Medical Staff Dosimetry

Simulation of an Interventional Cardiac Catheterization Procedure

Medical Staff Dosimetry

Restricted Problem – CONRAD WP4 & WP7

Jean-Marc Bordy -	Design of a Realistic Calibration Field for Diagnostic Radiology
Frank Schultz -	Simulation of an Interventional Cardiac Catheterization Procedure
Lara Struelens -	Summary of the Submitted Problem Solutions

Labs involved in problem definition and analysis:

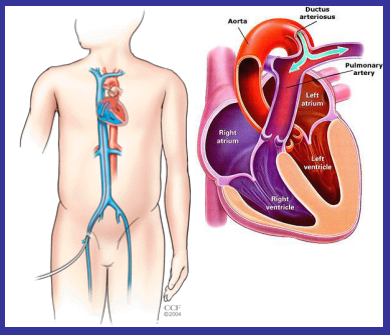
Outline

Background info on
- **Interventional Cardiology**
- **Individual Monitoring**

Introduction to
- **The Medical Staff Dosimetry Problem (P2)**

Interventional Cardiology

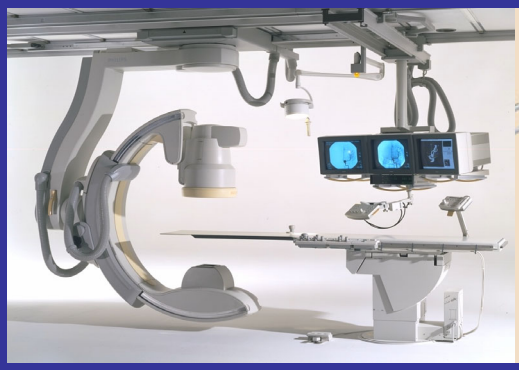
Image guided minimal invasive medical procedure
Replaces open heart surgery



catheters and miniaturized instruments

RF ablation – heart rhythm disturbance
Patent DA occlusion – disconnect shunt
ASD closure – close hole in chamber wall
balloon dilatation – open clogged artery
diagnostic catheterizations

Fluoroscopy guided catheterization



UMCN, Nijmegen

Cath Lab - UCSF

Relevance: Individual monitoring

- Protection of workers exposed to ionizing radiation
- EC council directive 96/29/Euratom, 1996
  → national legislation
  - Monitoring personal dose (effective dose)
  - Dose limits
- Personal dosemeter (TLD or film badge, APD)
  - Personal dose equivalent, $H_p(10)$
  - Registration in National Database

Complication

(highly) exposed workers wear protective clothing

- dosemeter outside apron or under apron?
- position of dosemeter?
- correction factor?

what relation?

- dosemeter reading $\leftrightarrow$ $H_p(10)$ $\leftrightarrow$ E $\leftrightarrow$ risk

Problem, P2

Simulate an interventional cardiology procedure (heart catheterization)

Monte **C**arlo technique

Provided:

- Geometry
- Technical parameters
- Materials properties

Requested:

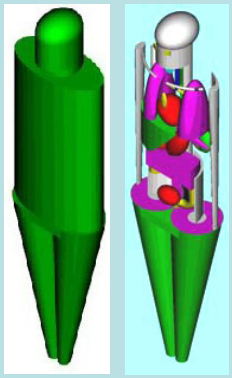
- Dosemeter reading at 3 positions on cardiologist,
  - without protective clothing
  - outside or under the apron
- Organ doses (effective dose) to the cardiologist

per unit Air Kerma Area Product

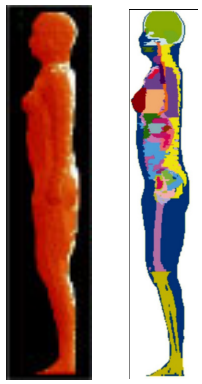
Objective:

Variation in personal dose estimates due to different participants simulating a clinical situation

