ICTP/IAEA Training Course on
Radiation Protection of Patients
September 16 - 27, 2013, Trieste, Italy

UDINE EXPERIENCE IN RADIATION DOSE MANAGEMENT

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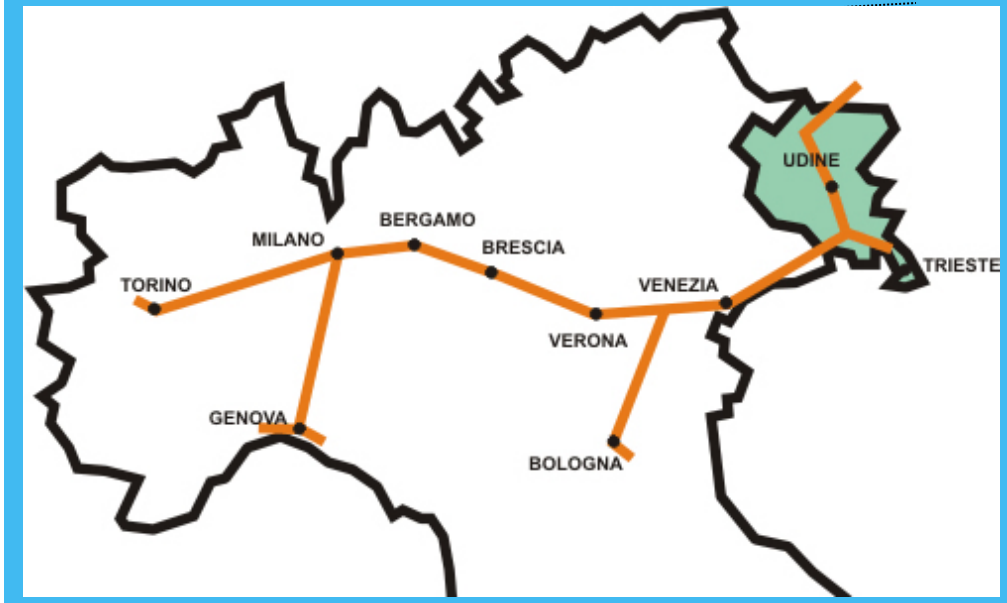
UDINE
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BRESCIA
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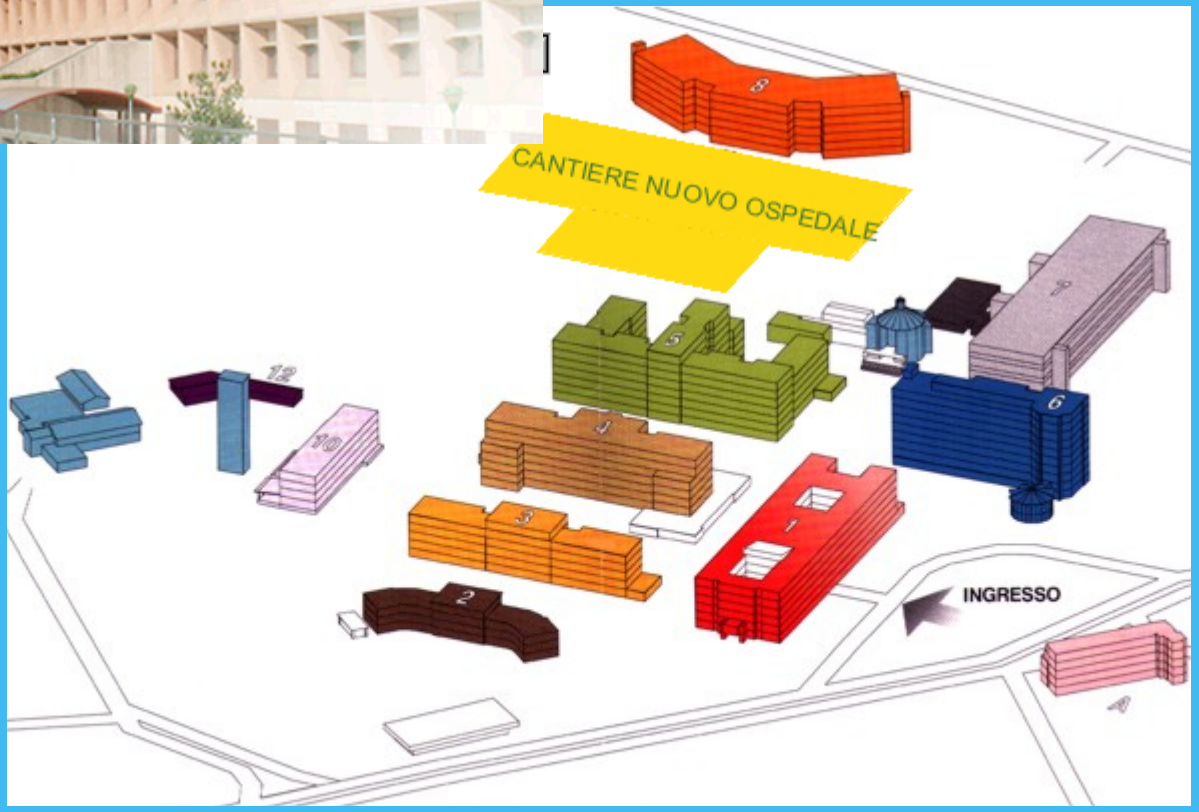
GRADO

