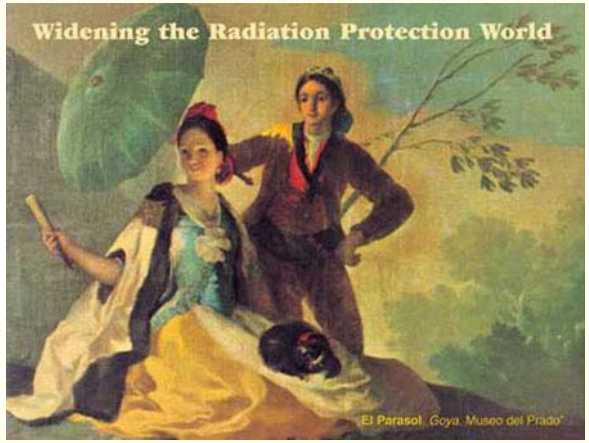
International Radiation Protection Association
11th International Congress
Madrid, Spain - May 23-28, 2004



Refresher Course

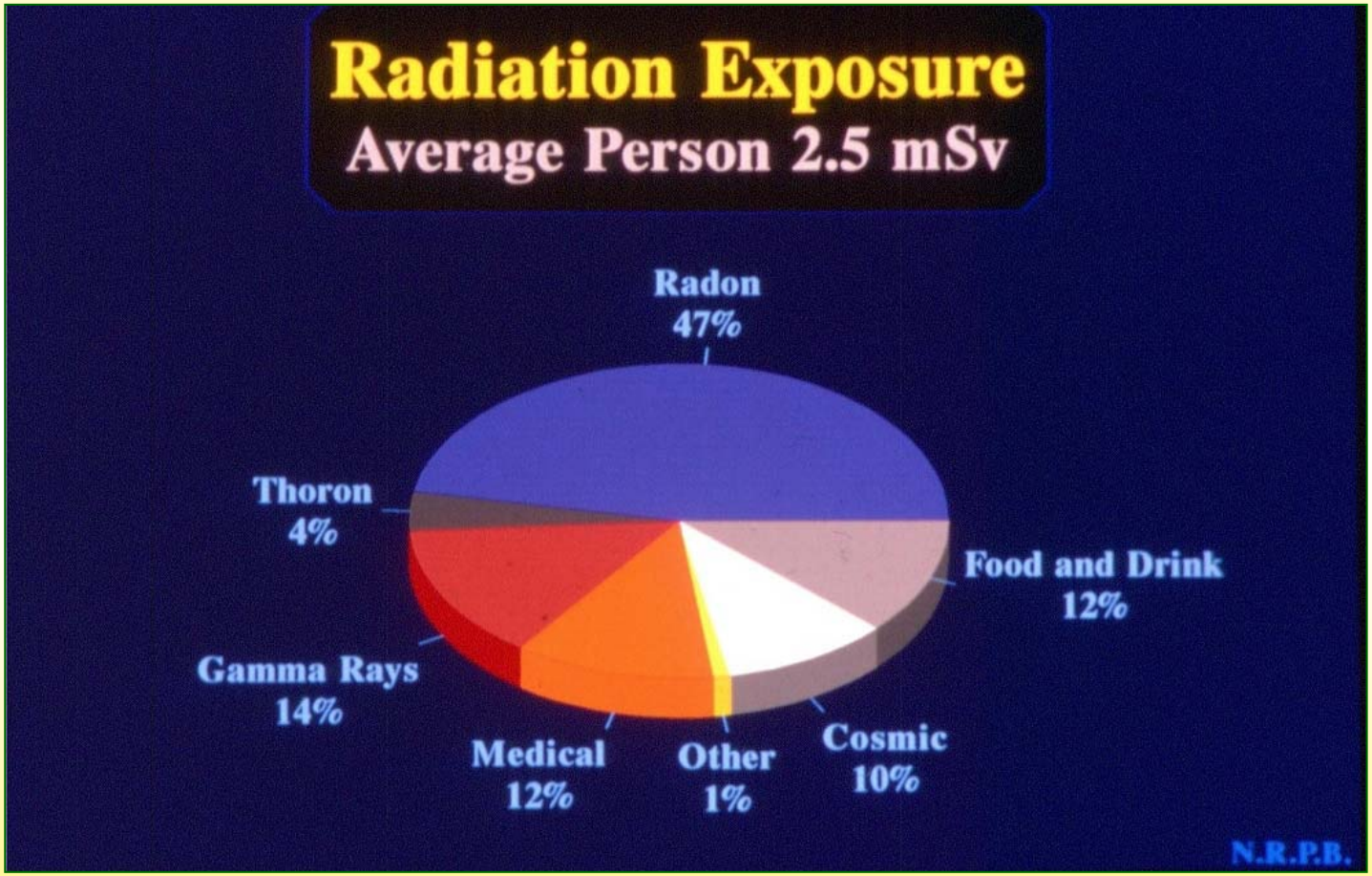
Radiation Protection in Cardiac and Interventional Procedures

C. Reek

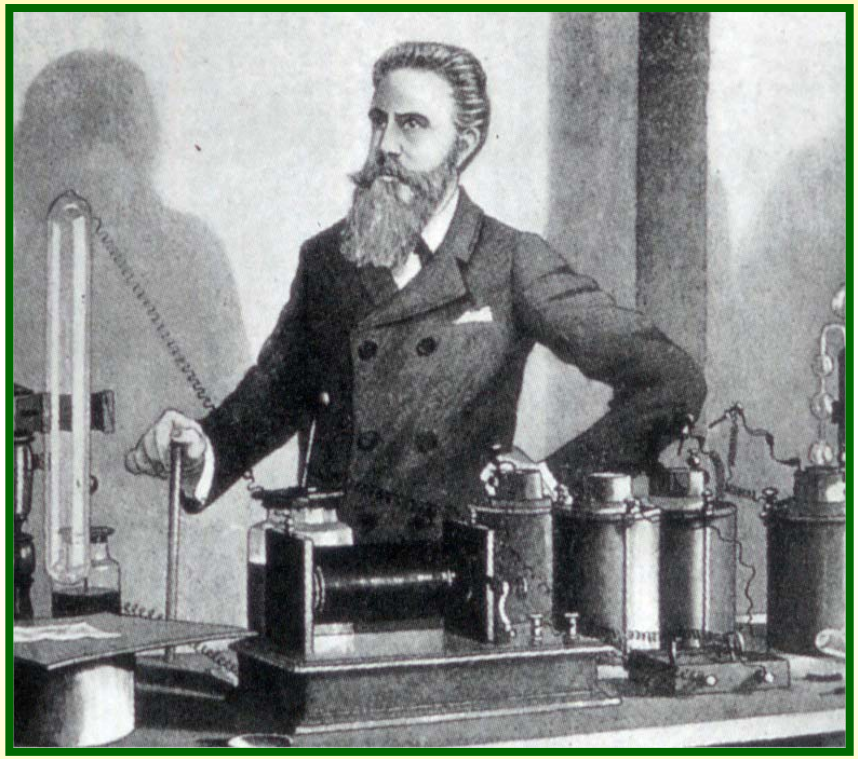
Overview

- Introduction and Background
- Regulations
- Dose
- Patient Dose Reduction-Factors
- Special Cases
- Limitation of Staff Dose
- Good Practice
- Recommendations

Sources of Radiation



November 8th 1895

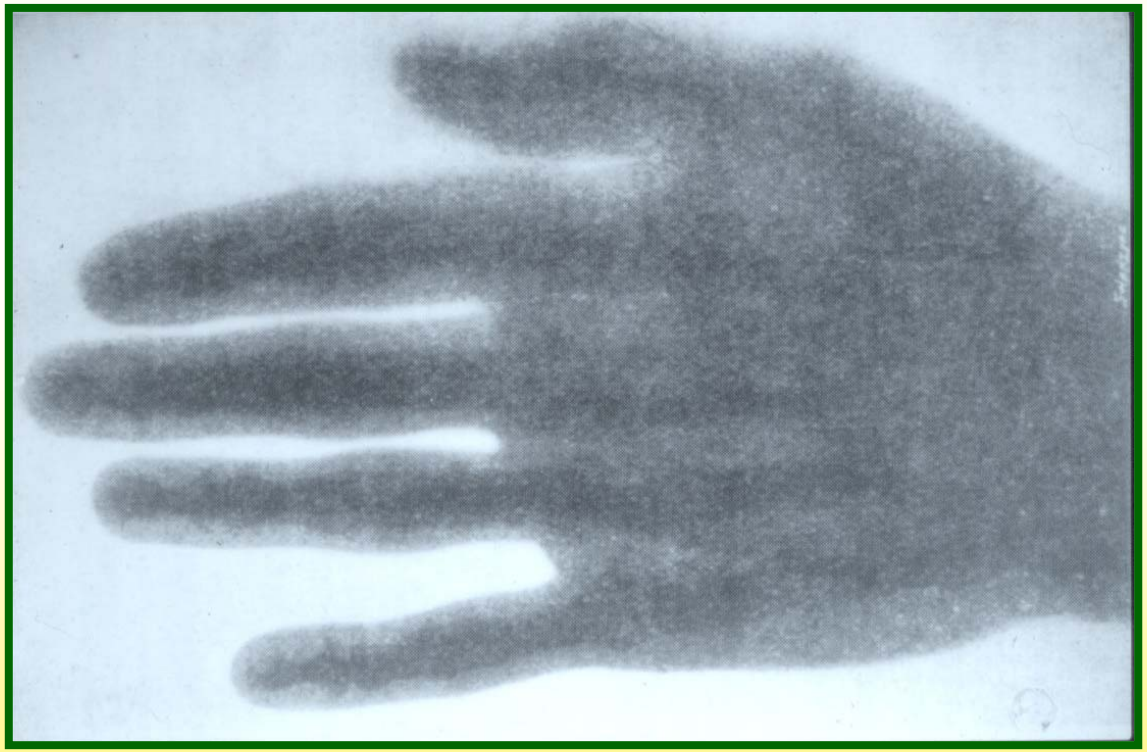


Wilhelm Conrad Röntgen

- 23rd January 1896
- Public lecture on X rays
- Hand of von Kolliker

First British Radiographs

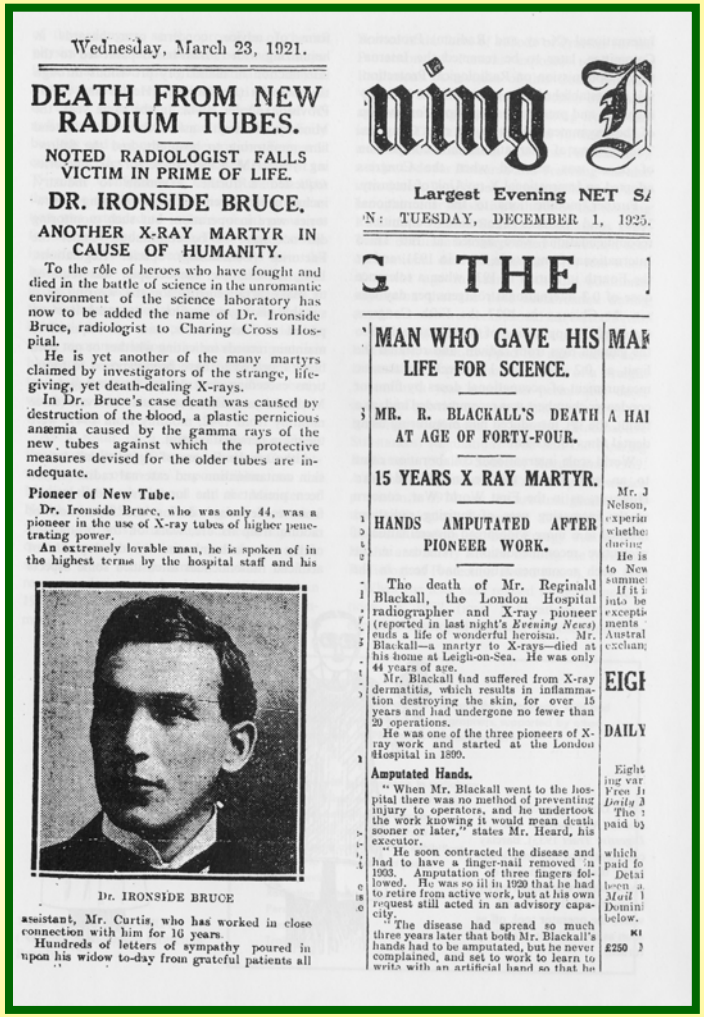
- 25th January 1896
- BMJ Alan Campbell Swinton



British Medical Journal 18th April 1896

- First published report of the dangers of X rays

1921



Wednesday, March 23, 1921.

