A HISTORY OF DIAGNOSTIC IMAGING

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Wilhelm Roentgen

Nov 8th 1895

The discovery of x-rays

- 1895 Wilhelm Roentgen professor of physics in Wurzburg
- Nov 8th working with cathode rays and noted fluorescence on a barium platinocyanide screen plus fogging of photographic plates at a distance, when the tube was shrouded
- He speculated that a new kind of ray might be responsible

Roentgen

- He named the new rays temporarily as x-Rays[unknown]
- Within two weeks he had taken an x-ray picture of his wife's[Anna Bertha] hand
- Roentgens original paper was published 50 days later on the 28th of December 1895

This is a picture of the first x-ray ever taken and is of Roentgens wife

Early x-rays

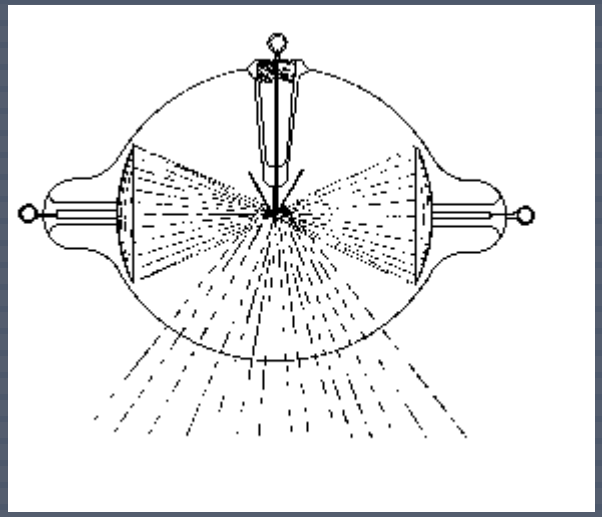
- Within three months of the description by roentgen there was a machine that could produce x-rays installed in almost every city in Europe.
- The earliest published description in the UK was in the BMJ in 1896 when a cavalry subaltern had come off his horse and injured his elbow. Examination was difficult but an x-ray indicated only a dislocation with no fracture

Roentgen

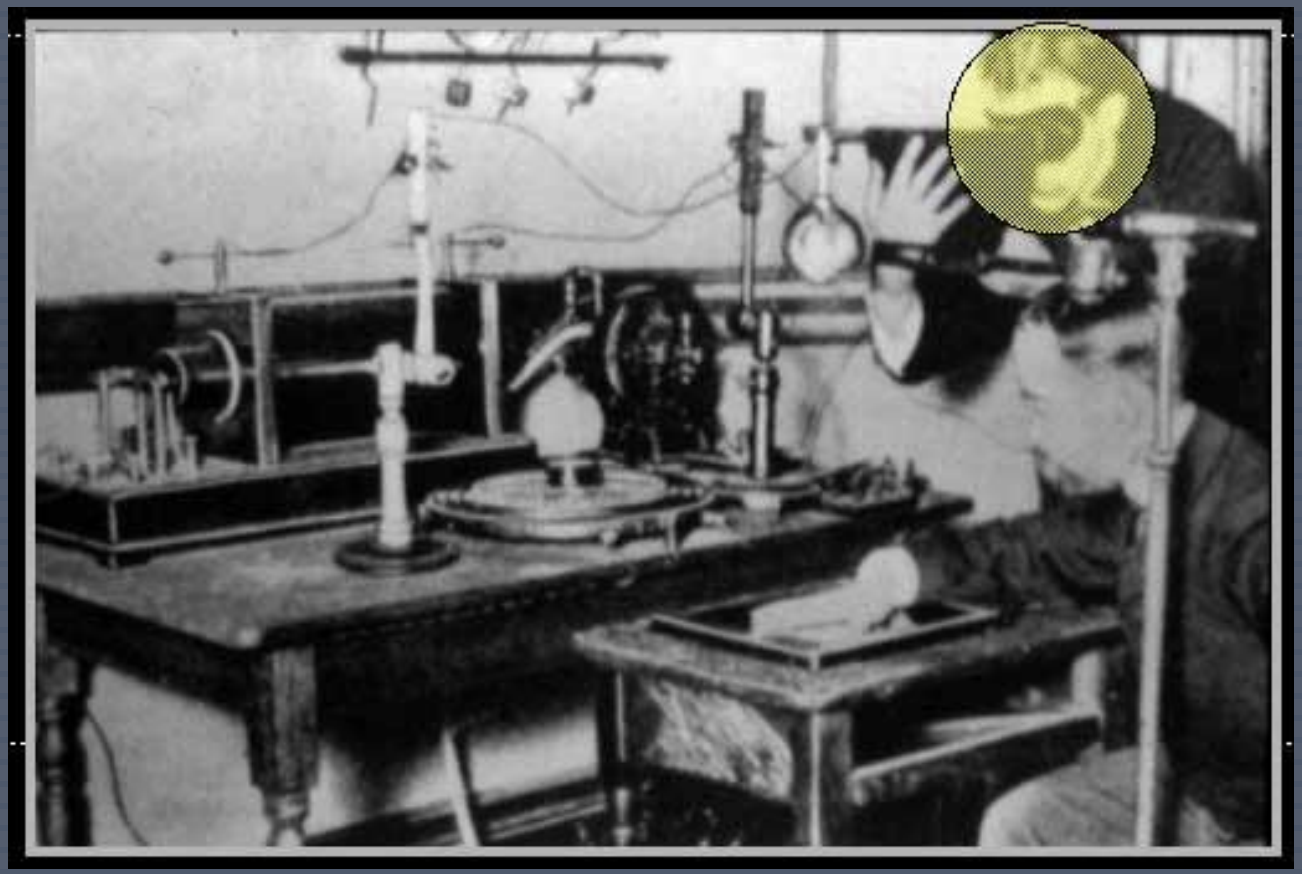
- Roentgen was expelled from high schoolbecause he would not reveal which of his colleagues had drawn an unflattering caricature of one of the teachers
- As a result he could not finish schooling in Germany or go to university there
- He finished University in Zürich
- In 1901 he was the first recipient of the Nobel Prize for physics for the discovery of x-rays

