Radiation Doses in Cardiology Procedures: Current Trends and Dose Reduction Practices in Hospitals

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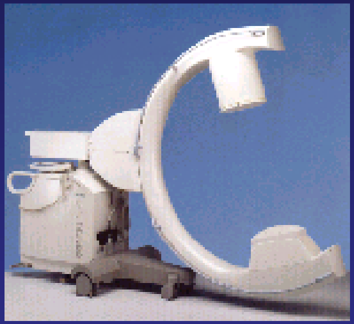
X-ray Imaging

X rays can penetrate or pass through the human body and produce shadow-like images of body structures.

- Radiography – plane images of organs on film or TV monitor
- Fluoroscopy –to see motion within the body and to observe certain diagnostic and treatment procedures that are being conducted within the body
- Computed tomography – uses x-ray but the computer can produced slices of images.

Radiography unit



Fluoroscopy unit

CT unit

Radiation Dsoes from Common Procedures

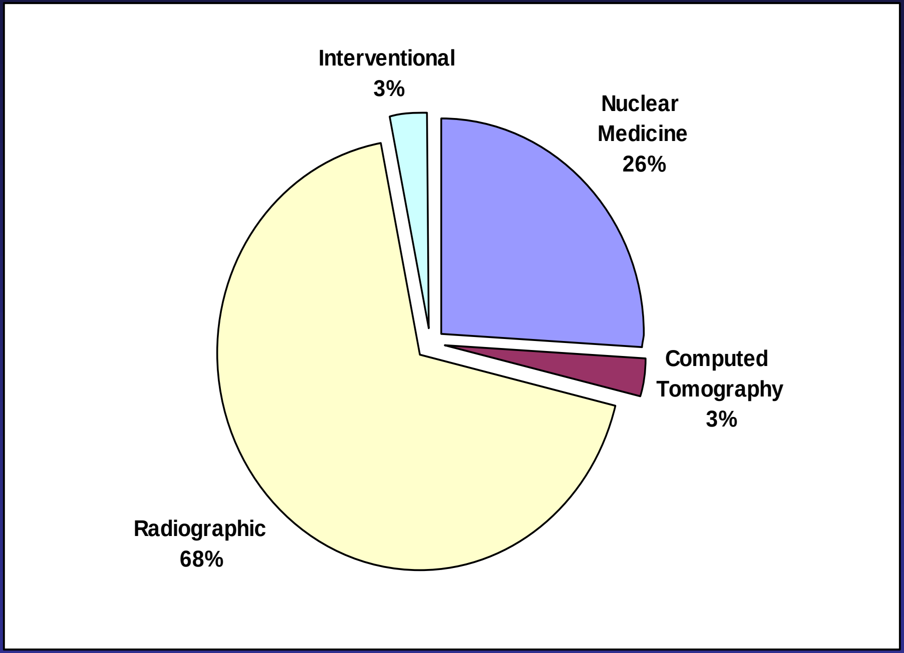
Procedure	Mean Effective Dose (mSv)
Chest	0.3
Abdomen radiography	1
Barium enema (fluoroscopy)	7
CT head	2
CT chest	8
CT abdomen	10 - 20

Radiography image

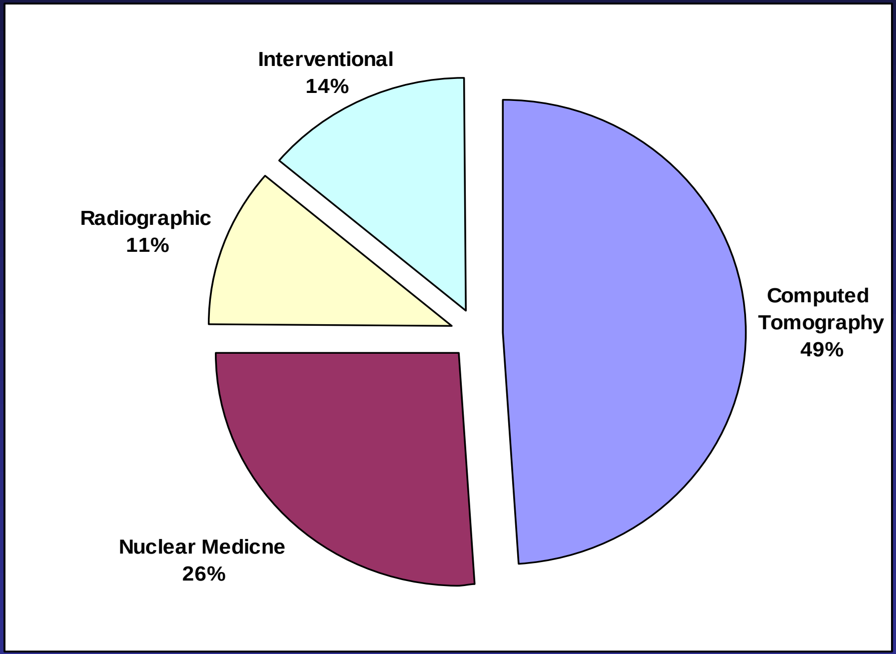
CT image of chest

Patient Collective Doses from Medical Exposures

Early 1980s



2006



Patient collective doses increased for computed tomography (CT) and interventional radiology procedures in 2006.

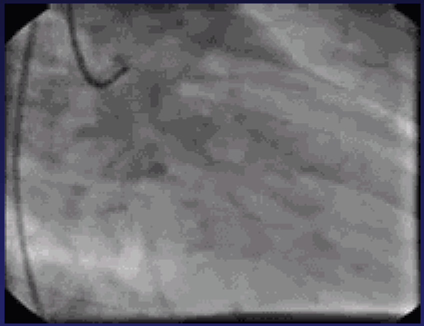
Source: NCRP Report No. 160 Ionizing Radiation Exposure of the Population of the US

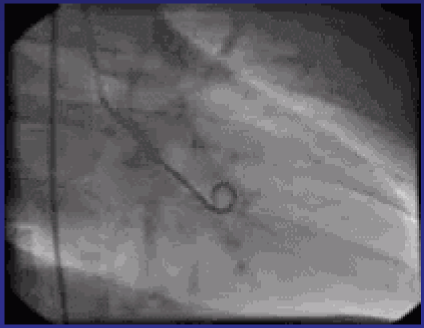
Reported incident due to CT overdose

Hair loss due to CT brain perfusion. It is believed that the dose was 6 to 13 times the FDA recommended dose of 0.5 Gy.
Permanent hair loss > 7 Gy (single exposure)
> 50-60 for multiple exposure

151 CT scans in 68 min.

What are cardiology procedures in interventional radiology?