DEATH FROM NEW RADIUM TUBES.

NOTED RADIOLOGIST FALLS VICTIM IN PRIME OF LIFE.

DR. IRONSIDE BRUCE.

ANOTHER X-RAY MARTYR IN CAUSE OF HUMANITY.

To the rôle of heroes who have fought and died in the battle of science in the unromantic environment of the science laboratory has now to be added the name of Dr. Ironside Bruce, radiologist to Charing Cross Hospital.

He is yet another of the many martyrs claimed by investigators of the strange, life-giving, yet death-dealing X-rays.

In Dr. Bruce's case death was caused by destruction of the blood, a plastic pernicious anæmia caused by the gamma rays of the new tubes against which the protective measures devised for the older tubes are inadequate.

Pioneer of New Tube.

Dr. Ironside Bruce, who was only 44, was a pioneer in the use of X-ray tubes of higher penetrating power.

An extremely lovable man, he is spoken of in the highest terms by the hospital staff and his

Dr. IRONSIDE BRUCE

aseistant, Mr. Curtis, who has worked in close connection with him for 16 years.

Hundreds of letters of sympathy poured in upon his widow to-day from grateful patients all

wing D

Largest Evening NET S/

N: TUESDAY, DECEMBER 1, 1925.

G THE

MAN WHO GAVE HIS LIFE FOR SCIENCE.

MR. R. BLACKALL'S DEATH AT AGE OF FORTY-FOUR.

15 YEARS X RAY MARTYR.

HANDS AMPUTATED AFTER PIONEER WORK.

The death of Mr. Reginald Blackall, the London Hospital radiographer and X-ray pioneer (reported in last night's *Evening News*) ends a life of wonderful heroism. Mr. Blackall—a martyr to X-rays—died at his home at Leigh-on-Sea. He was only 44 years of age.

Mr. Blackall had suffered from X-ray dermatitis, which results in inflammation destroying the skin, for over 15 years and had undergone no fewer than 20 operations.

He was one of the three pioneers of X-ray work and started at the London Hospital in 1899.

Amputated Hands.

"When Mr. Blackall went to the hospital there was no method of preventing injury to operators, and he undertook the work knowing it would mean death sooner or later," states Mr. Heard, his executor.

"He soon contracted the disease and had to have a finger-nail removed in 1903. Amputation of three fingers followed. He was so ill in 1920 that he had to retire from active work, but at his own request still acted in an advisory capacity.

"The disease had spread so much three years later that both Mr. Blackall's hands had to be amputated, but he never complained, and set to work to learn to write with an artificial hand so that he

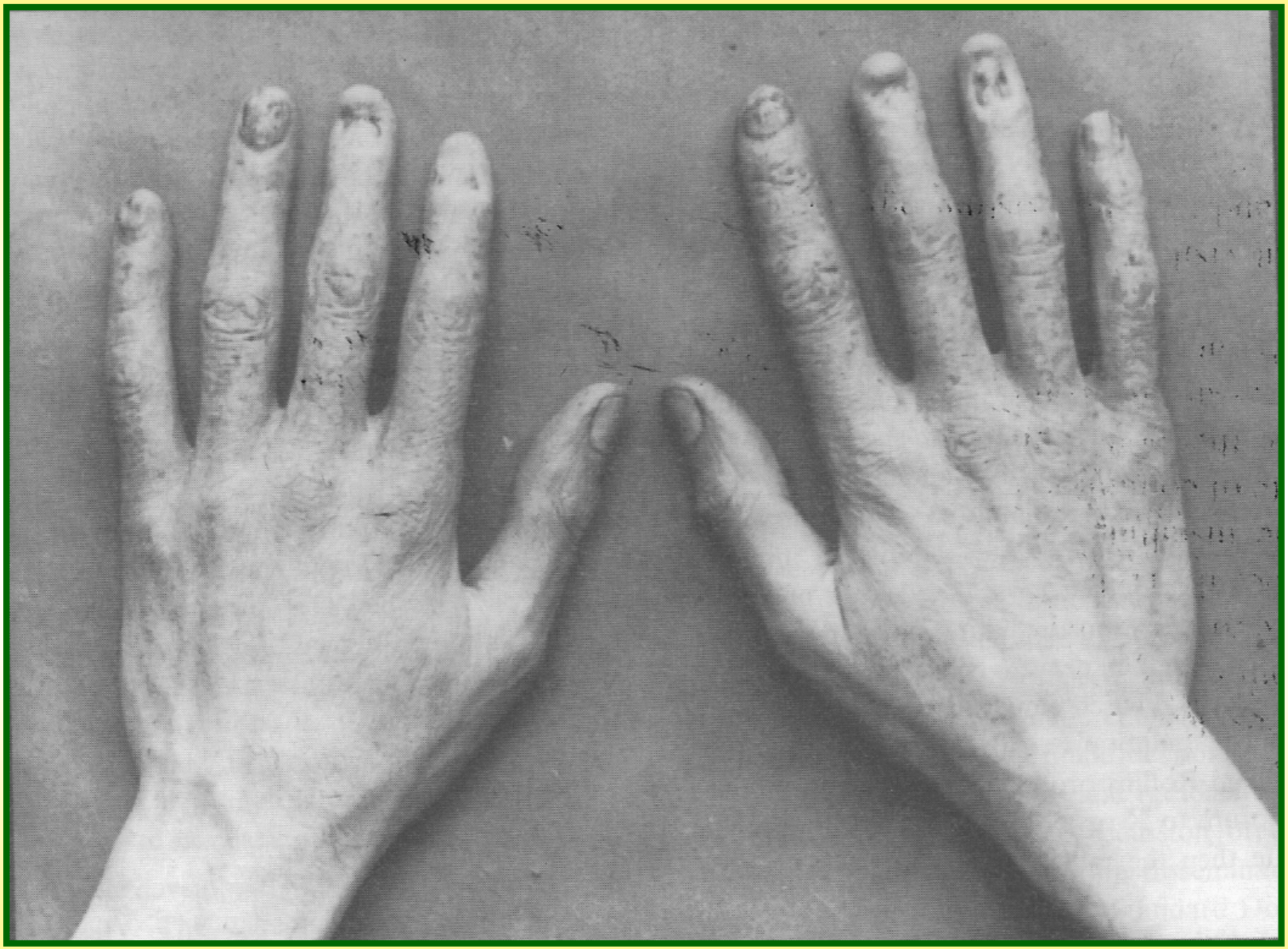
- Deaths attributed to X rays
- No regulations prior to 1928

Stochastic (Random) Effects

Smoking 10 cigarettes/day	1 in 200
Natural causes (40 yr old)	1 in 850
Accidents on road	1 in 9500
Accidents at work	1 in 43,500
Cancer from radiation exposure of 1 mSv	1 in 25,000
Majority of NHS staff (<0.3mSv/yr)	1 in 83,333

Deterministic Effects

Injury	Threshold Dose to Skin	Mins fluoro 0.02Gy/min	Mins fluoro 0.2Gy/min
Transient erythema	2	100	<<1
Permanent epilation	7	350	35
Dry desquamation	14	700	70
Dermal necrosis	18	900	90
Telangiectasia	10	500	50
Cataract	>5	>250 to eye	>25 to eye