Radiation dangers

- By 1896 x Ray dermatitis was already common in practitioners
- By 1903 most early practitioners had radiation injuries with many dying within five years progressive bone injuries and malignancies
- Protection around tubes was not used at that time
- By 1921 these dangers had been well-recognized and standards of exposure and protection at work were gradually introduced



Early x-rays



An x-ray is about
To be taken
Note how the
operator is
testing whether
Equipment is
In working order
By placing his own
hand In the x-ray
beam and examining
it with a fluoroscopy
Screen
Little wonder that
X-ray damage to the
hands was endemic
In early practitioners

Early x-rays

Caricatures like this were Frequent In the early post-discovery Time particularly lampooning Prussians as this was a time of significant international Tension and dispute

Early x-rays

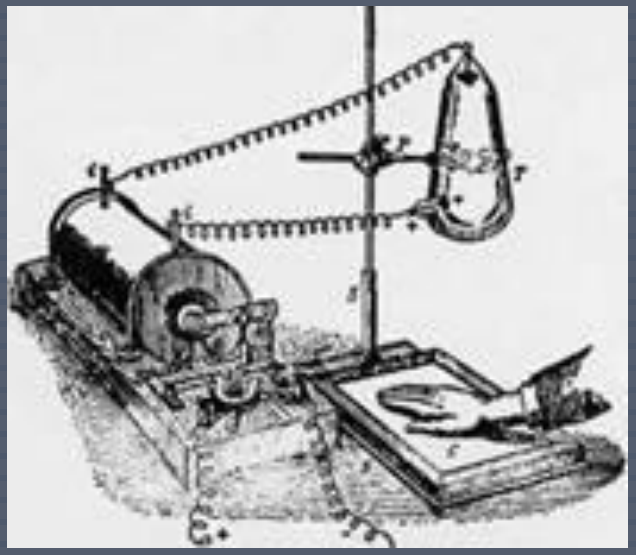
Some of the earliest applications
of x-rays were in fair grounds
And similar attractions as
Curiosities to amuse the public
Initially x-rays were used
Freely and indiscriminately
This practice was continued to
a lesser extent until the 1950s
When they were used to look
At the feet with a new shoes to
examine the fit