Free Choice of Anthropomorphic Phantoms



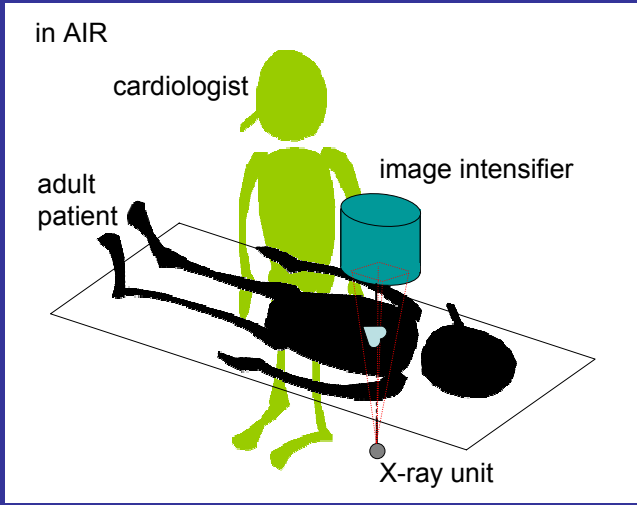
Mathematical, ADAM
(adult male) 1986
GSF Bericht S-885



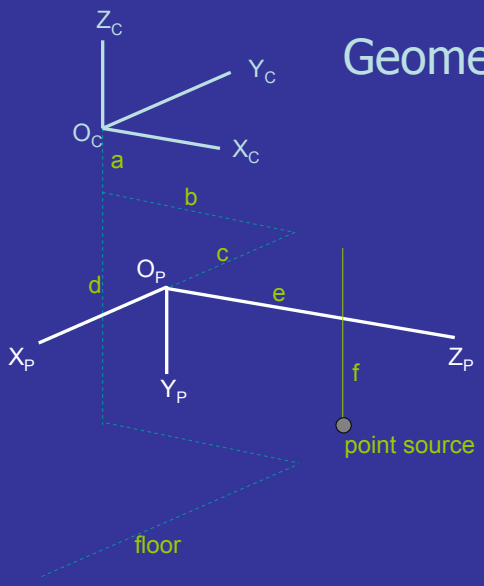
Voxel, FAX
(adult female) 2004
Phys. Med. Biol. 49: 5203–5216

Voxelized CT model, Rando phantom (adult male) 2004
Rensselaer Polytechnic Institute
www.phantomlab.com/rando.html

PA irradiation



Geometry



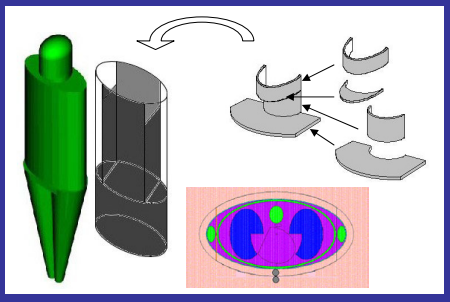
O_C: "cardiologist" phantom ADAM
O_P: "patient" phantom ADAM

distances (cm):
a = 76-(80+10) = -14
(O_c below O_p!)
b = 0
c = (55/2)+2+2+10 = 41.5
(table, dosemeters on and under the apron, ½ cardiol. thickness)
d = 80+10 = 90
(table, ½ patient thickness)
e = 51
(position of the heart region)
f = 65+10 = 75
(FSD, ½ patient thickness)

Protective clothing

The cardiologist may wear a wrap-around protective apron of **0.35** mm Pb-equivalent material, leaving the arms free

In combination with the apron he also wears a thyroid collar of the same material and thickness



Wrap-around apron and thyroid collar;

example, in case the mathematical phantom ADAM is being used to represent the cardiologist.

The collar covers the front half of the neck, the underside of the chin and part of the lower mandible (in ADAM, from Z_C=70 through Z_C= 75, to fully shield the thyroid). A part of the trunk's top surface is also covered, connecting to the apron's front side.