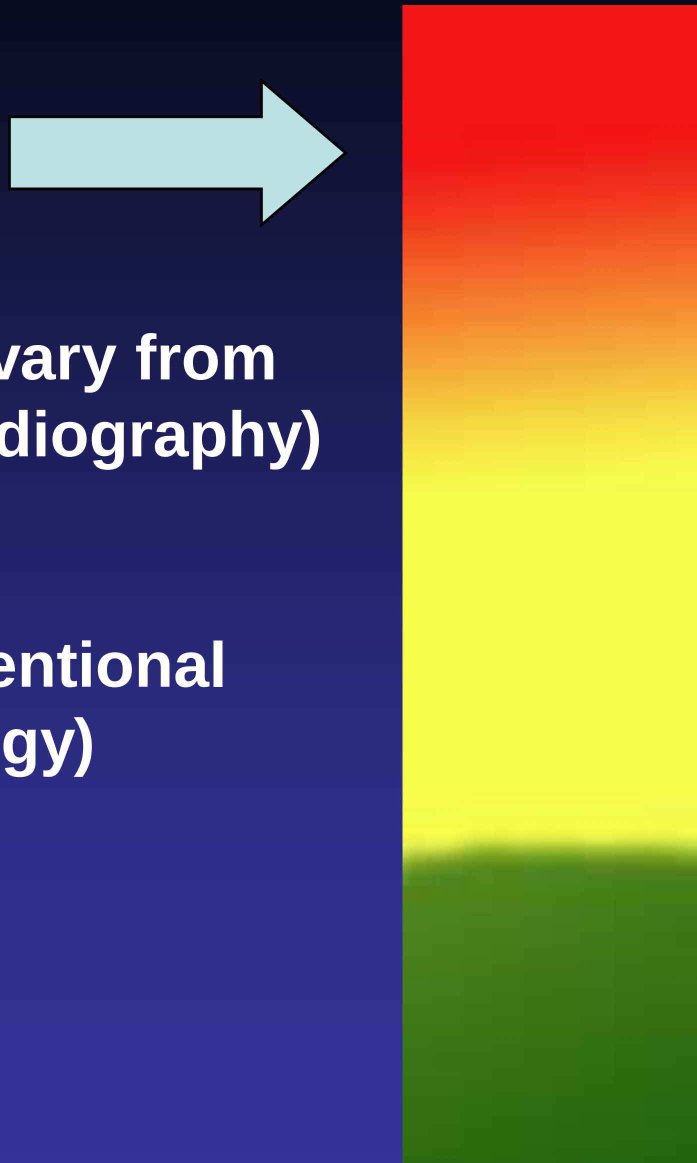
- **They are procedures that assess the conditions of the heart using catheters stents.**
- **Cardiologists are guided by fluoroscopy in insertion and placement of catheters and stents vessels or chamber of the heart.**
- **Examples are:**

  coronary angiography

  percutaneous coronary intervention

PATIENT DOSES IN RADIOLOGY

Could vary from low (radiography) to very high (interventional radiology)



Interventional Radiology

CT

Radiography

Comparison of radiography and fluoroscopy doses with cardiology doses

Procedure	Mean Effective Dose (mSv)
Chest (radiography)	0.03
Abdomen (radiography)	0.6
ERCP (endoscopic retrograde choangiopancreatography)	3.9
Cardiology:	
Coronary angiography (CA)	3.1
PTCA (percutaneous trnasluminal coronary angioplasty)	15.1
Cardiovascular embolization	19.5
Interventional radiology:	
Renal angiography	13.7
Vascular stenting	10.4
TIPS (transjugular intrahepatic portosystemic shunt)	53.6

The Cardiology X-ray System

X-ray tubes of the system that are used during the procedure giving high dose to the patient.

X-ray tubes can be in different orientations.

The Cardiolgy environment

- Lengthy and complex procedures
- Prolonged exposure time
- Staff are very close to the patient
- No shielding

One must look for

- Modern sophisticated X Ray systems
- Use of protection tools, goggles, specific shielding, etc
- Suitable knowledge of the system
- Skill, rational (shared) workload

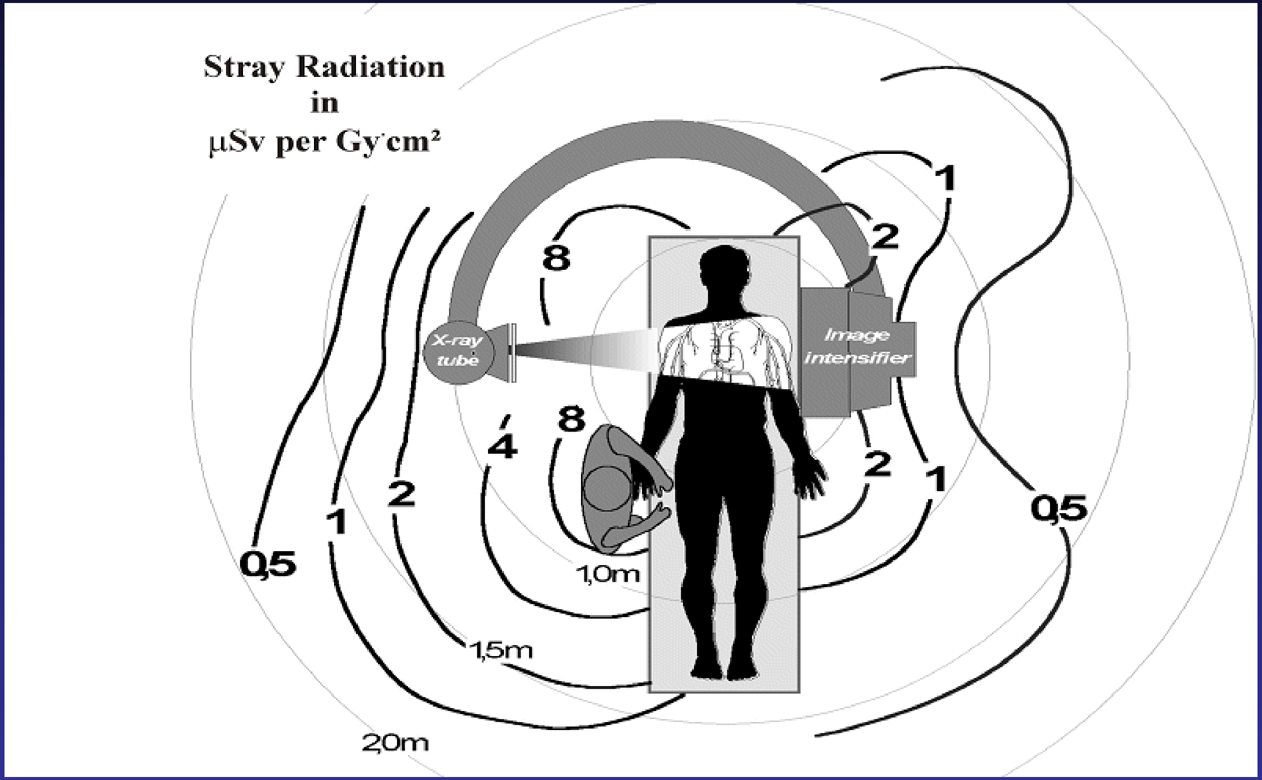
Radiation level in IR/Cardiology Procedures: Important factors

- Fluoroscopy time
- Number of series (Images)
- Patient size
- Performance of the X Ray system used
- Available protection tools

Radiation doses to patients

- Are due to the primary x-ray beam
- Can be high when the time of exposure is long
- Dose becomes high when the amount of x-rays is increased.