Development of Interventional Cardiology

1929

First documented human cardiac catheterisation

Eberswald, Germany

Dr Werner Forssman

1958

Diagnostic coronary angiogram

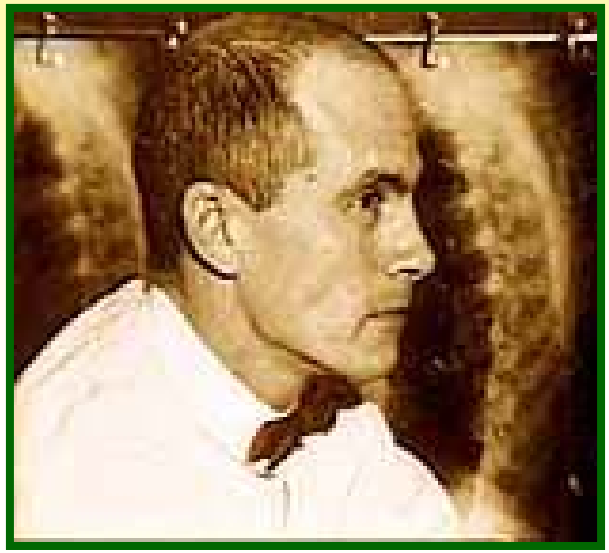
Dr Mason Sones

Development of Interventional Radiology

1964

Transluminal angioplasty

Dr Charles Dotter



1967

Judkins technique

Dr. Melvin Judkins

Development of Interventional Cardiology

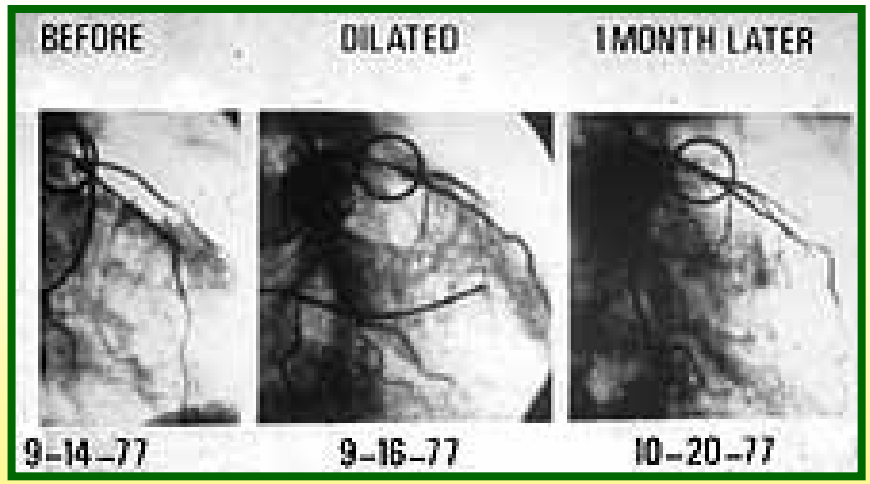
1974

First peripheral balloon angioplasty

Dr Andreas Gruentzig

1977

First cath lab PTCA on awake patient



Development of Interventional Cardiology

1980

Use of angioplasty in evolving myocardial infarct

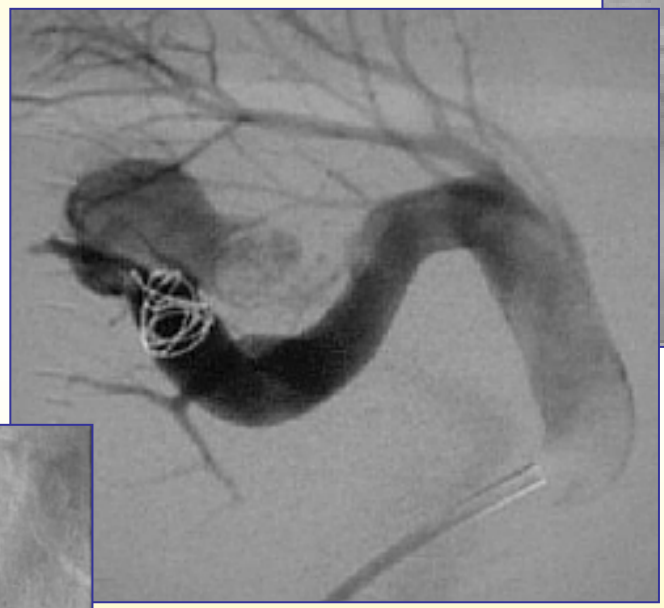
Dr Geoffrey Hartzler

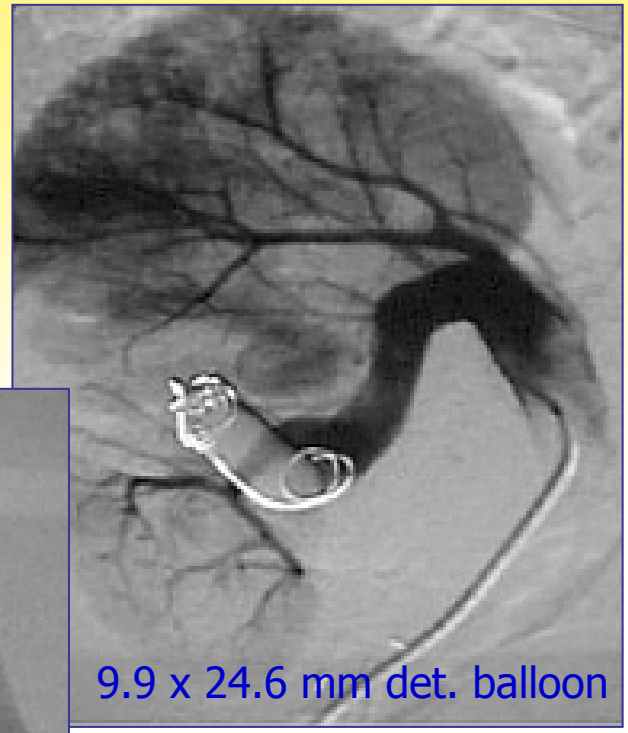
1987

First use of coronary stents in human

Embolisation: detachable balloon occlusion

- Transplant post-biopsy





Regulations

- **I**onising **R**adiation **R**egulations 19**99**

  -relate to public and staff safety

- **I**onising **R**adiation (**M**edical **E**xposure) **R**egulations **IR(ME)R 2000**

  -govern the fate of patients undergoing a medical exposure

Regulations

- Duties of all bodies- employer, practitioner, operator and referrer
- ALARA/ ALARP principle
- Training
- Diagnostic Reference Levels (DRLs)
- Local Rules-policies, procedures, protocols
- Other Bodies eg NRPB, ICRP, ACC, BCIS, European Commission's Radiation Protection Research Program

Dose Definitions

- Gray - energy absorbed per unit mass
  (in diagnostic = KERMA, energy transferred)

- Sievert - equivalent dose=absorbed dose x radiation weighting factor

- Effective dose – equivalent dose in each organ and tissue x tissue weighting factor and summed over whole body

Dose Definitions

- DAP - dose area product (Gycm²)
  incident dose x area of X ray field

- Entrance skin dose – absorbed dose in the skin at a given location on the patient (Gy)

Annual Dose Limits

	Classified Staff	Unclassified / trainees	Public
Whole body	20 mSv	6 mSv	1 mSV
Eyes	150 mSv	50 mSv	15 mSv
Organs	500 mSv	150 mSv	50 mSv
Fetus	1 mSv	1 mSv	

Monitoring

Ensure

- Film badges and TLDs are easily available
- Results of monitoring are available to all
- Reminders to wear them are in appropriate places

Dose to patient

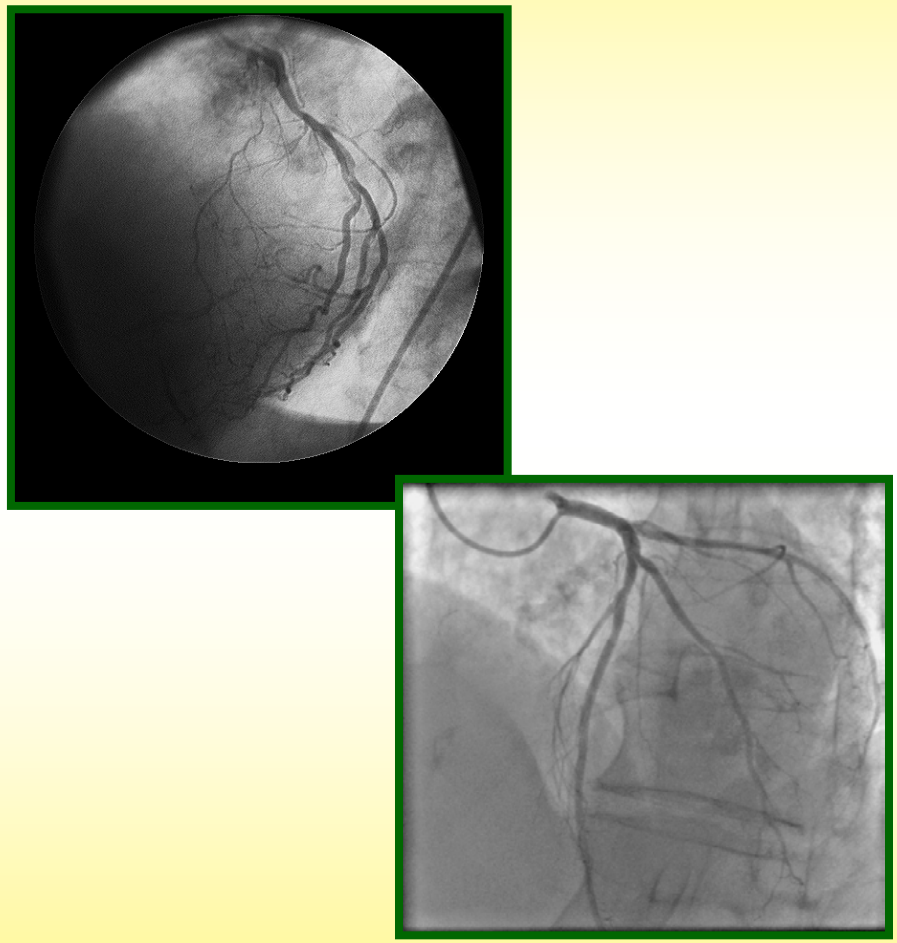
Procedure	DAP cGycm²	ED mSV
Coronary angiography	3040	5.6
PTCA	3760	6.9
CA + ad hoc PTCA	5060	9.3
PTCA + stent	4920	9.0
CA + ad hoc PTCA + stent	7070	13.0

Diagnostic Reference Levels

- Set for categories of procedures – 20/annum
- At least 100 cases
- DAP (dose area product) or screening time and mAs
- Level set - 90th percentile
- No national DRLs for coronary angiography
- NRPB – proposed 36 Gcm²
- European DIMOND – proposed 45 Gcm²

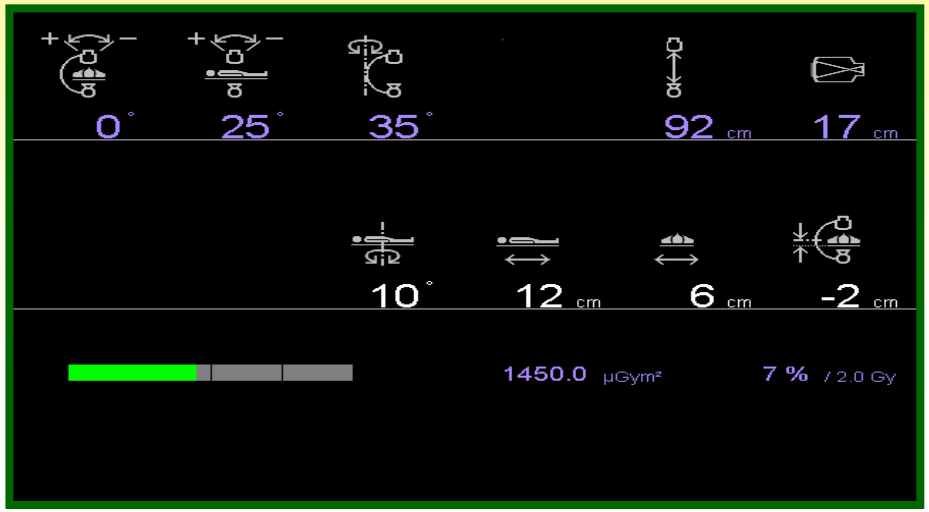
Dose Reduction - Equipment

- Frame rate selection
- Pulsed fluoroscopy
- Fluoroscopy and image acquisition dose rate selection
- Last image hold
- ‘Replay fluoro’
- Electronic magnification
- Image processing
- Flat panel detectors



Dose reduction -Equipment

- Road map
- Reload facility
- Virtual collimation
- Intelligent filtration
- Dose display

