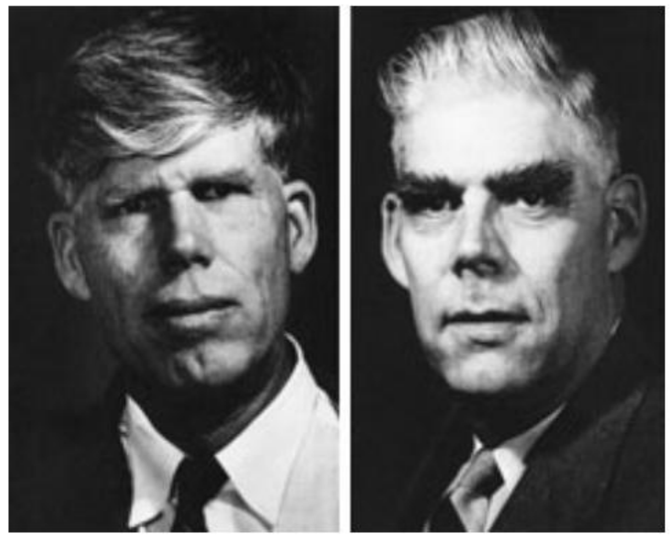
The major problem with the betatron was the very low x-ray output

Once Co-60 units became available betatrons were relegated to electron beam treatments only



Development of linear accelerators

The linac grew out of the development of the klystron and the magnetron for the generation of microwaves for radar during the 2nd World War by Russell & Sigurd Varian in Palo Alto, CA and Mark Oliphant in Birmingham, England, resp.



Russell and Sigurd Varian (photographs by Ansel Adams)