Staff doses are due to scatter radiation from the patient



In high dose fluoroscopy mode – dose rates will be in mSv/hr (same numerical values) which are 1,000 times greater.

Effects on Patients

Effects on patients???

Tissue Reactions (deterministic effects)

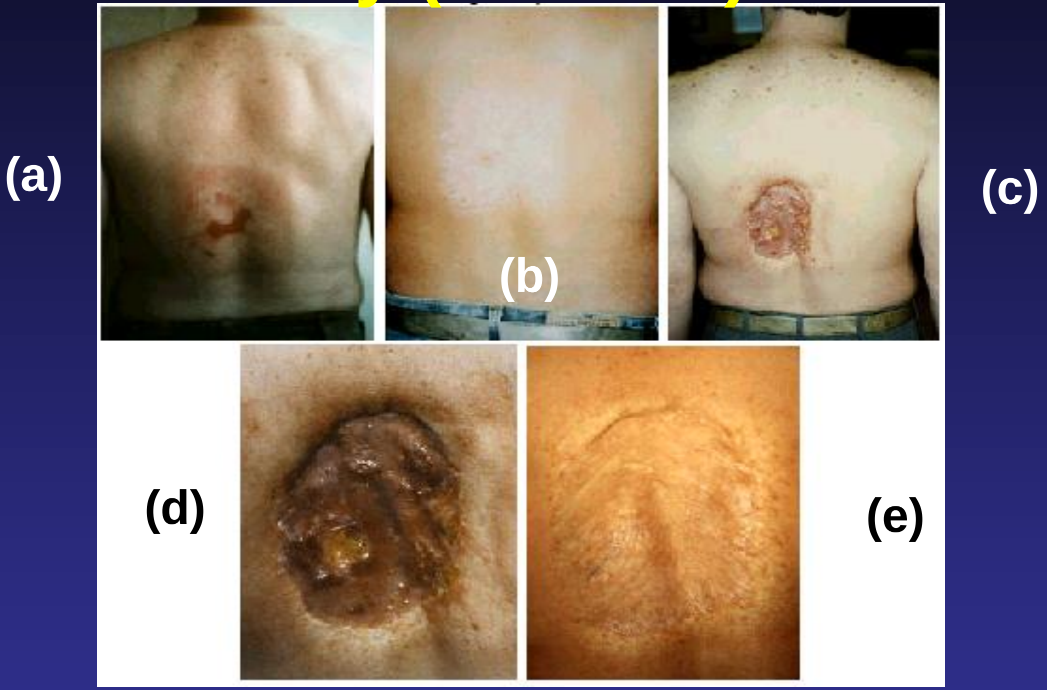
Skin injuries for patients

When do patients have skin injuries?

Acute radiation doses, delivered to tissues during a single procedure or closely spaced procedures, will cause:

- Erythema at 2Gy
- Permanent epilation at 7Gy
- Delayed skin necrosis at 12 Gy

Coronary angioplasty twice in a day followed by bypass graft because of complication. Dose ≈ 20 Gy (ICRP 85)



- (a) 6-8 weeks after multiple coronary angiography and angioplasty procedures.
- (b) 16-21 weeks
- (c) 18-21 months after the procedures showing tissue necrosis .
- (d) Close-up photograph of the lesion shown in (c).
- (e) Photograph after skin grafting. (Photographs courtesy of T. Shope & ICRP).

Skin Injuries

Reports Received by FDA of Skin Injury from Fluoroscopy.

Procedure with Report of Injury	Number of Injuries Reported from Procedure
RF cardiac catheter ablation	12
Catheter placement for chemotherapy	1
Transjugular interhepatic portosystemic shunt	3
Coronary angioplasty	4
Renal angioplasty	2
Multiple hepatic/biliary procedures (angioplasty, stent placement, biopsy, etc.)	3
Percutaneous choloangiogram followed by multiple embolizations	1

Effects on Staff

Radiation Related Cataract Formation

Dose Threshold Values for the Lens of the eye

ICRP regulations 1990 and 2007:

Detectable opacities

0.5-2 Gy (total dose received in a single exposure)

5 Gy (total dose received in fractionated exposure)

>0.1 Gy/y (annual dose per year, fractionated exp.)

Visual impairment

5 Gy (total dose received in a single exposure)

Cataract

>8Gy (total dose received in fractionated exposure)

>0.15 Gy/y (annual dose per year, fractionated exp.)

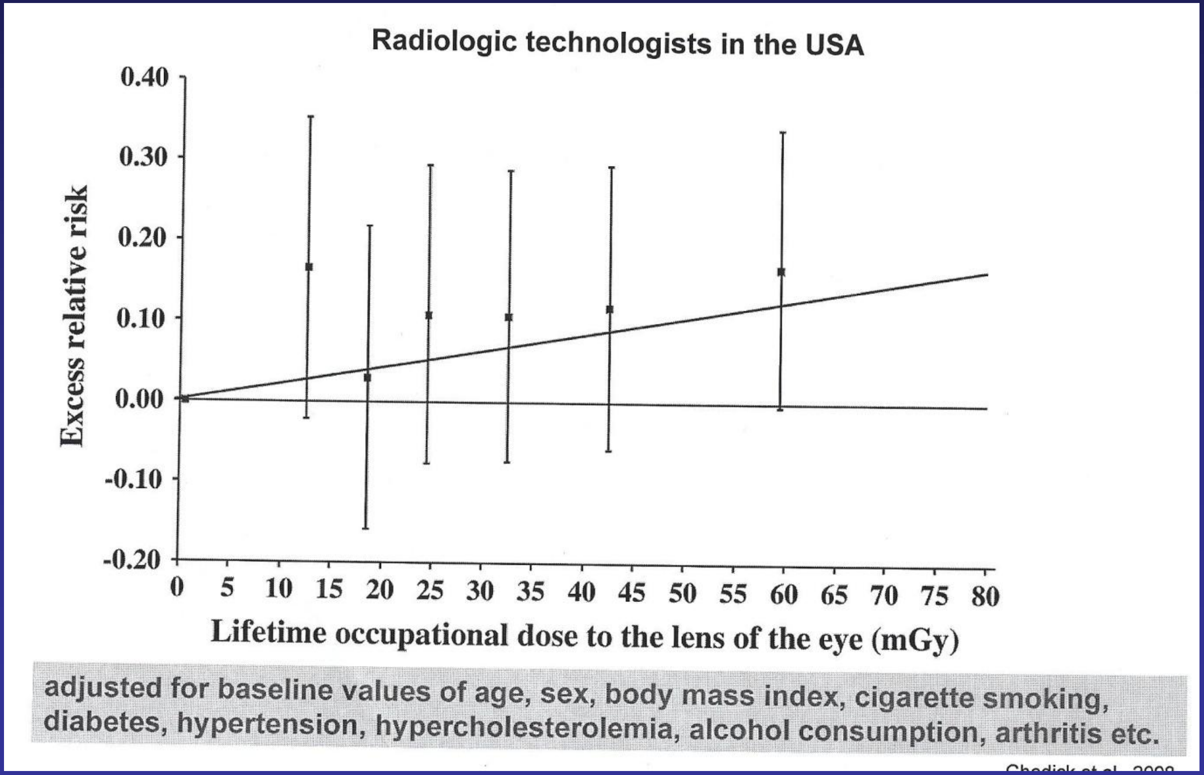
Operated cataract **cataract not yet operated**