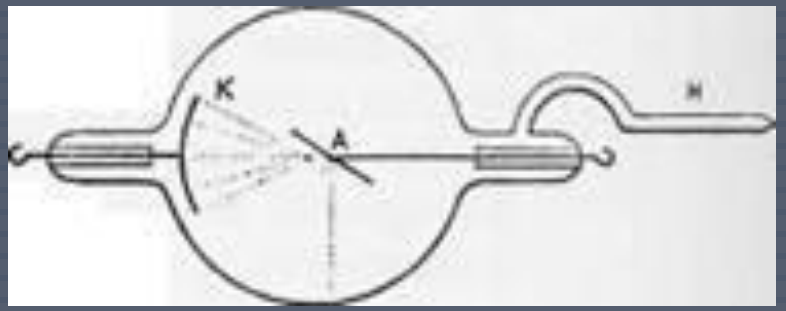
Early x-rays

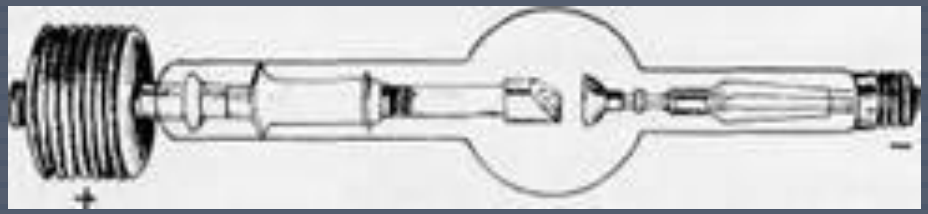
Note in this picture that the eyes of the operator are in the direct line of the x-ray entering through the patients back