UDINE HOSPITAL



UDINE HOSPITAL

- Public, general & university hospital
  1000 beds, 4500 workers
  - Imaging Dpts
    - 40 radiologists, 100 technicians
    - 3 MRs, 1 PET/CT, 1 SPECT/CT, 4 CTs, 6 angio rooms
    - 3 digital mammo, 1 tomosynthesis mammo
    - 10 radiography rooms, 40 mobile equ. 3 gammacamera
  - Radiotherapy Dpt
    - 9 oncologists, 15 technicians
    - 4 linacs (IMRT, VMAT, IGRT), 1 mobile linac (IORT), 1 brachytherapy
  - Medical Physics Dpt
    - 8 medical physicists, 6 technicians

  (all systems are digital, hospital/regional RIS/PACS)

CONTENTS

- Introduction
- Dose Management
- Research activities

WHY?

We are practicing in an era of increased <u>emphasis on patient safety</u>

- NCRP 160 (2007) and Mettler et al. (2008):
  - Dose to population (Effective Dose in mSv) double in the last 20 ys
    3.6 mSv/y (1980) → 6.0 mSv/y (2006)
  - Radiation exposure due to medical practice increased from 15% of 1980 to 50 % in 2006 (it could be more in 2013!)

WHY?

It's stated by regulation: mandatory since 1996

- Justification →
  - To determine risk-benefit
- Optimization →
  - To guarantee appropriate protocols and procedures
  - To evaluate the impact on patient dose of new techniques and protocols
- Dose evaluation→
  - To establish Diagnostic Reference Levels (DRL)
  - To monitor and follow up high dose patients

WHAT CAN WE DO?

- **Reduce** the risk of stochastic effects for operator, staff, and patient
- **Prevent** most tissue effects such as radiation - induced cataracts and skin injuries
- **Recognize** situations where a high probability for injury exists so the patient can be appropriately medically managed

PRE-PROCEDURE

IDENTIFY HIGH-RISK PATIENTS

- Certain conditions are suspected to pre-dispose patients to radiation induced skin injuries (i.e. Diabetes mellitus, Connective tissue disorders, drugs, …

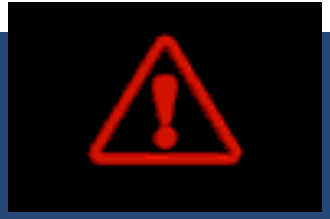
- Also, a recent high dose procedure can result in the induction of effects at lower doses in the future (ICRP 85)
  - → privilege fluoro instead of acquisition runs
  - → postpone procedure ?
  - → prefer other practices ?

EQUIPMENT

- **Dedicated equipment:**
  - **Spectral beam shaping**
  - **Pulsed fluoroscopy (often at reduced frame rates)**
  - ***Store Fluoro* function**
- **Compliance with standards (IEC 60601 - 2 – 43 interventional fluoro safety standard):**
  - **Dosimetric indicators display**
  - **Low dose flruoroscopy mode**

- **Evaluate the impact of new technologies**

EQUIPMENT



Performance of a 41×41 cm^2 amorphous silicon flat panel x-ray detector designed for angiographic and R&F imaging applications

Paul R. Granfors[a)] and Richard Aufrichtig
G.E. Medical Systems, c/o PerkinElmer Optoelectronics, 2175 Mission College Boulevard, Santa Clara, California 95054

Med. Phys. 30 (10), October 2003

DOSES IN CARDIAC PROCEDURES?