Radiologic technologists in Colombia and Uruguay

TABLE 2
Posterior Subcapsular Lens Opacities in Interventional Cardiologists, Associated Personnel and Unexposed Controls

Subjects (*n*)	Posterior lens opacities in one or both eyes	*P* value	Relative risk[a]	95% Confidence interval
Interventional cardiologists (58)	22 (38%)	< 0.005	3.2	1.7–6.1
Nurses and technicians (58)	12 (21%)	0.13	1.7	0.8–3.7
Unexposed controls (93)	11 (12%)			

[a] Compared to unexposed controls.



Source: German Research Centre for Environmental Health

Why do skin and eye effects occur?

IAEA Findings :

Lack knowledge on effects and training in radiation protection for those performing these studies, such as:

- Cardiologist
- Urologist
- Gastro-enterologist
- Orthopedic Surgeon
- Vascular Surgeon
- Traumatologist
- Pediatrician
- Anesthesiologist

The Fact is…

On Patients

- **Many interventionists cardiologists are not aware of the potential for injury from procedures and their occurrence**
- **Lack of knowledge on simple methods for decreasing their incidence utilizing dose control strategies.**
- **Gross lack of information on radiation doses.**
- **Many patients are not being counseled on the radiation risks, nor followed up for the onset of injury.**

The Fact is…

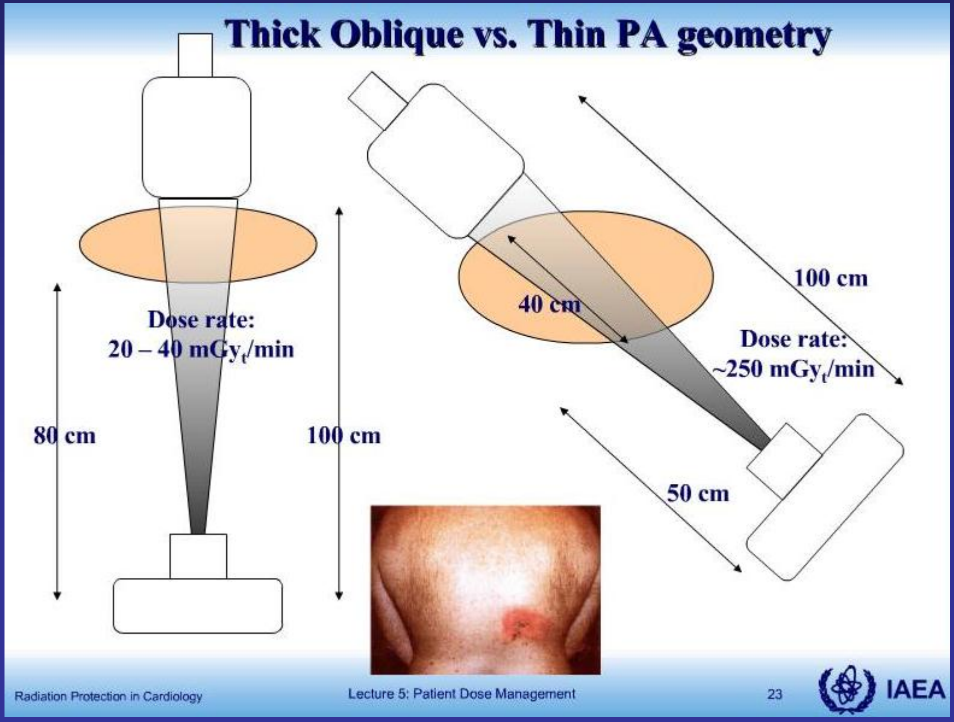
On Staff

- Interventionists/cardiologists are having their practice limited and are exposing their staff to high doses.
- Occupational doses can be reduced by reducing unnecessary patient dose, the correct use and procurement of equipment (including the use of shielding devices).
- Lack of information on staff doses such that monitoring devices are not properly used.

Factor Affecting Patient and Staff Doses

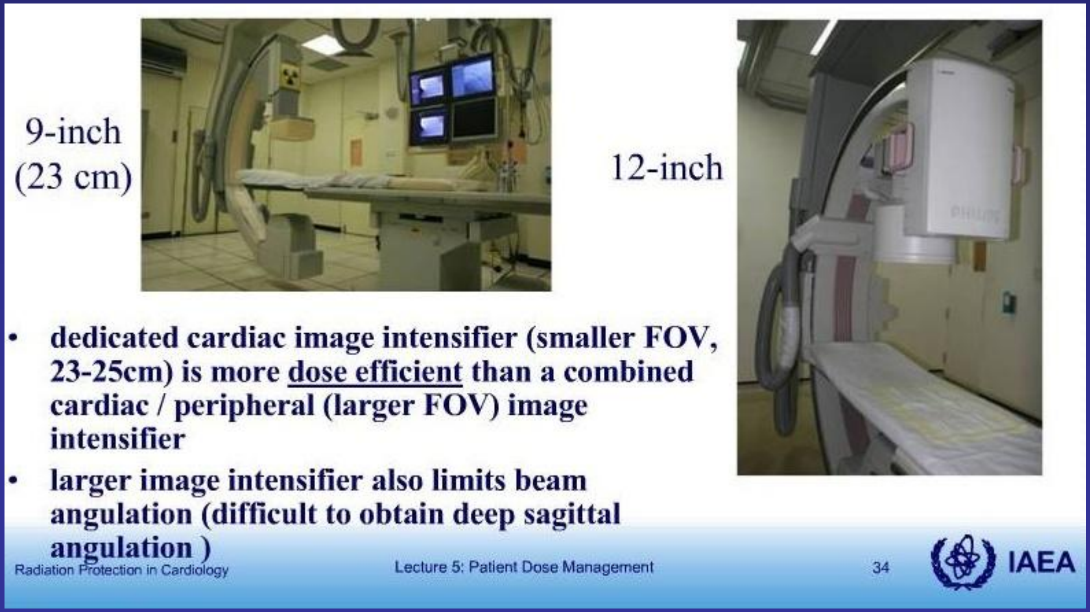
Patient factors :

- body mass or body thickness in the beam
- complexity of the lesion and anatomic target structure
- radiosensitivity of some patients
- connective tissue disease and diabetes mellitus.