X ray source

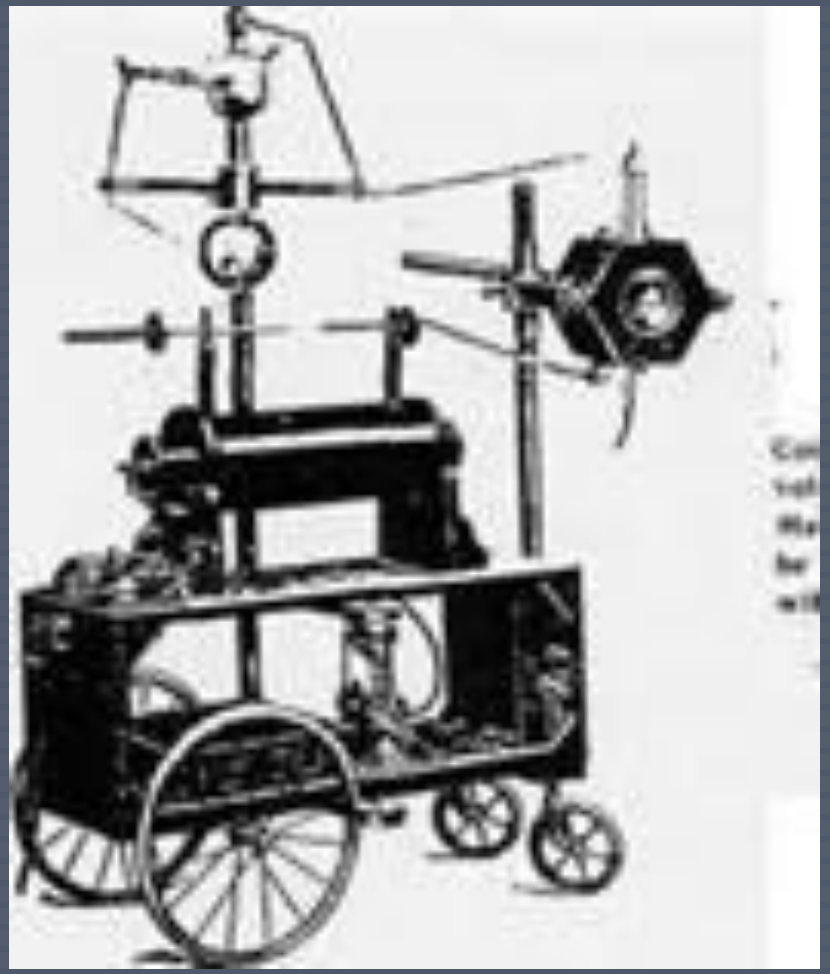
A variety of x-ray tubes



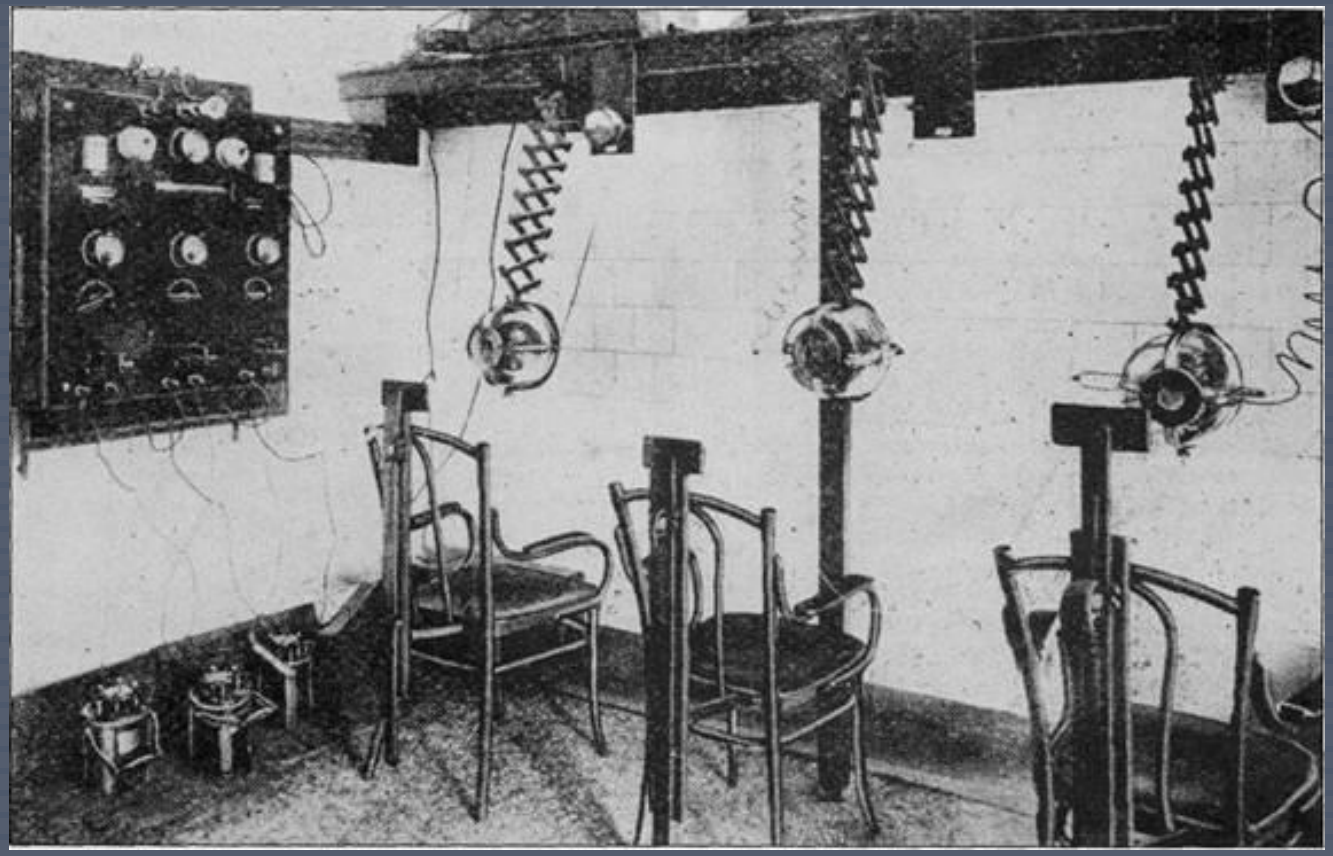




1896 an x-ray of a foot being performed



An early mobile x-ray apparatus to take x-rays on ward of inpatients



The London hospital 1896.Treatment of scalp ringworm

Early x-rays

- Initial radiographs were made on to glass photographic plates coated with emulsion which used to slip off so the job of the junior was to wax the margins of the plates to prevent this
- Film was introduced in 1918 but the celluloid was very inflammable and the Cleveland clinic caught fire and 129 people died in the early 1920s which was the direct stimulus to move to non inflamable but more expensive film media