Dosemeter

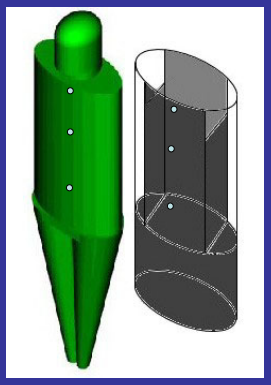
Sphere with radius of 1 cm
Filled with ICRU 4-element tissue
Dosemeter reading is absorbed dose to the center, "$H_P(10)$"

Dosemeters are worn on the front of the trunk at 3 levels:
- waist
- chest
- neck,

either outside or under the apron

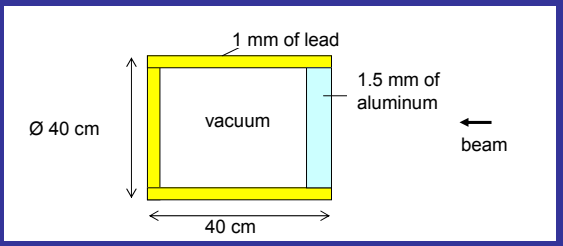
When using the ADAM phantom, the choice would be
- waist: Z_C= 20 cm
- chest: Z_C= 50 cm
- neck: Z_C= 69 cm,

in the sagittal plane of symmetry



Other objects

Image Intensifier (II)

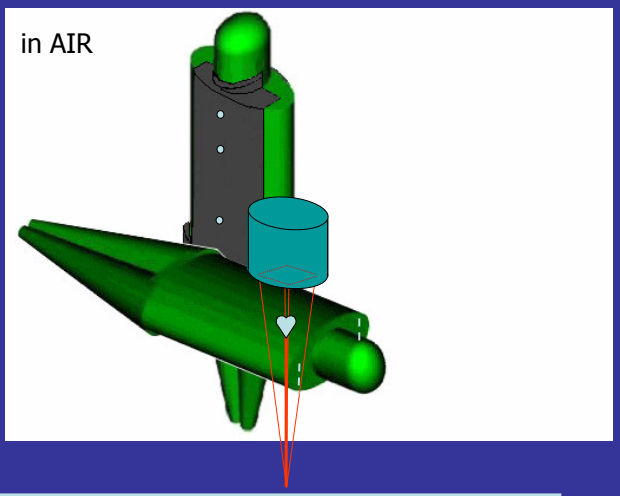


L.Struelens, SCK•CEN

Patient table
Not modeled; width = 55 cm, surface at 80 cm above floor
Cardiologist leans against the table

Air
Surrounding dry air is present, with composition and density according to ICRU specification

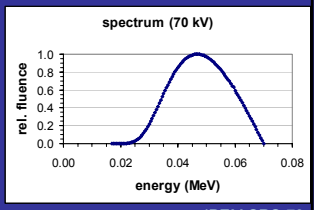
Geometry for 2 ADAM Phantoms



Technical parameters

Beam quality:
X-ray beam of **70** kV
Filtration: 4.5 mm Al + 0.2 mm Cu

Anode angle is 12 degrees
The generator is assumed to show 0% ripple



IPEM SRS-78

Distances:
FSD = 65 cm
FID = 95 cm

Field size:
17 cm x 17 cm at image intensifier

Materials

material: **fraction by weight**

element	PMMA	water	ICRU tissue	ICRU air	aluminum	lead
hydrogen	0.080538	0.111894	0.101	-	-	-
nitrogen	-	-	0.026	0.755268	-	-
oxygen	0.319614	0.888106	0.762	0.231781	-	-
carbon	0.599848	-	0.111	0.000124	-	-
argon	-	-	-	0.012827	-	-
aluminum	-	-	-	-	1.0	-
lead	-	-	-	-	-	1.0
density (g cm^{-3})	1.19	1.0	1.0	1.205×10^{-3}	2.699	11.35

Tasks

2.1 Calculate "dosemeter readings" per unit of dose area product, at waist, chest and neck level

a) **without protective clothing**
b) **above the 0.35 mm Pb wrap-around apron**
c) **under the 0.35 mm Pb wrap-around apron**

reference values for Individual Monitoring Protocol?

and, optionally,

2.2 Calculate effective dose to the cardiologist per unit of dose area product,

a) **if no protective clothing is worn**
b) **if the cardiologist wears a 0.35 mm Pb wrap-around apron (+ thyroid collar)**

reference values for SWG2?

Participants' Solutions

See next lecture:

Lara Struelens -	**Monte Carlo modelling for medical staff dosimetry**

Questions / Comments?

Frank Schultz - Simulation of an Interventional Cardiac Catheterization Procedure