Equipment factors:

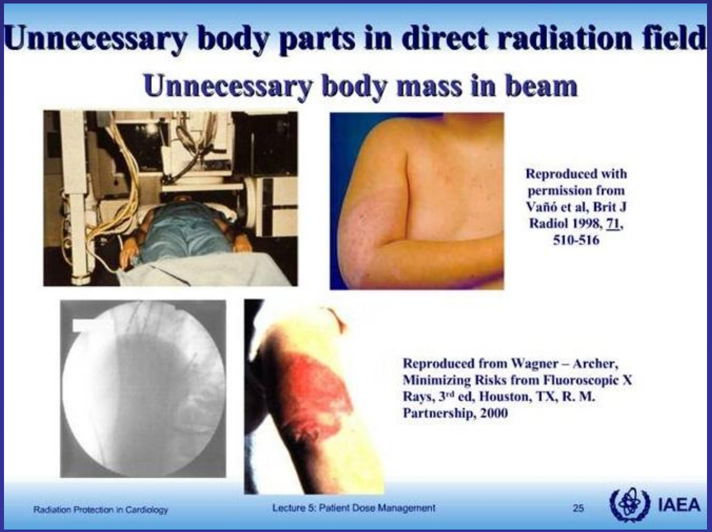
- **setting done by the manufacturer on fluoro (high and low dose) and cine mode (gives highest doses)**
- **appropriate quality control**
- **existence of cine loop**
- **last image hold**
- **pre-selectable number of radiographic frames per run virtual collimation.**



Factor Affecting Patient and Staff Doses

Procedure dose related factors are

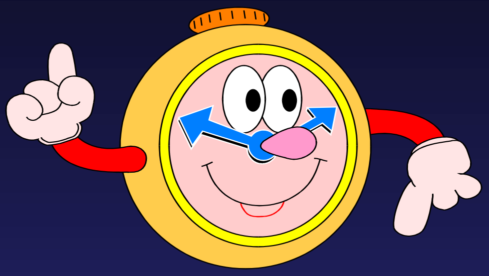
- number of radiographic frames per run
- Collimation
- fluoroscopic and radiographic acquisition modes
- fluoroscopy time
- wedge filter
- magnification
- distance of patient to image receptor (image intensifier or flat panel detector)
- distance between X ray tube and patient
- tube angulations



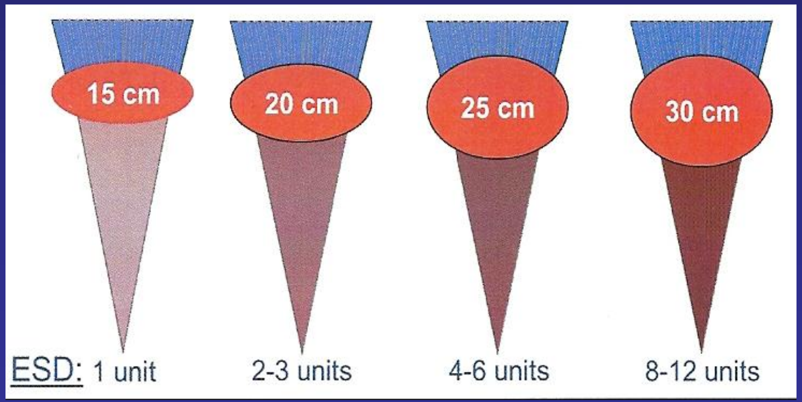
Because of the high doses in cardiology procedures, dose optimization is needed for patient protection !

Practical Dose Reduction Practices

- **Keep beam-on time to an absolute minimum . Record the time.**
  However, time is not a good indicator of dose.

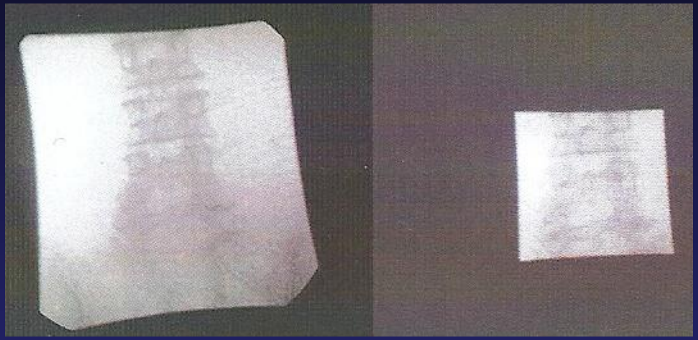


- **Remember that dose rates will be greater and dose will accumulate faster in thicker patients. Therefore reduce time.**

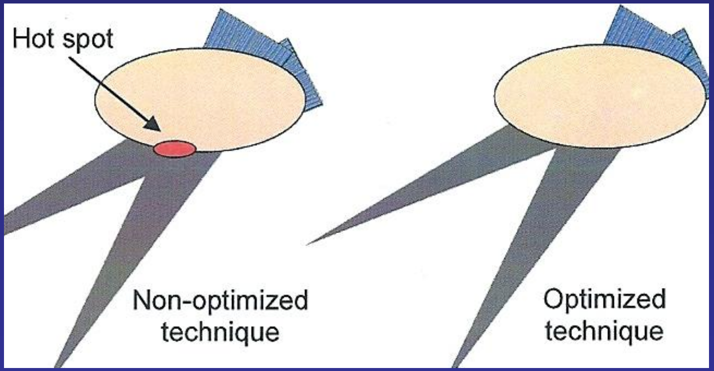


Practical Dose Reduction Practices

- Collimate the beam. Bigger x-ray field results to higher patient dose.

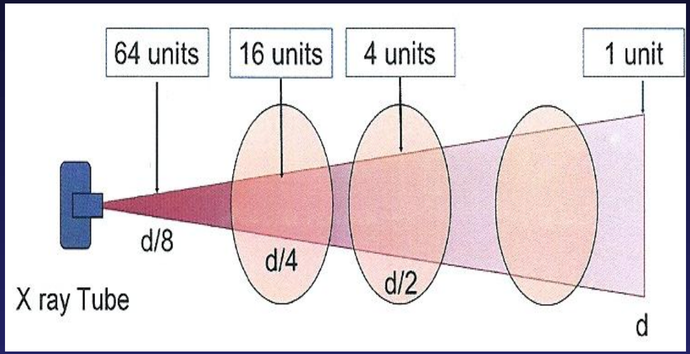


- Avoid exposing the same area of the skin. Use different beam entrance port.