Early x-rays

- For the first 50 years of x-rays image was focused on to film.
- In the early days a skull film would take 11 minutes to expose and a chest x-ray on a young girl in 1896 took 30 minutes
- Current exposures are much less [as little as 2% of the exposure of 100 years ago]
- Currently film is bracketed by light-sensitive screens to improve film sensitivity. The fluoresence of the screens primarily exposes the film rather than the x rays

Early x-rays

- It was not until the invention of the Coolidge tube in 1913 that predictable results were obtained from x-ray tubes
- It introduced a reliable vacuum and safer electric connections plus cooling
- The risk of electrocution with early tubes was high

Early x-rays

- One of the earliest obstacles to the acceptance of x-rays was in physicians of that time who found it hard to accept that an abnormality could exist when it was not clinically apparent and could only be seen radiographic
- Any change now

Contrast medium

- The first “safe” contrast was used in bronchi and was a mixture of iodine and poppy seed oil used in bronchi
- Iodinated compounds emerged which could visualize blood vessels and other organs
- Barium was used for the G.I. Tract because it is so insoluble that despite it being highly poisonous none of it was absorbed and it was very dense to x-rays first used in Vienna in 1904

Vascular catheterization

- The first person to catheterise the heart was Claude Bernard who stuck a thermometer through the carotid artery of a horse through the aortic valve and into the left ventricle and continued using this technique for the next 40 years.
- The first person to catheterise a human heart was a Werner Forssmann a junior urologist in 1929