A. Trianni[1,2]

angiographic and R&F x-ray imaging systems. The results indicate that the detector enables very good image quality in these systems. Of course, the quality of images from an x-ray imaging system is determined by other components in addition to the detector. Future studies will evaluate the technical performance of the x-ray imaging system which includes, in addition to the detector, all of the other components necessary to produce clinical images: the x-ray source, collimator, detector calibration by the system, x-ray anti-scatter grid, image processing, display, and so forth. Finally, the ultimate test of an x-ray system is in the performance achieved in clinical imaging.

are they?

Eur Radiol (20
DOI 10.1007/s

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EQUIPMENT

Radiation Protection Dosimetry (2005), Vol. 117, No. 1–3, pp. 97–101
doi:10.1093/rpd/nci747 Advance Access published on February 3, 2006

ARE NEW TECHNOLOGIES ALWAYS REDUCING PATIENT DOSES IN CARDIAC PROCEDURES?

A. Trianni[1,2,*], G. Bernardi[3] and R. Padovani[1]

Table 1. Results for CA procedures in terms of mean total dose–area product (DAP), fluoroscopy time and relative contribution of fluoroscopy and acquisition mode to total DAP.

CA	Mean fluoroscopy time (min)	Mean DAP (Gy cm^2)	DAP Fluoro (%)	DAP Cine (%)
II system	4.3 ± 4.5	31.1 ± 30.2	32	68
FPD system	4.3 ± 3.8	33.4 ± 19.1	41	59

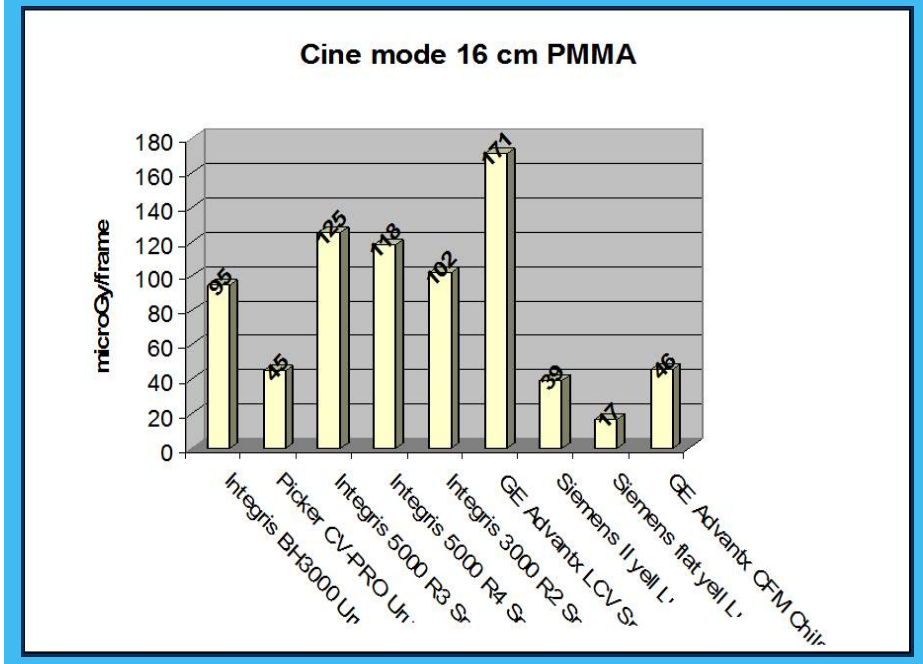
Table 2. Results for PTCA procedures in terms of mean total DAP, fluoroscopy time and relative contribution of fluoroscopy and acquisition mode to total DAP.