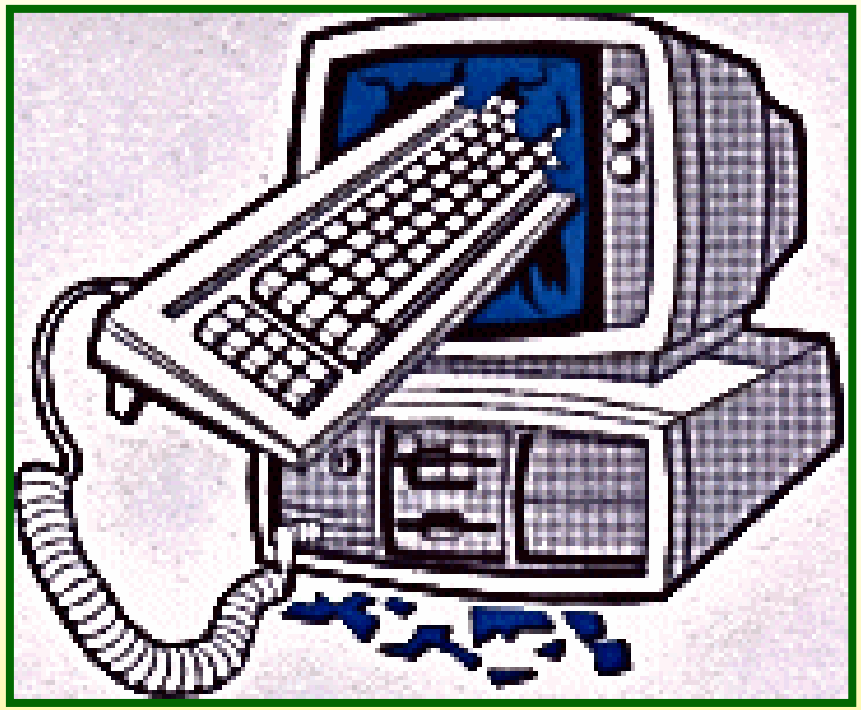


BUT

- Most dose reduction features optional
- Improved imaging allows more complex cases

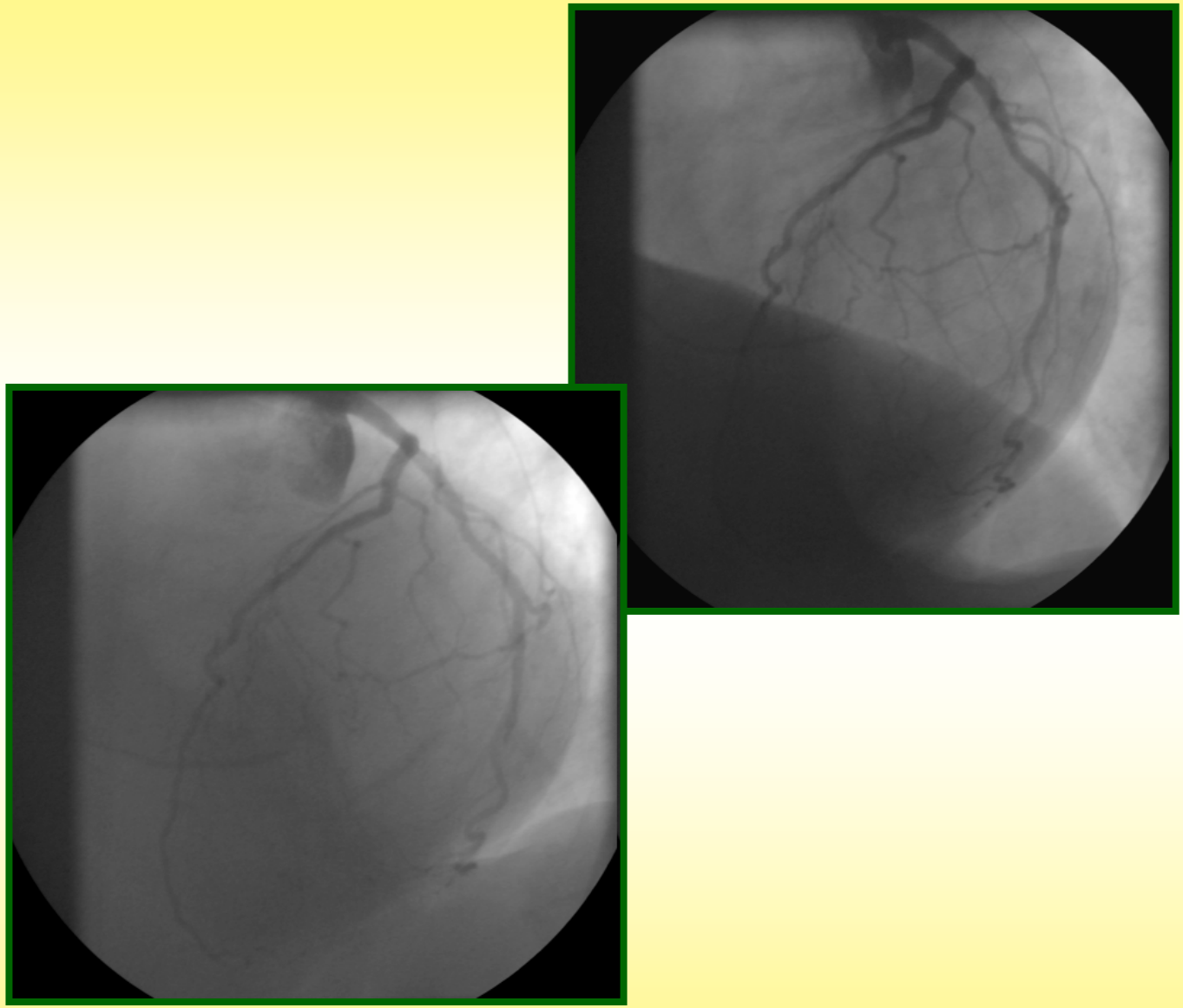
Dose Reduction - Equipment

- Modification of existing equipment
- Equipment maintenance
- Quality assurance
  - regular IQ and dose checks
  - manufacturer
  - medical physicists



Factors affecting exposure

Inspiration

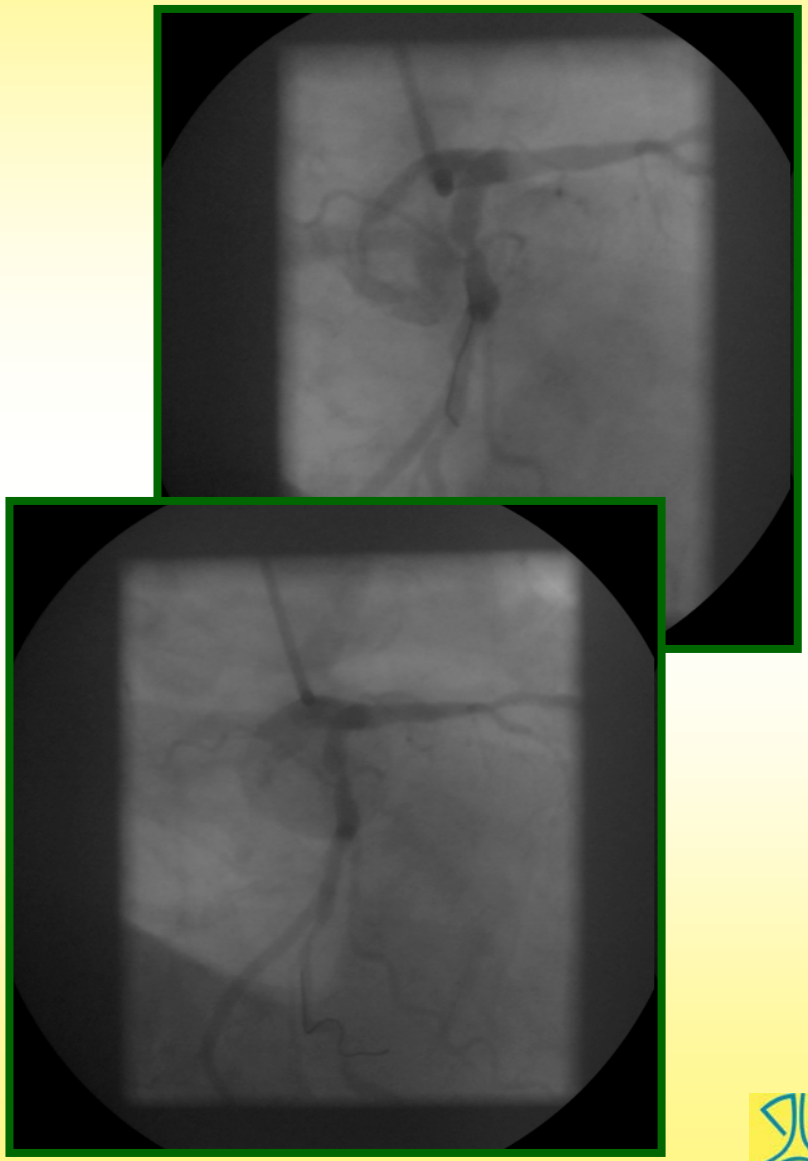


Operational Factors

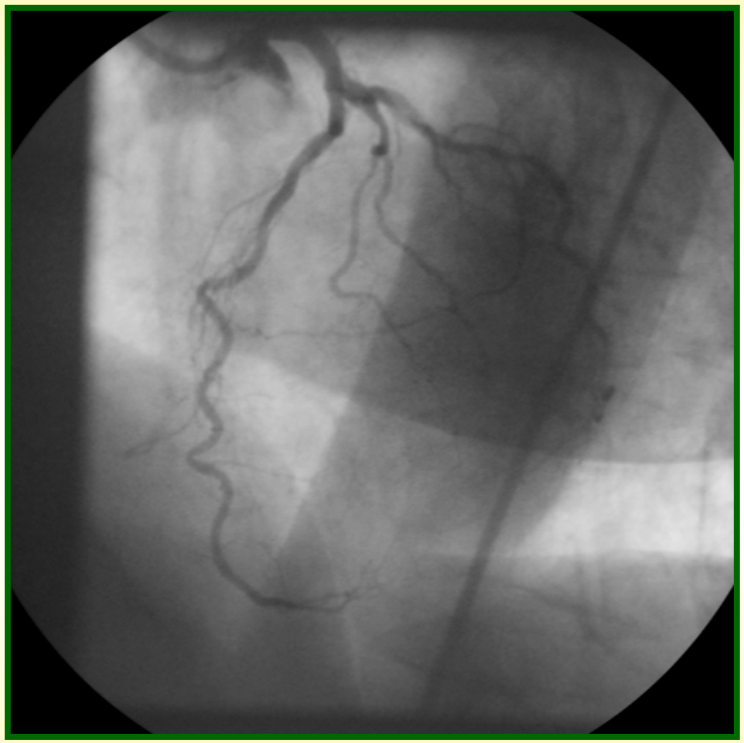
- Arterial access
- Oblique views

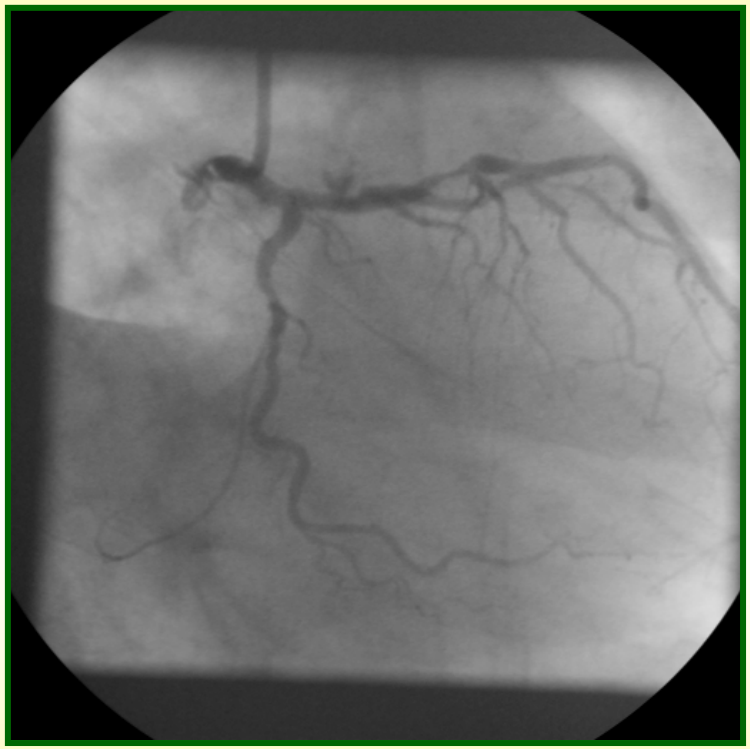
Operational Factors

- Suitable kV and mA
- Centring
- Diaphragms-ROI
- Field size -panning
- Magnification