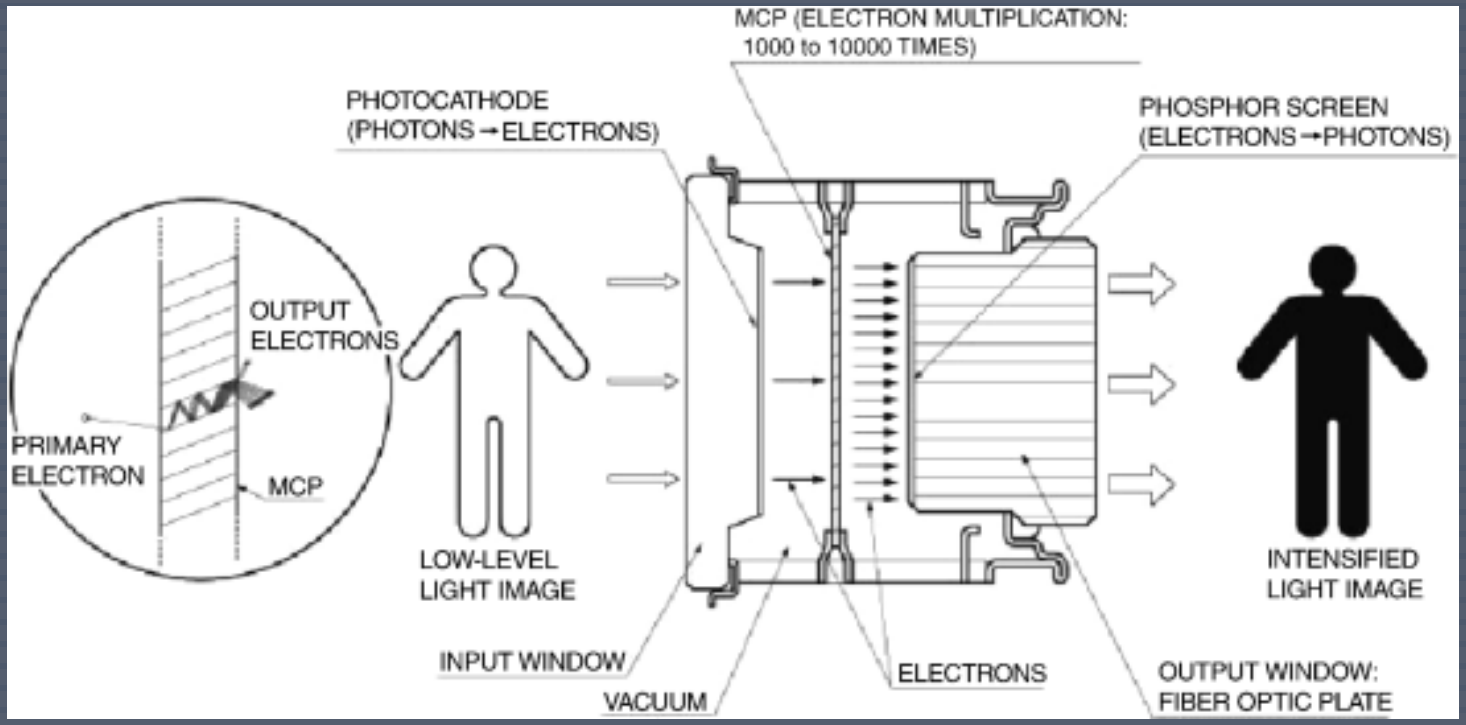
Heart catheterization

- Forssman disected his own antecubital fossa veins with a mirror and inserted a ureteric catheter which he pushed proximaly using the veins to take it to the heart. He had first tied his assistant to the operating table to prevent him interfering.
- He then walked to the x-ray department to take an x-ray to confirm this.
- In return for this innovative approach he was dismissed from his post but shared the Nobel Prize for medicine in 1956

Image intensifiers

- in the 1950s image intensifiers and television displays and television cameras fundamentally changed flouroscopy
- Radiologist looked at the television not directly a screens on which x-rays impinged
- Together with cut film changers this development allowed angiography to flourish

Schematic of how a imaging intensifier works



Angiography

- Radiologists learnt to use the blood vessels as conduits around the body to reach organs via their blood inflow and also saw some reflection of disease pathologies in solid viscera
- Blood vessels can be used as an access to many organ systems using contrast with image intensifiers during angiography

Therapeutic angiography

- The first vessel dilation's were carried out by Charles Dotter in Portland, Oregon using coaxial vessel dilations(**Charles Theodore Dotter** (1920-1985) was a vascular radiologist who is generally credited with developing interventional radiology)
- Problematic to do but some effectiveness
- Andreas Gruntzig developed a balloon on the end of a catheter which could be expanded at a site of stenosis which can improve vessel diameter substantially and consistently building on work of Dotter
- This was the first true useful method of therapeutic vascular intervention

And expandable balloon is glued to
a smallbore catheter
This is maneuvered into the site of
Stenosis and expanded
The vessel is overexpanded but the result
Is an improvement in diameter of narrowed
portion

the first angioplasty in a patient
carried out in 1977 in LAD of the
heart

Beginning of the Modern Era of Radiology

- Nuclear medicine first carried out in the 1950s introduces low level radioactive chemicals into the body which are metabolised and incorporated into functioning body areas therefore this is the first true molecular imaging technique
- Multiple sophisticated techniques are now utilize including pet scanning