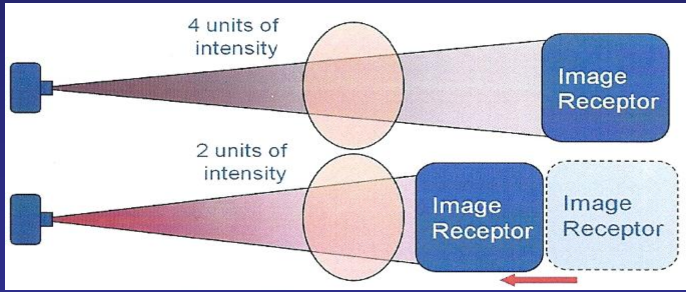


Practical Dose Reduction Practices

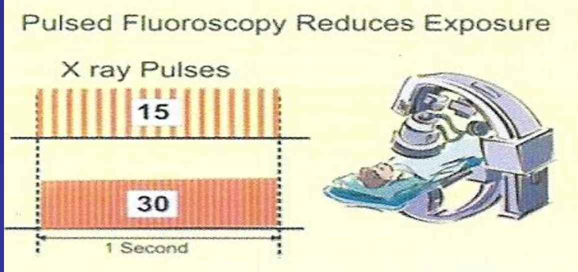
- Keep the X Ray tube at maximal distance from the patient.



- Keep the image receptor as close to the patient as possible.



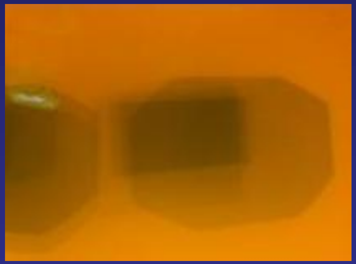
- Use pulsed fluoroscopy



Practical Actions in Controlling Dose

- Records of dose should be kept if the estimated maximum cumulative dose to skin is 3Gy or above.
- All patients with estimated skin doses of 3 Gy or above should be followed up 10 to 14 days after.
- The patient's personal physician should be informed of the possibility of radiation effects.
- If the dose is sufficient to cause observable effects,
- the patient should be counseled after the procedure.
- A system to identify repeated procedures should be set up.

dose assessment



Film

TLD

QA/QC is needed for optimizations of protection.

Perform routine and annual QC tests and make corrections when needed.

Establish image quality criteria

Monitor patient doses and ensure that skin doses do not reach more than 2 Gy.

Record patient skin doses and review protocols to lower patient doses.

IAEA Research Projects on Radiation Protection

Year 2002 – 2 coordinated research projects on patient dose optimization and establishing guidance levels

Year 2004 – training of cardiologists

Year 2005 – IAEA launched regional projects on avoidance of skin injuries in IR

IAEA Research Projects on Radiation Protection for patient and Staff Safety

Year 2005 – 2007 - a research project for Saudi Arabia on "Developing a National Core of Expertise in Radiation Safety for Patient Protection in Interventional Radiology Practice in Saudi Arabia"

Year 2007 – launched the Asian network of cardiologists in radiation protection

Year 2008- research study on Retrospective Evaluation of Lens Injuries and Dose (RELID)

IAEA Recommendations for Avoidance of Skin Injuries

- Establish grade levels for single exposure for skin injuries following the National Cancer Institute:

  0- 2 Gy – no grade

  2-5 Gy – Grade 1

  5-10 Gy – Grade 1-2

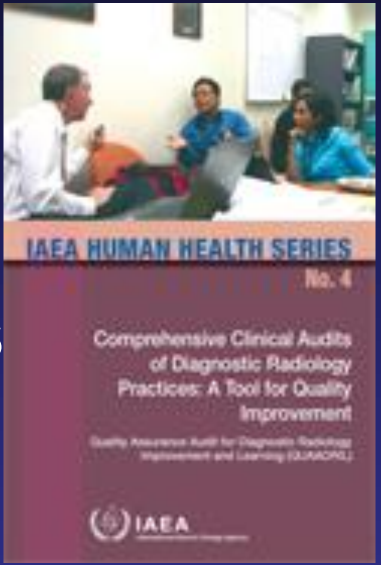
  10-15 Gy – Grade 2-3

  > 15 Gy - Grade 3-4

- For no overlap of beams, consider doses separately
- If it is likely to overlap some part of the skin, increase the time between exposures.

IAEA Recommendations

- **Creation of awareness through training courses**
- **Monitoring of the practice of radiation protection**
- **Creation of network of cardiologists in radiation protection**
- **Wider communication among community of interventional radiologists**
- **Patient and staff dose monitoring should be implemented.**



Practices for Staff Dose Reduction

- Reducing patient doses reduces staff doses
- Use of protective shields especially lead goggles for eye protection.
- Avoid to be in the direction of the beam.
- Stay in the image receptor side.

Lead goggles

Lead screen

Thyroid shield

RADIATION DOSE TRENDS: THE KFSHRC STUDY

KFSHRC- CARDIOLOGY

The KFSHRC has the largest Cardiac Centre in Saudi Arabia.

For cardiology interventional and diagnostic procedures it has :

- ***2,000*** **pediatric patients per year**
- ***3,000*** **adult patients per year**

Objectives of the study

To assess patient doses in cardiac catheterization procedures and determine the trends.

To determine factors that contribute to high doses.

Research Project Concept

- ☞ Identify IR procedures that give high patient entrance doses
- ☞ Identify causes for high doses
- ☞ Recommend dose reduction techniques
- ☞ Develop a data base of patients doses
- ☞ KFSHRC to be the center for training in radiation protection in interventional radiology

Procedure & Room Selection

Pediatric - Cardiac Procedures

- COA dilatation
- Diagnostic
- Pulmonary
- PDA occlusion

Only one room dedicated for pediatric patients was used in the study.

Adult Patients

1. Cardiac Procedures

- Coronary angiography (CA)
- Percutaneous Transluminal Coronary Angiography (PTCA)

2 rooms were included in the study.

Patient Data

Patient number
Age
Weight
Height (pediatrics only)
Gender

Machine Data

Manufacturer
Type
HVL
AEC

Procedure Data

- Name of procedure
- Room Number
- Technique factors: kVp, mA, fluoro time
- Projections
- Frame rate
- No. of frames for cine radiography
- Magnification
- DAP readings

Patient Dosimetry Techniques Used

- Dose area product meter
- Films

Dose Area Product Meter
(Parallel plate ion chamber)

EDR2 Film
(can measure up to 1 Gy)

ISP Gafchromic XR Type R Film
(can measure up to 8 Gy)

Patient skin dosimeter was considered but was not favorable with radiologists.