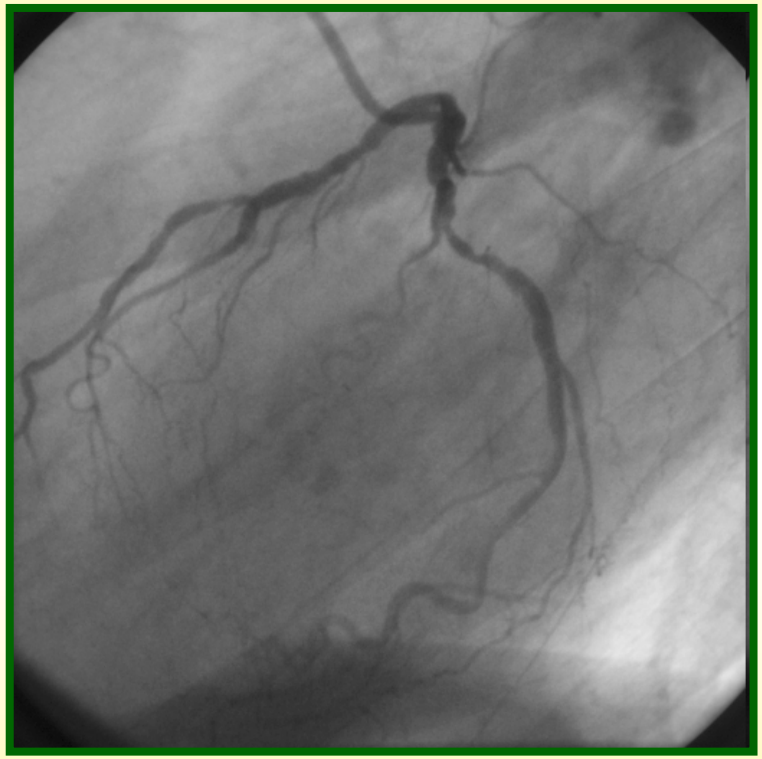
Appropriate Views

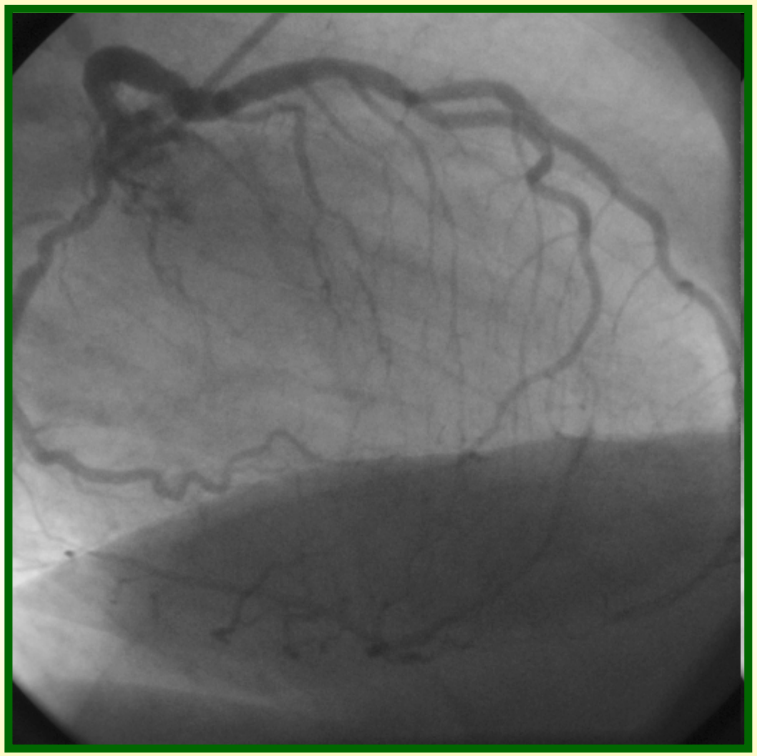




Views should not be prescriptive-depend on patient

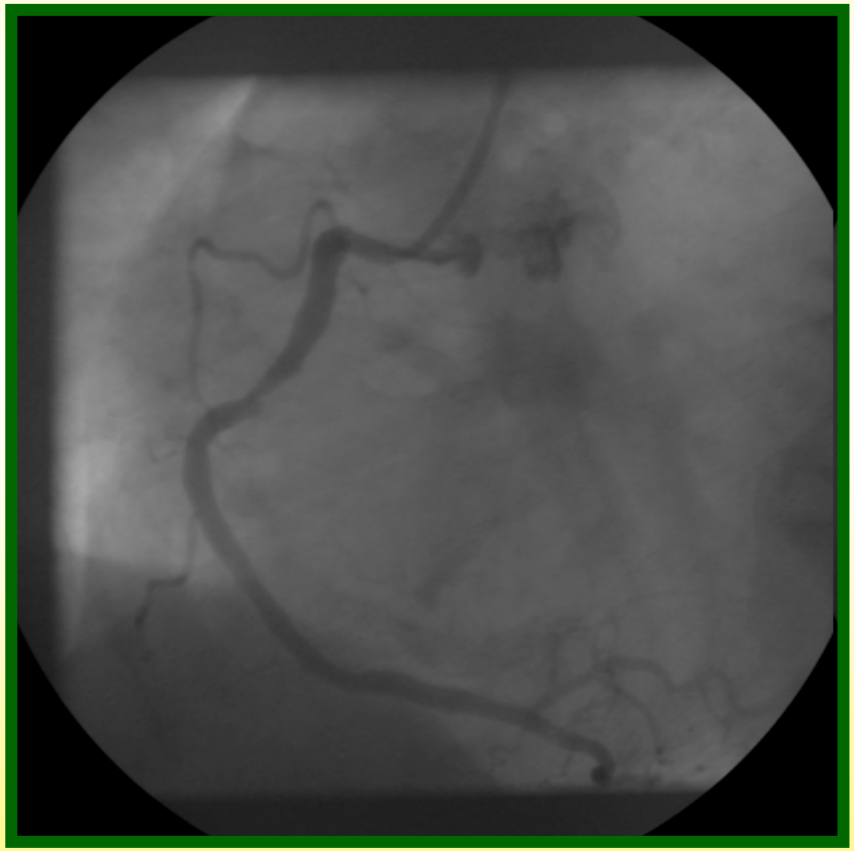
Lateral View

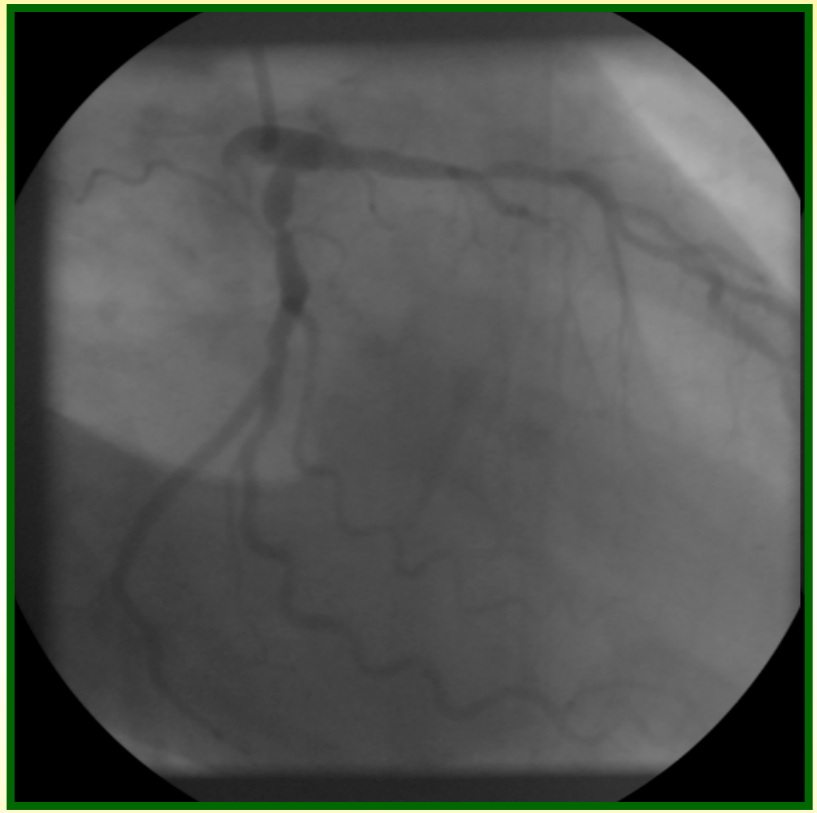




Operational

- Stenting strategy





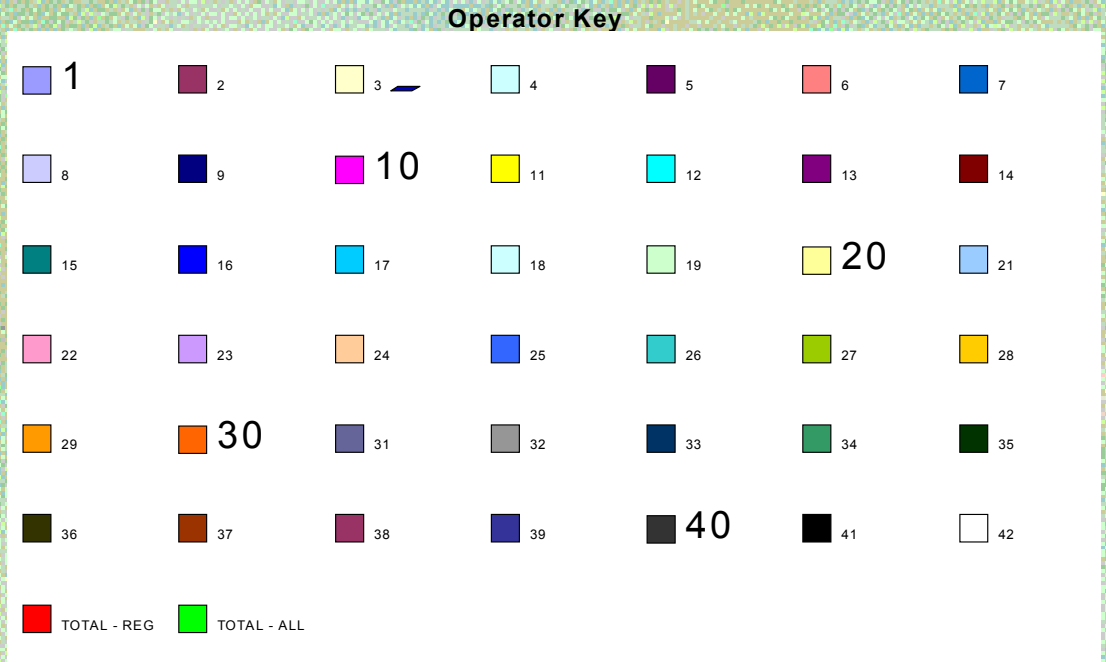
Behavioural

- Table and detector in correct position before screening
- Screening time
- Image acquisition –operator / radiographer?
- Use of equipment features-dose reduction programmes etc
- Prolonged procedures – reduce skin dose
- Operator fatigue