Sir Mark Oliphant

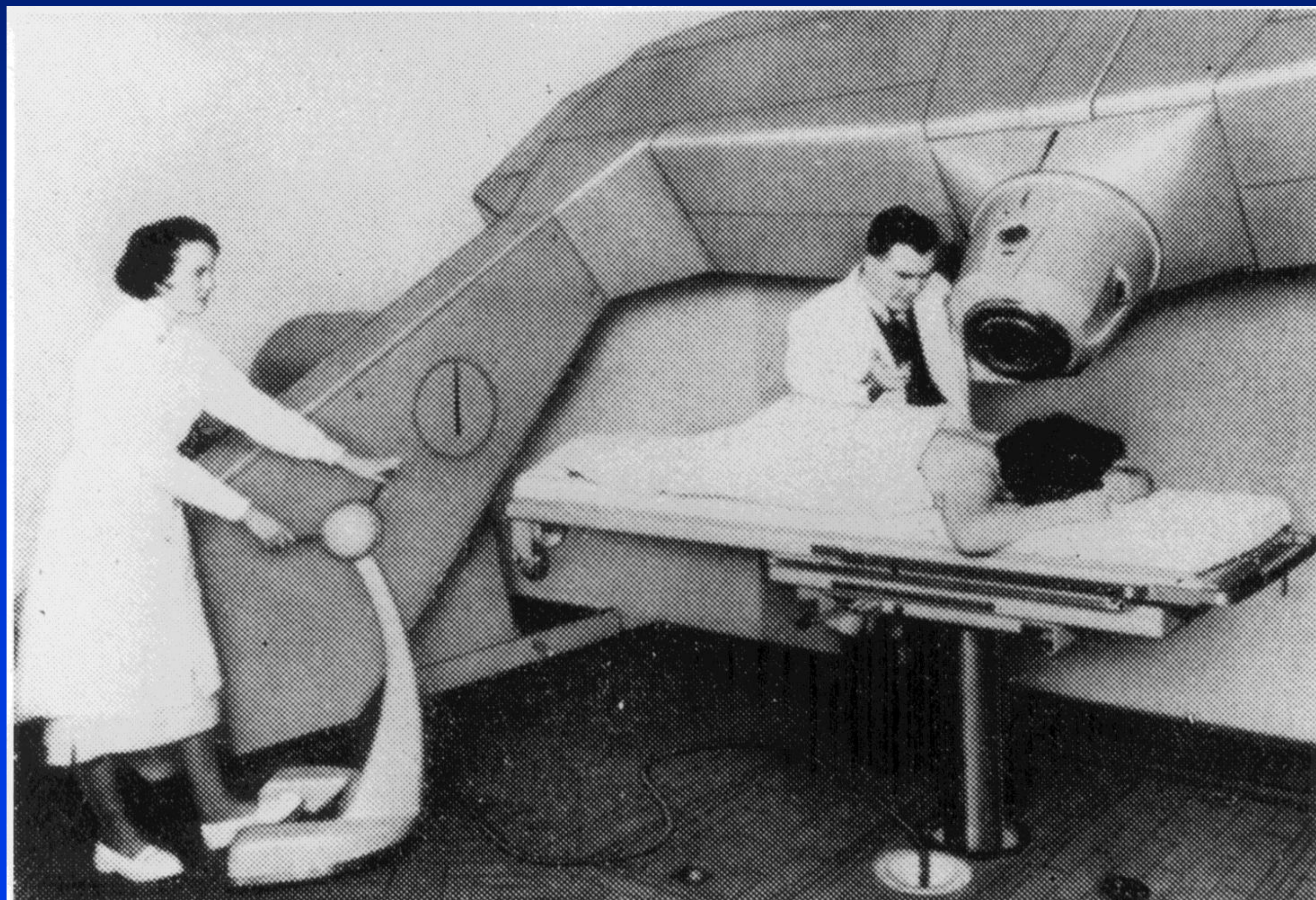
Medical linacs

- In the USA, Henry Kaplan realized the potential of linacs for radiotherapy
- He worked with Edward Ginzton to design a medical linac and applied for an NIH grant to construct it, but it was disapproved
- In the UK, the British Atomic Energy Research Establishment designed a medical linac and contracted with the Metropolitan Vickers Electrical Company to build it

1st medical linacs

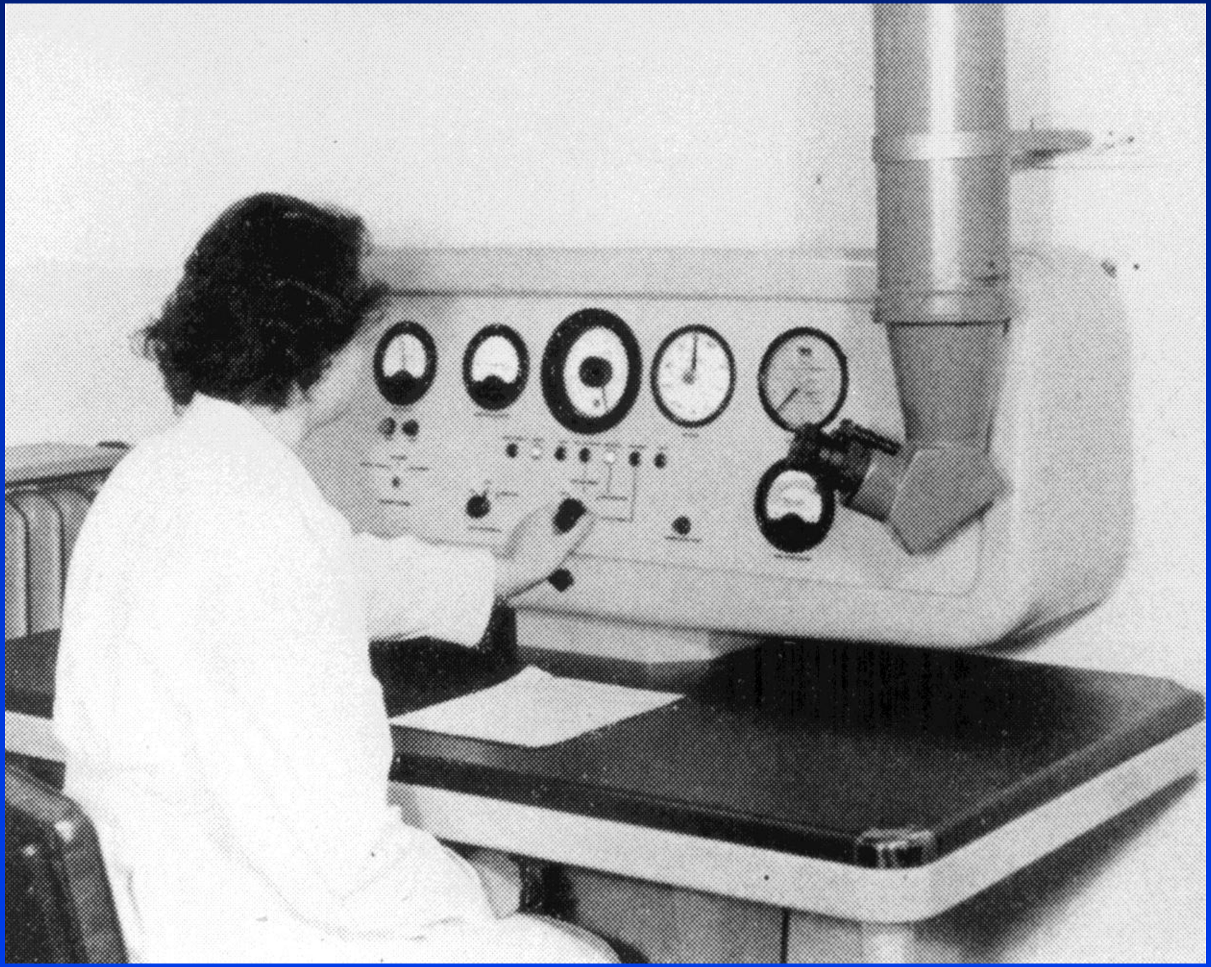
- The 1st therapy linac was an 8 MeV stationary machine built by Metropolitan Vickers and installed at Hammersmith Hospital, London, with the 1st patient treated on 19 August, 1953
- Later that year, a 4 MeV isocentric machine was installed by Mullard Research Laboratories at the Newcastle General Hospital