Film Dosimetry

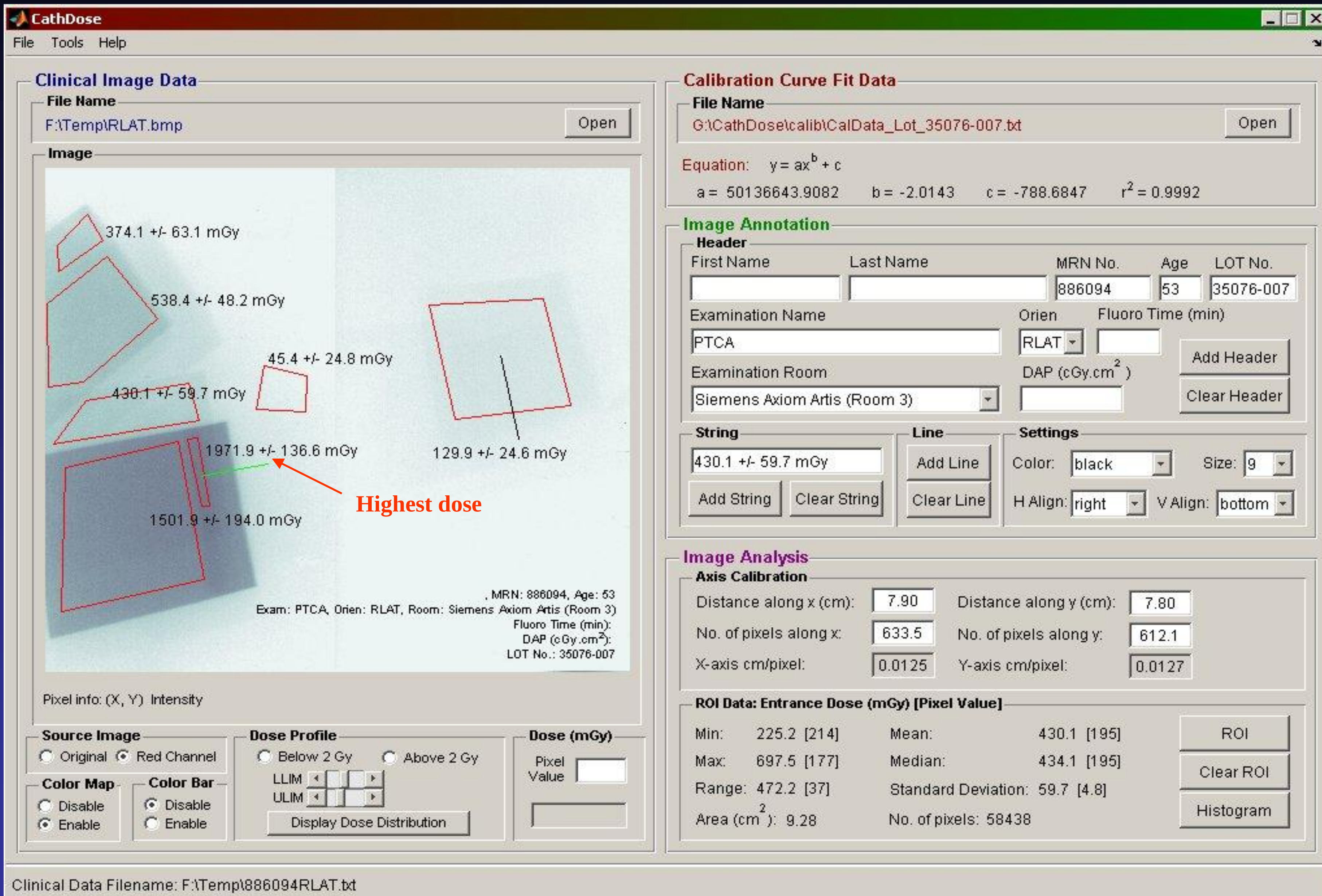
Maximum skin doses were determined from the calibration curves of the *EDR 2* and *radiochromic films*. Evaluation of the radochromic films was made using the KFSH&RC software Mathlab based program.

Film Set-up

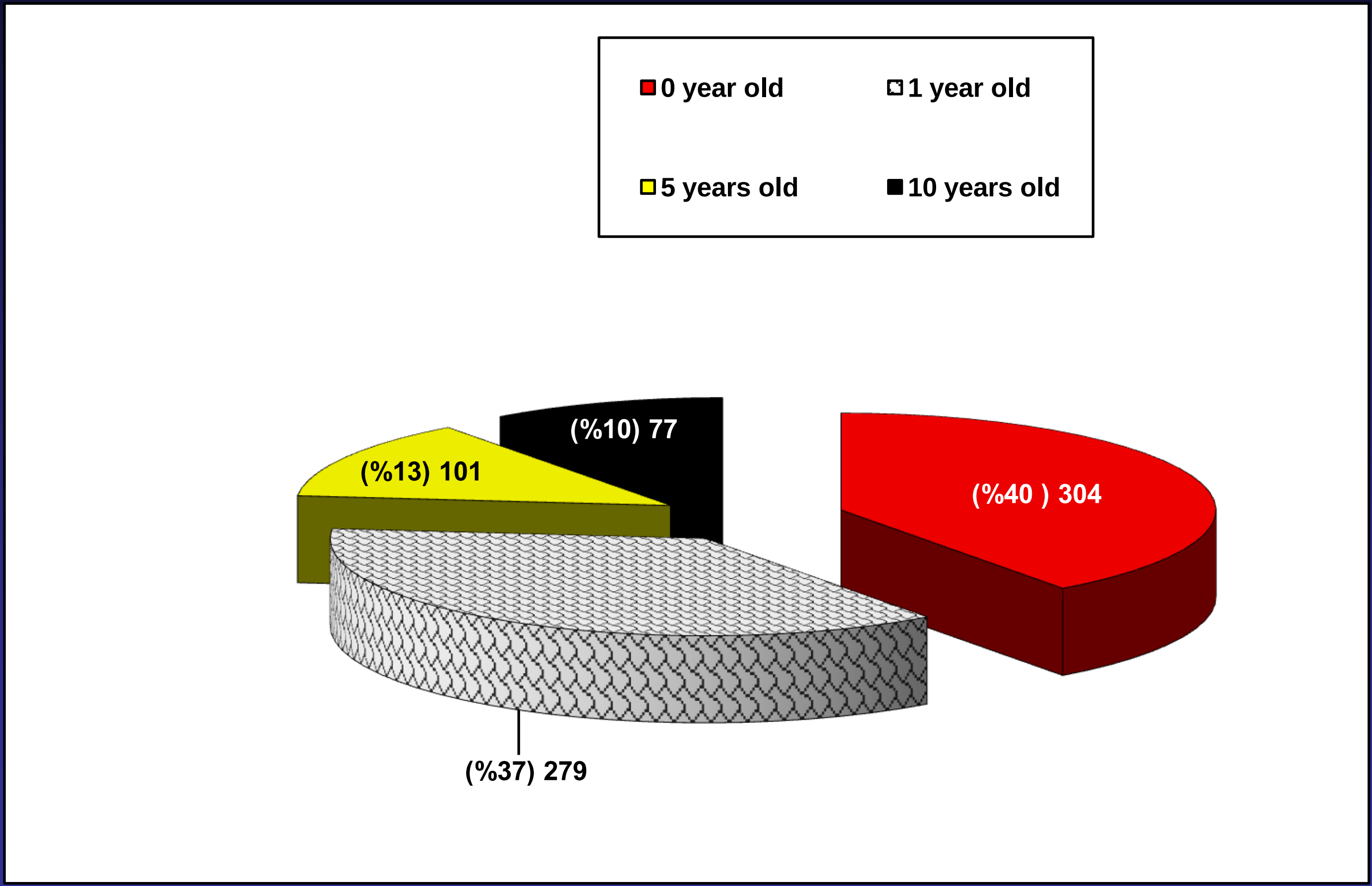
EDR 2 Film (saturation is about 1 Gy)