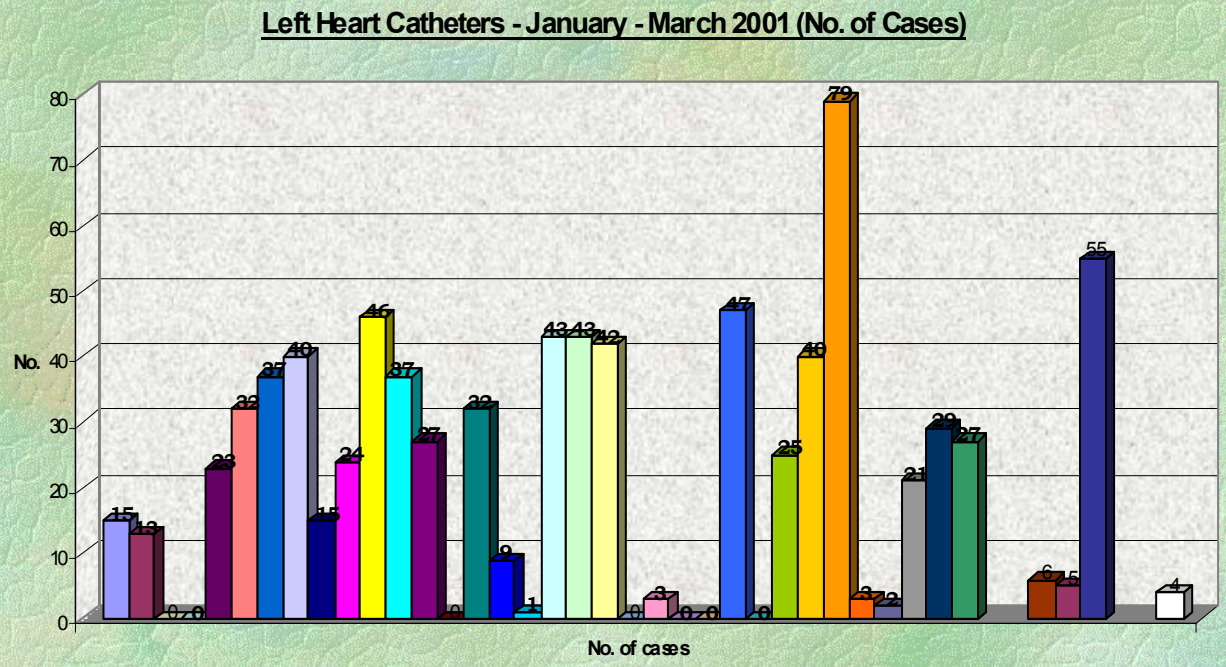
Radiation Awareness

- Regular audit
- Feedback on dose information
  - patients
  - staff
- High standards of equipment maintenance and quality assurance
- Appropriate theoretical training with annual updates
- Practical training and regular re-assessment

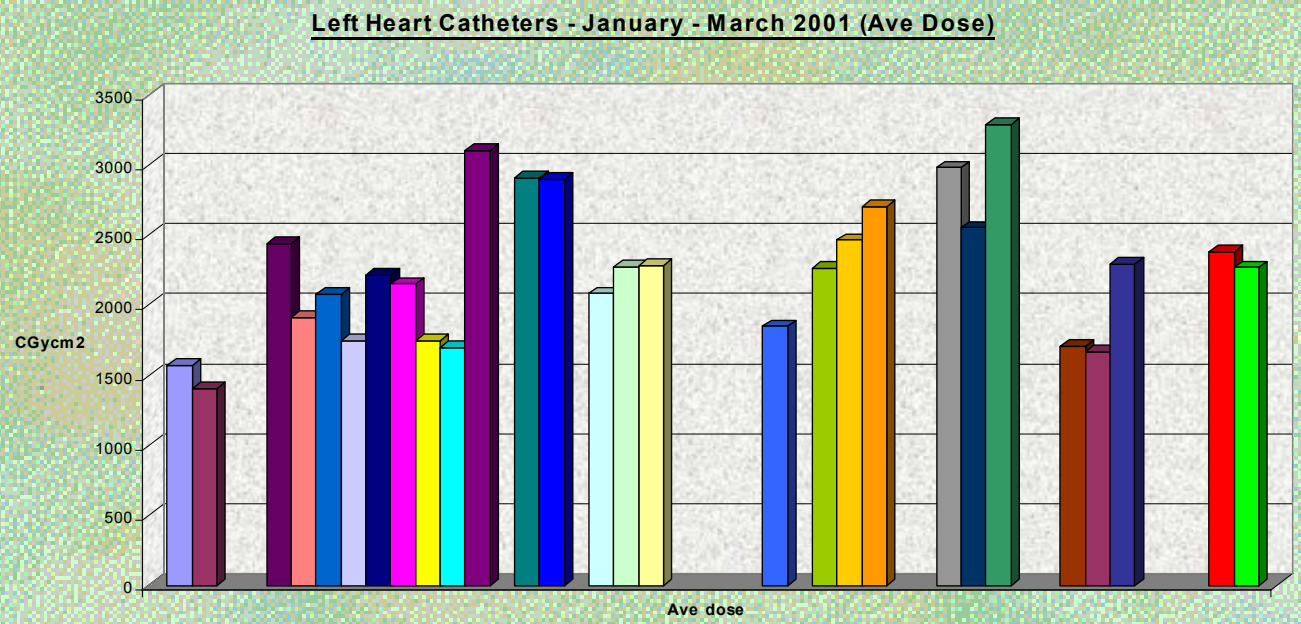
Audit - Operator key



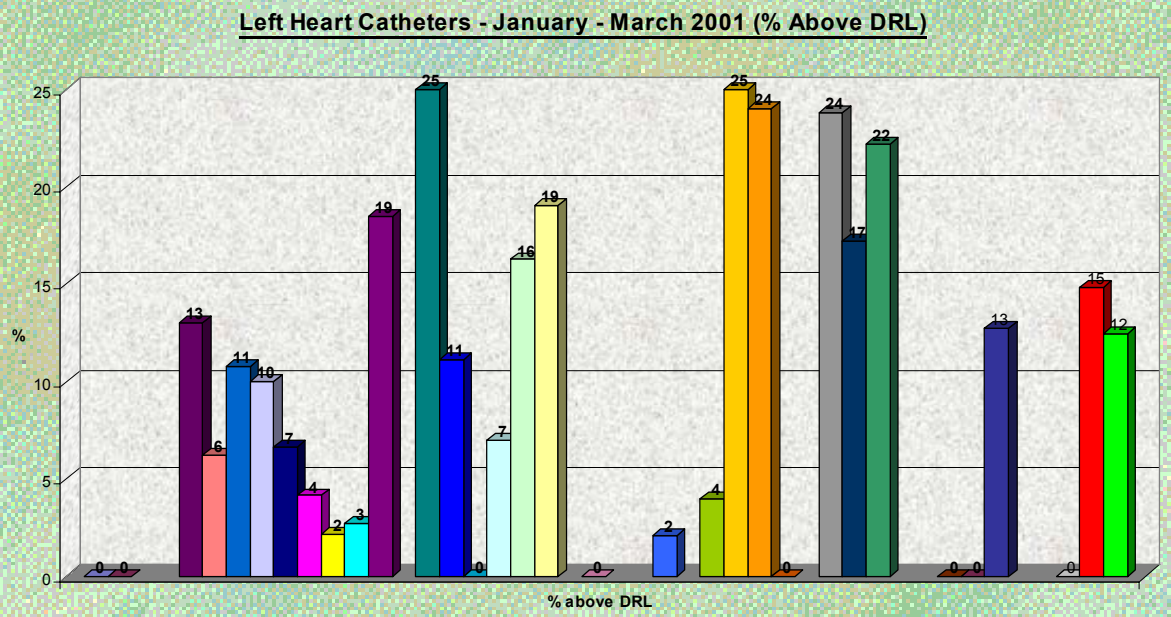
Audit


Left Heart Catheters - January - March 2001 (No. of Cases)
No.
No. of cases
0
10
20
30
40
50
60
70
80

Audit


Left Heart Catheters - January - March 2001 (Ave Dose)
CGycm2
3500
3000
2500
2000
1500
1000
500
0
Ave dose

Audit

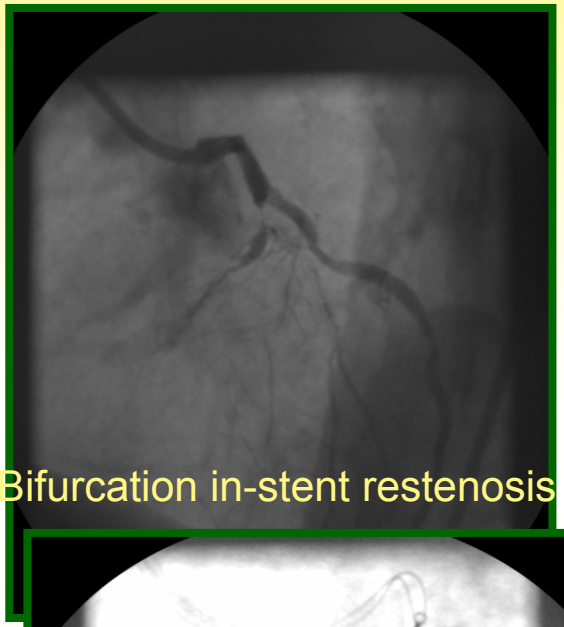

Left Heart Catheters - January - March 2001 (% Above DRL)
25
20
15
%
10
5
0
% above DRL