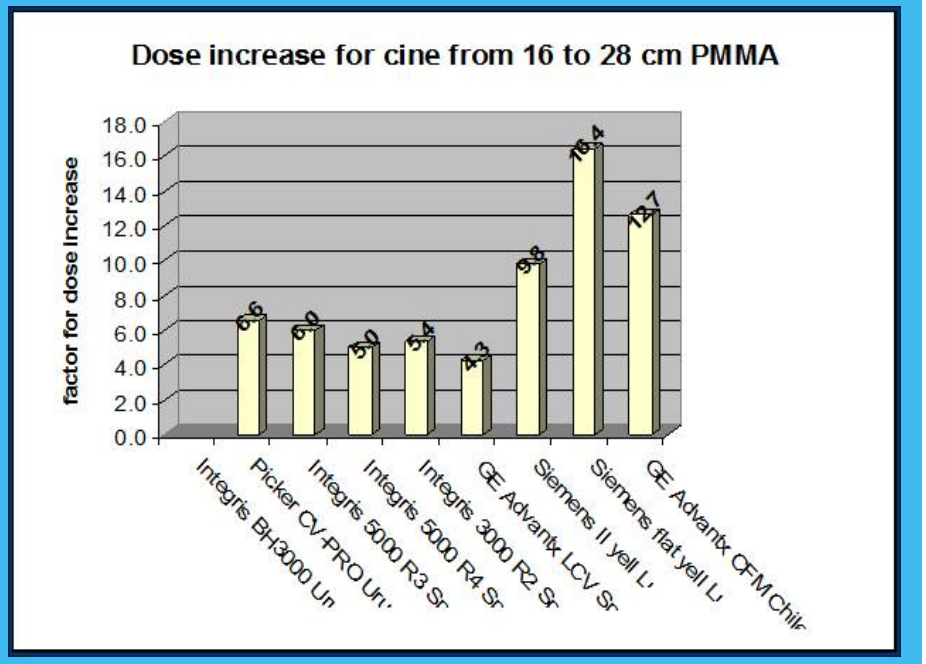
PTCA	Mean fluoroscopy time (min)	Mean DAP (Gy cm^2)	DAP Fluoro (%)	DAP Cine (%)
II system	11.4 ± 9.3	52.0 ± 45.0	56	44
FPD system	10.7 ± 8.7	66.9 ± 54.4	52	48

When compared, angiographies based on DFP detectors have higher sensitivity than systems based on II. The DFP system, in fact, produces images at comparable or higher quality with lower entrance dose rates, compared to the II system. However, if the two systems use different settings in the clinical practice, the final performances in terms of patient dose could give the opposite result. DAP and MSD

EQUIPMENT

CRITICAL POINT → protocol configuration





SENTINEL → ESAK to a 20 cm PMMA phantom for cardio low dose fluoroscopy 13 mGy min^{-1} (Padovani et al., RPD 129:1-3; 2008)

EQUIPMENT

PROTOCOLS OPTIMIZATION

- IQ depends on the type of procedures (cardiac, vascular, neuro,..) and can change during the procedures itself
- IQ strictly related to dose

- Needs to adapt IQ level to different procedures and steps of procedure (fluoroscopy → few µGy/p; fluorography → hundreds µGy/im; DSA → some mGy/im)

ESSENTIAL COLLABORATION
OPERATOR/PHYSICIST/RADIOGRAPHER/FIELD ENGINEER

EQUIPMENT

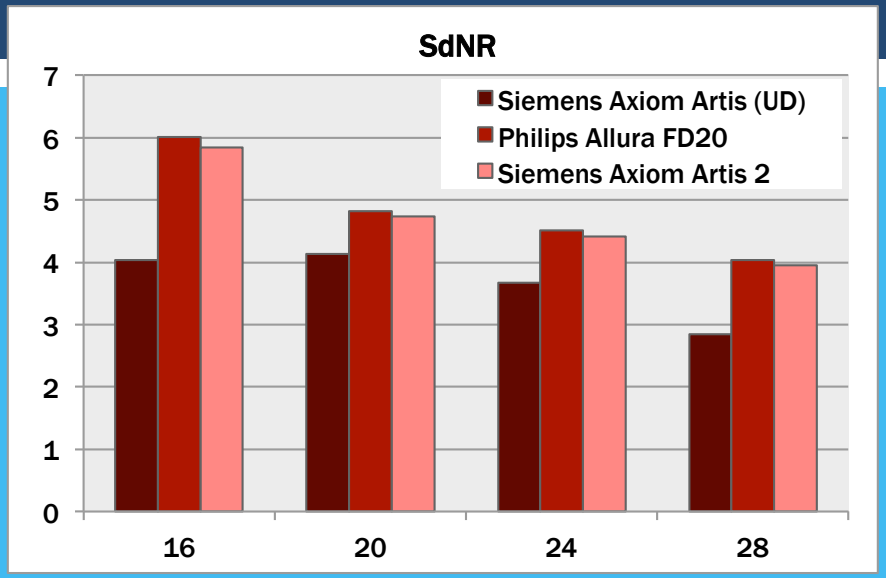
APPROPRIATE MAINTENANCE AND QC (acceptance test + constancy tests 1-2 times/year)