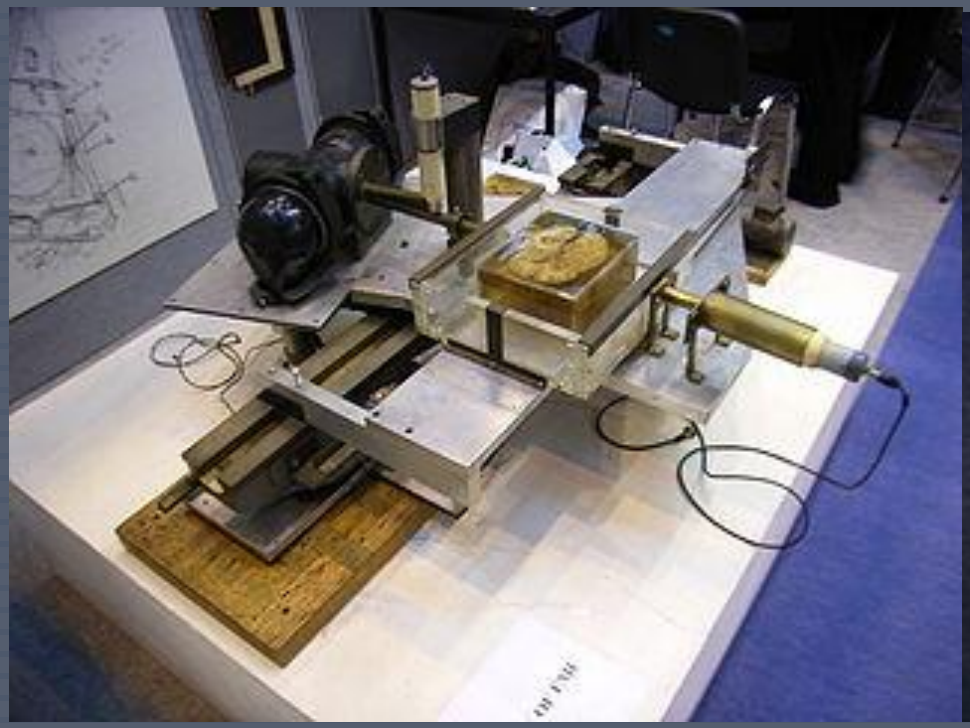
Ultrasound scanning

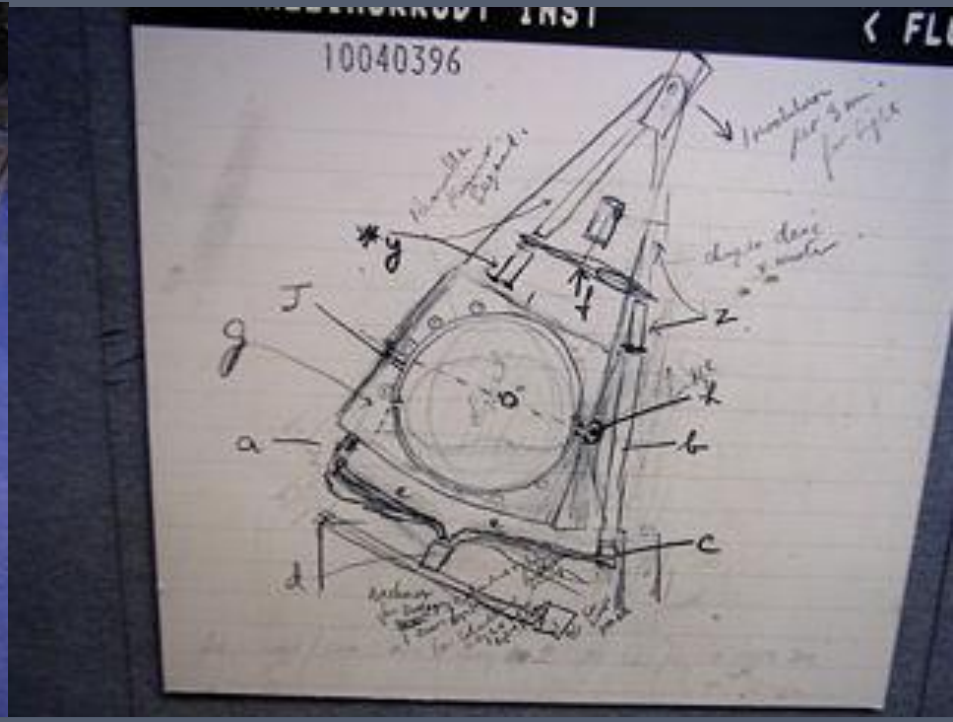
- Sonar was developed during the second world war
- In the 1960s these principles were applied to diagnostic imaging
- Continuous development has happened since then with continuous improvements in image quality

Cross-sectional imaging

- The principles of CT were first described by Godfrey Hounsfield in the first EMI scanner was installed at the Atkinson Morley hospital [neuro] in 1972
- While on an outing in the country, Hounsfield came up with the idea that one could determine what was inside a box by taking X-ray readings at all angles around the object and by measuring densities at multiple sites work out the densities of materials inside the box

This is the original diagrammatic representation Hounsfield created and below is the first prototype taking an image of a preserved human brain





Cross-sectional imaging

- The principles Hounsfield developed for the first CT scanner revolutionized radiology forever, the greatest discovery in imaging since Roentgen
- This development also for the first time integrated computers and imaging equipment
- For the first time the image was not the result of x-rays impinging on a light-sensitive material but was calculated from measured densities and an image created using pixel densities on the screen

Cross-sectional imaging

- The original EM I scanner only worked on brains because of the size of the gantry
- By 1975 Hounsfield had built a prototype that could scan any body area
- A different era of imaging had begun taking radiology from darkened rooms into the forefront of patient management in all areas
- Hounsfield received the Nobel Prize for medicine in 1979 for his work on CT