1953: Newcastle General Hospital isocentric 4 MeV linac



Control desk

Note that a submarine periscope was used to see the patient

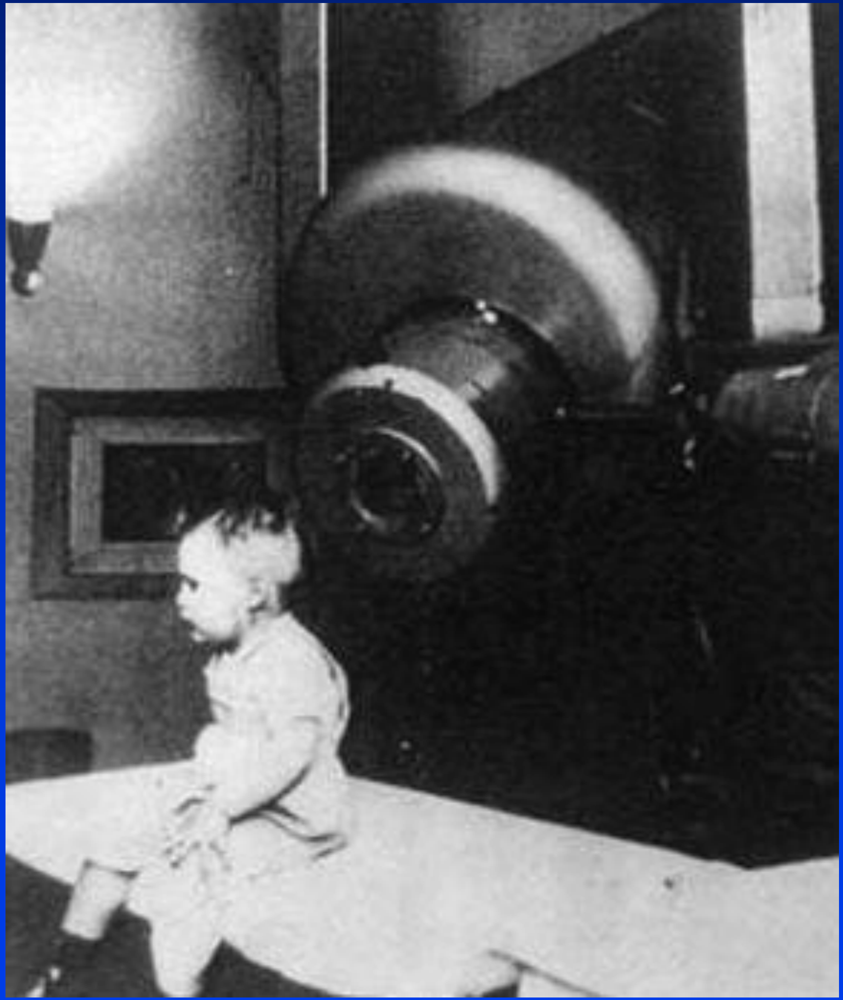


Varian linear accelerators

Edward Ginzton and Bill Hansen worked with the Varian brothers to build a 6 MeV linac at Stanford University for Henry Kaplan

1st patient treated in the USA (January, 1956)

A 7 month old boy was the 1st patient treated by Dr. Kaplan (for retinoblastoma)



1968: birth of the modern era of radiotherapy

This was the year Varian released the Clinac 4, which would gradually replace Co-60 units and become the workhorse of therapy in the USA in the 1970s