Illustration of Gafchromic films wrapped around the patient (saturation is about 8 Gy).

Dose Analysis using the Software Program



KFSHRC Research Project Data
Pediatric Cardiac Catheterization Procedures



Total No. of cases: 761

Pediatric Cardiac Catheterization Procedures

Mean values of the DAP, effective dose and total number of frames for each procedure in a large medical centre in Saudi Arabia

Procedure	No. of Frames Mean (SD)	DAP ($Gy\text{-}cm^2$) Mean (SD)	Effective Dose (mSv) Mean (SD)
COA dilatation	2,123 (1,782)	11.35 (24.35)	11.3 (11.9)
PDA occlusion	1,022 (637)	23.21 (101)	19.9 (81.3)
Diagnostic	1,230 (838)	7.77 (14.33)	8.7 (10.7)
Pulmonary	2,472 (4,344)	9.96 (15.14)	12.3 (14.3)

One PDA patient has an extremely high DAP value.

Adult Cardiac Catheterization Procedures

Patient profile on the number of cases, gender, height and weight.

Procedure	Weight (kg) Mean (SD)	Mean Age (yr)
CA	68.9 (17)60	60
PTCA	79. (13)	62

Localized Skin Dose and DAP Values for Cardiac Procedures

Procedure	Ave. kVp	Fluoro time (min) Mean	Max	Min	Loc. skin dose (mGy) Mean (SD)	Max	DAP (Gycm^2) Mean (SD)
CA	73	5.9 (3.8)	11.4	2	580 (244)	994	58 (43)
PTCA	87	25.4(13.7)	54.7	10.1	1,961(897)	3,556	145 (83)

Patient Doses for Adult Cardiology Procedures from other Studies

Study	Mean DAP (Gy-cm^2)		
	UK	Singapore	Greece
CA	26	35	39.9
PTCA	_	36.2	79.3
CA+LV	_	36.2	29.9

FINDINGS & CONCLUSION

- The age groups 0 and 1 year old constitute the largest percentage of patients (73%) and are found in all procedures. Review of protocols to reduce mA, fluoro time and cine frame rate is recommended.

- There is a wide variation in patient trunk thickness and weight but the computed average ECD $\pm 1\sigma$ for all age groups is in good agreement with the standard trunk sizes published by NRPB. ($ECD = 2[(w/\pi \cdot h)]^{0.5}$)

- *PDA* showed the highest mean value for DAP and this is due to extremely high dose of one patient. The mA and cineradiography could have contributed to the high dose.

- The high mean DAP value for *COA* and *pulmonary* is due to the contribution of cine. Cine series should be reduced.

FINDINGS & CONCLUSION

- Correlation of fluoro time is weak in all procedures due to high variation. There is a need to have a standard image quality criteria and review training needs of operators both for adult and paediatric procedures.
- Exposure techniques for pediatric and adult procedures should be standardized.
- Reduction of fluoro time for *PTCA i*s needed.
- *PDA* for pediatrics and *PTCA* for adults can exceed the threshold value of 2 Gy for skin erythema. Protocol should be reviewed for dose reduction.

Practical Dose Reduction Practices

- Collimate reduces field size
- Limit use to necessary evaluation of moving structures.
- Employ last-image-hold to review findings
- Avoid unnecessary/Inadvertent fluoro – Make Aware!
- Make use of the time bell warning
- Reduce fluoroscopy pulses/sec to as low as possible/suitable (7 or 3/ sec)
- Use low frame rate (4 or 2 or 1/sec


Thank you !

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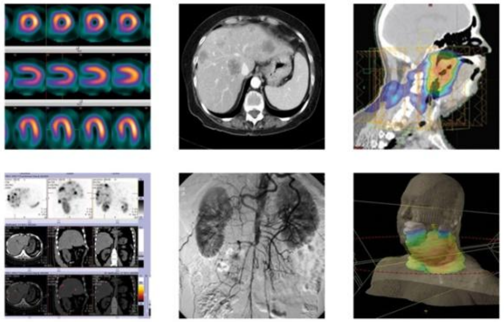

OBJECTIVES OF THE CONFERENCE

- To highlight the role of Medical Physicists
- To give an overview of Postgraduate Education and Training Programs
- To be aware of new Developments and Implementations of Relevant Technologies in Medicine.

TOPICS OF THE CONFERENCE

- Scope of Practice, Activities and Duties of the Medical Physicist
- Role and Importance of the Medical Physicist in the Hospitals
- Postgraduate Education and Training Programs
- Molecular Imaging; PET/CT and PET/MRI
- Molecular Imaging Guided Radiation Therapy Treatment Planning
- Proton and Particle Therapy
- Latest Advances in Conventional Radiation Therapy and Gamma Knife
- Overview of MRI system and Digital Mammography
- Quantitative Analysis
- Safety Concerns in MRI and in Fluoroscopy Based Equipment
- Dose Reduction in Digital Equipment and CT
- Radiation Protection in Radiological Imaging

TARGET PARTICIPANTS

- Medical Physicists
- Radiologists
- Radiation Oncologists
- Clinical Scientists
- Radiological Technologists
- Radiation Therapists
- Nurses
- Biomedical Engineers
- Students

CME CREDIT HOURS

30 CME Hours

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- **REGISTRATION FEES**

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Students:
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