Radiation dosage

Recommended national reference doses for complete examinations on adult patients

Examination	DAP per exam (Gy cm ^{2})	Fluoroscopy time per exam (mins)
Barium (or water soluble) swallow	11	2.3
Barium meal	13	2.3
Barium follow through	14	2.2
Barium (or water soluble) enema	31	2.7
Small bowel en	50	10.7
Biliary drainage/intervention	54	17
Femoral angiogram	33	5.0
Hickman line	4	2.2
Hysterosalpingogram	4	1.0
IVU	16	-
MCU	17	2.7
Nephrostogram	13	4.6
Nephrostomy	19	8.8
Retrograde pyelogram	13	3.0
Sialogram	1.6	1.6
T-tube cholangiogram	10	2.0
Venogram (leg)	5	2.3
Coronary angiogram	36	5.6
Oesophageal dilation	16	5.5
Pacemaker implant	27	10.7

Radiation dosages

Radiograph	ESD per radiograph (mGy)	DAP per radiograph (Gy cm ^{2})
Skull AP/PA	3	-
Skull LAT	1.5	-
Chest PA	0.2	0.12
Chest LAT	1.0	-
Thoracic spine AP	3.5	-
Thoracic spine LAT	10	-
Lumbar spine AP	6	1.6
Lumbar spine LAT	14	3
Lumbar spine LSJ	26	3
Abdomen AP	6	3
Pelvis AP	4	3

Radiation dosages: middle column expresses dosages in comparison to how many chest x-rays could be done with this amount of radiation

Chest x ray (PA film)	0.02	1	2.4 days
Skull x ray	0.07	4	8.5 days
Lumbar spine	1.3	65	158 days
I.V. urogram	2.5	125	304 days
Upper G.I. exam	3.0	150	1.0 year
Barium enema	7.0	350	2.3 years
CT head	2.0	100	243 days
CT abdomen	10.0	500	3.3 years

MRI

- MRI has become the primary diagnostic technique in many areas of the body frequently improving on CT results and is not associated in any ionizing radiation
- The MR image is based on multiple tissue parameters which can alter tissue contrast

MRI

- N M R. spectroscopy of chemicals and substances has been utilized since 1948 [Nobel Prize for physics 1952 Bloch and Purcell) and became a vital technique for nondestructive analysis of small samples
- In the late 60s and early 70s Damadian observed that tumor tissue had different relaxation times to other tissues. He has remained a controversial figure in MR but his observations were one of the main sources of impetus to the introduction of MR into medicine

MR imaging

- 1973 short paper in nature :Image formation by induced local interaction, examples employing magnetic resonance by Paul Lauterbur [Professor of Chemistry Stoney Brooke State University of New York]
- This short apparently insignificant paper describing new imaging technique which he called zeugmatography (zeugma=yoke)
- Joining a week gradient field with a strong main magnetic field allowing spatial localization of material

MRI

- Methods used in CT were used to provide images by back projection
- The advances in the technology of MR have continued from that day and have not yet finished
- MR is unrecognizable now from the technique that was originally introduced and because it is sensitive to multiple different tissue parameters a huge range of different types of imaging may be carried out varying from vessel angiography to parenchymal imaging to quantitative data of tissue using chemical spectra to measuring Brownian motion within tissues and so on

MRI

- Lauterbur attempted to patent his discovery in terms of how the image using MR
- Stoney Brooke University where he worked were not sufficiently interested to follow this up and felt that it would cost far too much money to put the whole process into place
- This is possibly one of the worst ever University hierarchy decisions recorded in our annals
- They should now be known as Stony Broke
- Mansfield who shared the Nobel Prize with Lauterbur in 2003 obtained several patents and retired a wealthy man

Lauterbur was awarded the Nobel along with Mansfield in the fall of 2003. Controversy occurred when Raymond Damadian took out full-page ads in *The New York Times*, *The Washington Post* and *The Los Angeles Times* headlined "The Shameful Wrong That Must Be Righted" saying that the Nobel committee had not included him as a Prize winner alongside Lauterbur and Mansfield for his early work on the MRI. Damadian claimed that he discovered MRI and the two Nobel-winning scientists refined his technology. *The New York Times* published an editorial saying that while scientists credit Damadian for holding an early patent in MRI technology, Lauterbur and Mansfield conducted the work that led to present MRI technology. The newspaper pointed out a few cases in which precursor discoveries had been awarded with a Nobel, along with a few deserving cases in which it had not, such as Rosalind Franklin and Oswald Avery.[9][10]