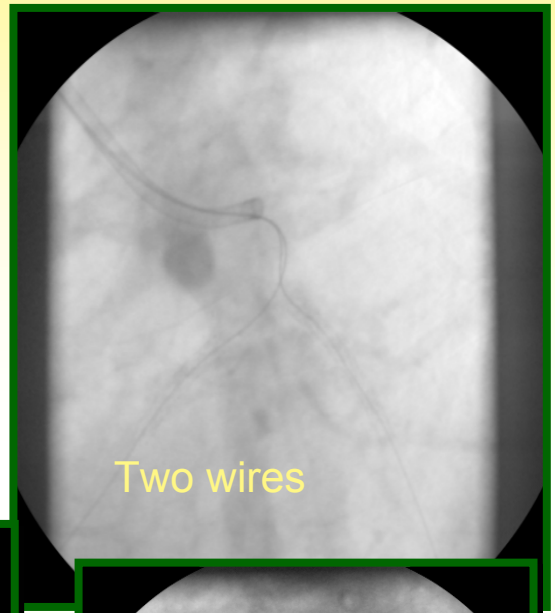
Special Cases-Cardiology

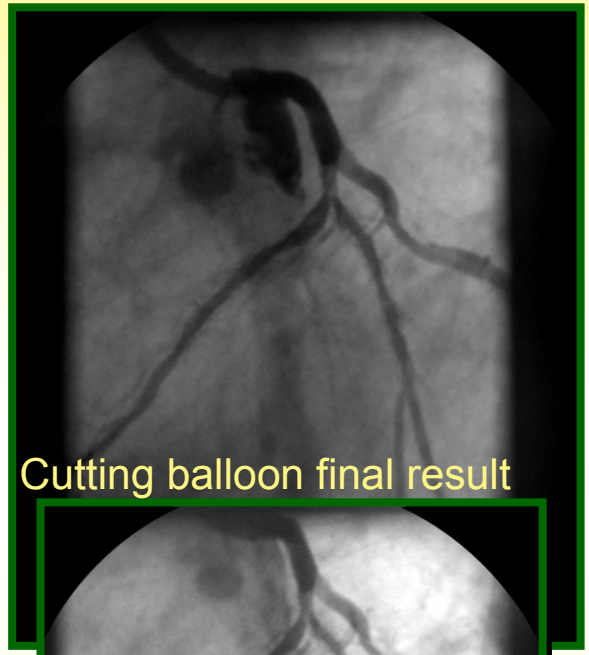
- EPS/RFA
- Brachytherapy
- CT angiography
- Radio-isotopes
- Echocardiography
- Magnetic Resonance Imaging

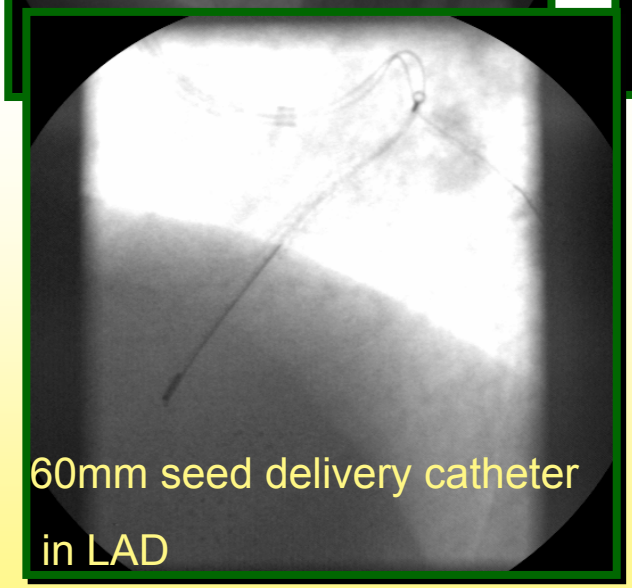
Electrophysiology

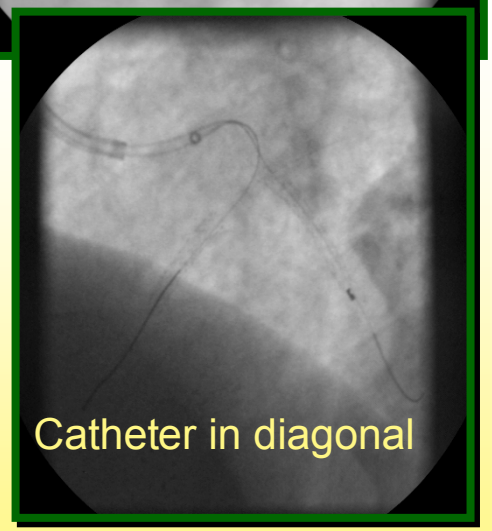
Brachytherapy

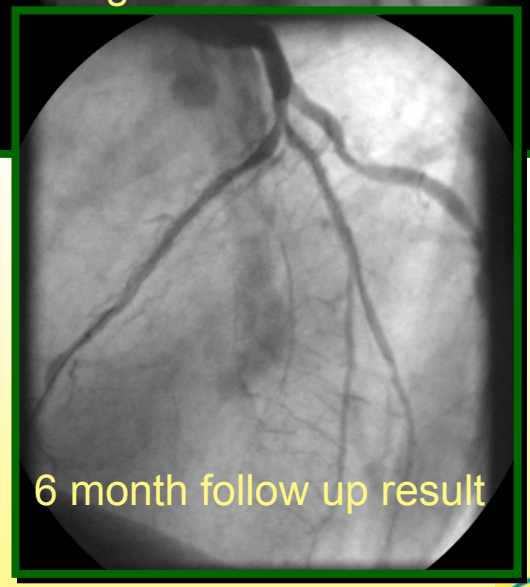

Bifurcation in-stent restenosis


Two wires


Cutting balloon final result

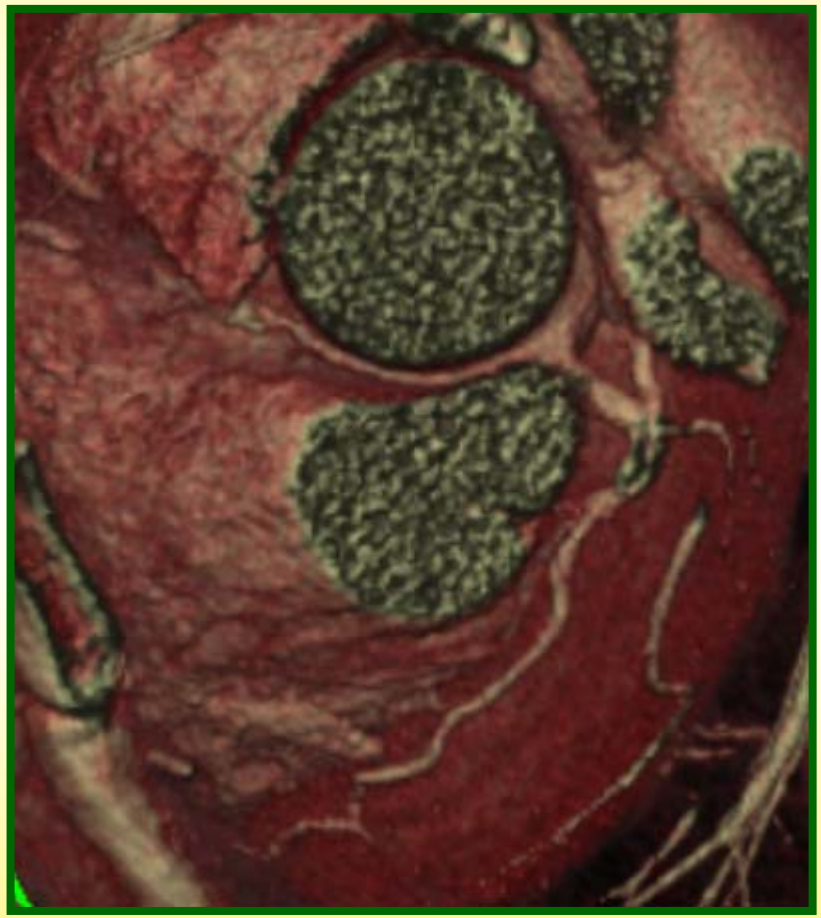

60mm seed delivery catheter in LAD


Catheter in diagonal

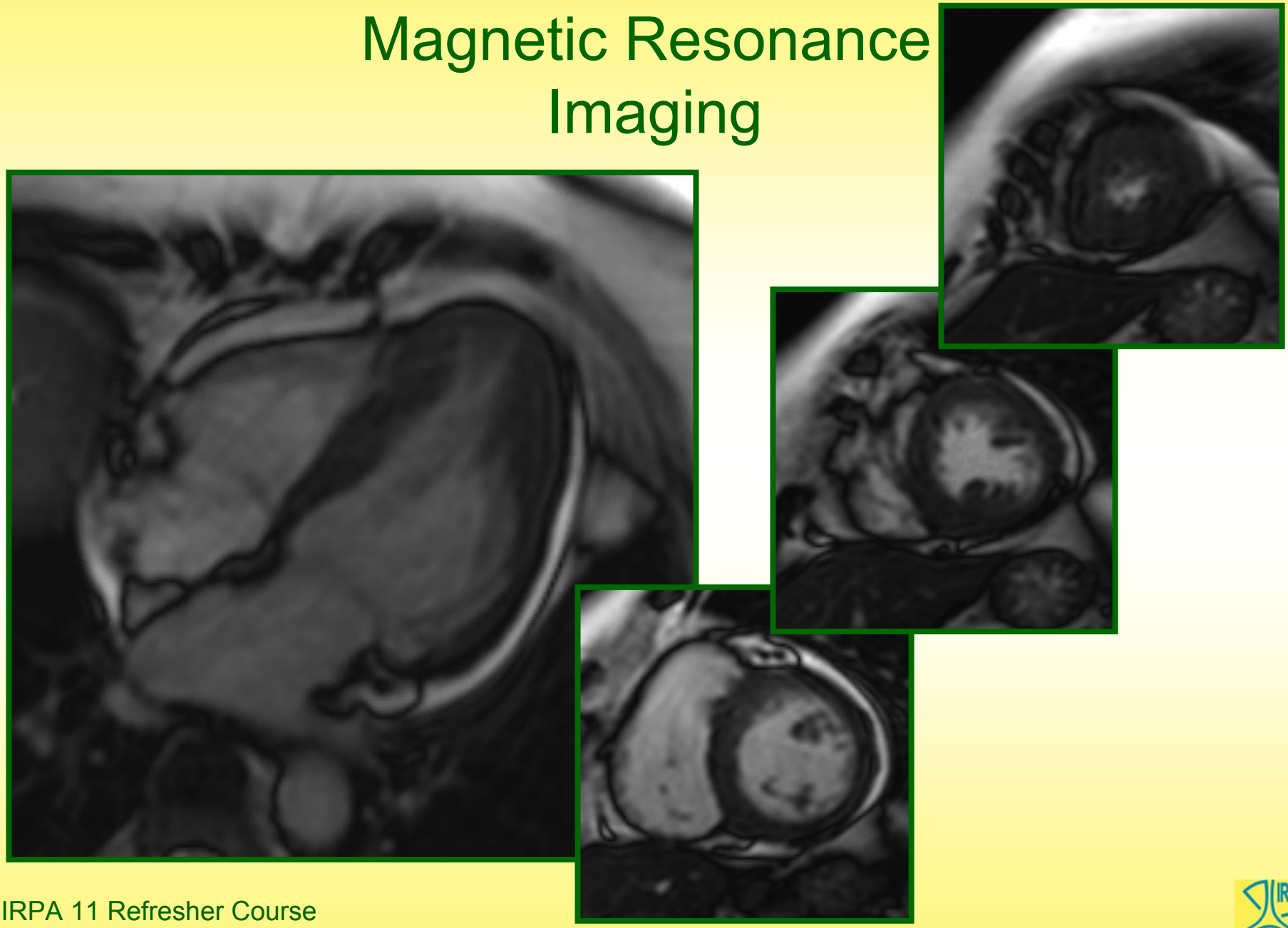

6 month follow up result

CT Angiography

- Anomalous right coronary artery arising from LC sinus
- Occlusion of RCA



Magnetic Resonance Imaging



Special Cases-Radiology

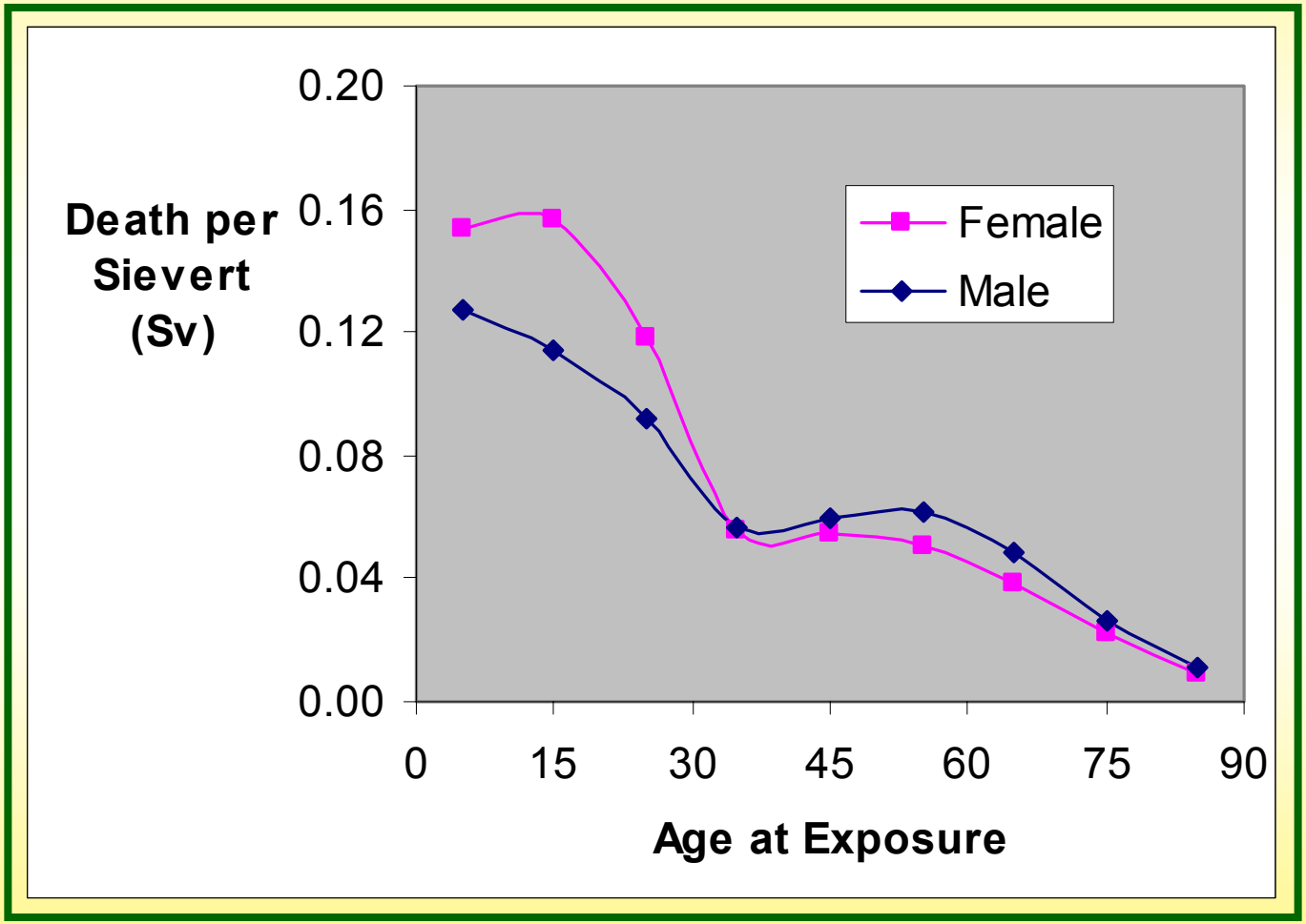
Per-operative arterial rupture

Covered stent deployment

Radiology

- Dose ranges depend on type and site of intervention
- Dose reduction to patient -principles as cardiology
- Tube movements less
- Position of operator more variable
- Use ultrasound guidance where possible
- CT fluoroscopy-decreased operation times

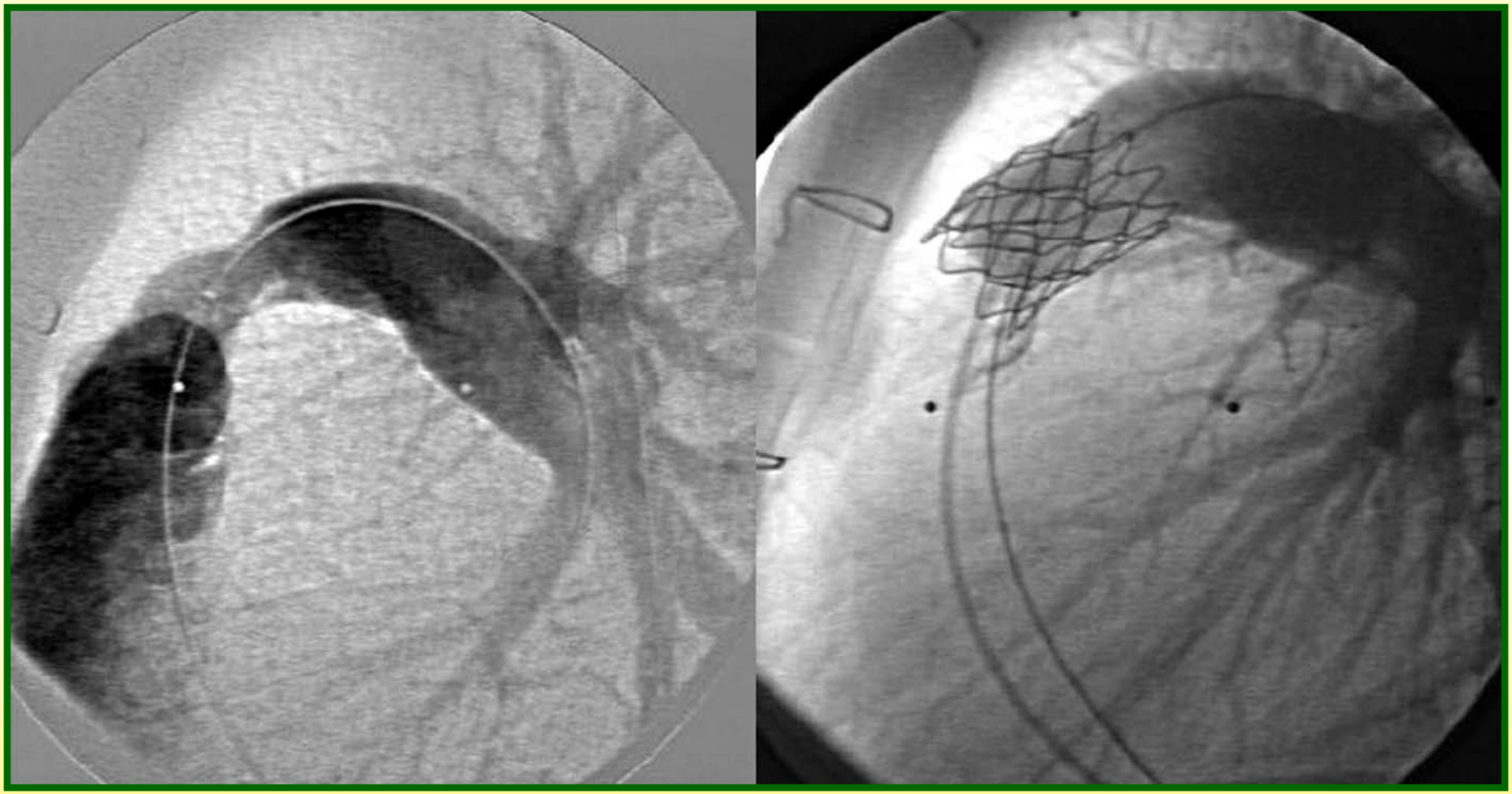
Risk


Death per Sievert (Sv)
0.20
0.16
0.12
0.08
0.04
0.00
0
15
30
45
60
75
90
Age at Exposure
Female
Male

Doses

Dose from common paediatric procedures	DAP cGcm²	ED mSv
Tetralogy of Fallot	670	8.4
Closure of persistent ductus arteriosus	450	3.8

Paediatric Intervention



Limitation of Staff Exposure

- Reduce patient exposure - reduce staff exposure
- Radiation awareness and education
- Dedicated interventional equipment
- Reduce time of exposure
- Use inverse square law
- Use shielding by barrier

Limitation of Staff Dose

Use lead shields

Wear appropriate lead protection

- Lead glasses
- Thyroid shield
- Lead apron – 3.5 - 5mm lead equivalent
- Monitoring

Use mobile barriers

- Lead shield for operator
- Mobile barrier for radiographer
- Other staff appropriately positioned

- Position monitors so that operator looks away from beam

Paediatrics-always a special case

Good Practice 1

- Follow Local Rules, procedures and protocols
- Have all available information about patient

  eg. previous grafts, echo data etc
- Check patient identity, exposure justification, consent
- Position patient
- Ensure all appropriate staff in room are protected and wearing monitors
- Use all lead shielding

Good Practice 2

- Position table before screening
- Keep mA low-kV high (60-90kV for coronaries)
- X ray tube at max and II at min distance from patient
- Check staff position
- Use dose reduction programmes if possible
- Acquire images on full inspiration where possible
- Collimate to area of interest and choose views carefully

Good Practice 3

- Prolonged procedure-change beam angulation
- Minimise fluoroscopy, high dose rate time, number of acquisitions
- Remember software features to reduce dose eg replay fluoro
- Don’t over use magnification
- Remove grid for small patients
- Check and record screening time and DAP cf DRL

Recommendations

- Dedicated interventional equipment
- Radiation dose reduction packages should be mandatory
- Radiation dose should be displayed on monitors
- Radiation awareness should be promoted by audit and regular feedback
- Local standards-regular review and improvement
- Continuing education-including practical training with annual updates and testing
- Research continued-to develop international standards