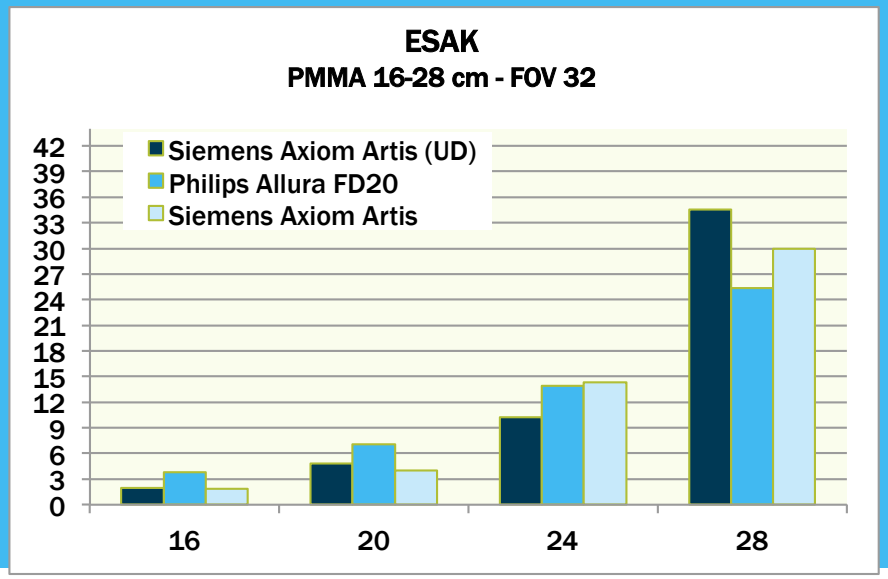
- Example:
  - IR angio system compared with other two angiographic equipment dedicated to the same procedures in terms of:
    - Entrance surface air kerma rates (ESAK) for different thickness of PMMA absorber placed on patient coach
    - Image quality (IQ) assessed using the Leeds TOR 18-FG phantom and evaluating the signal difference to noise ratio (SdNR)

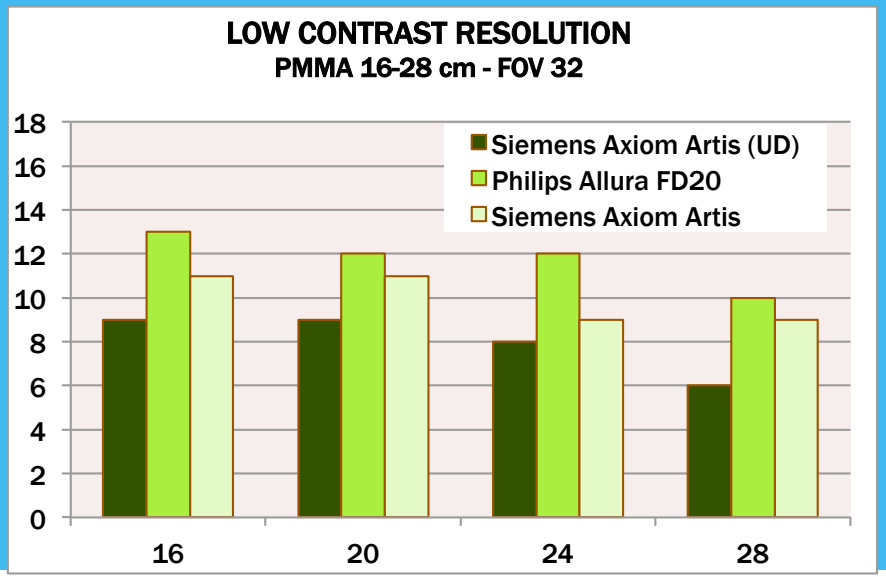
EQUIPMENT

- Comparable doses
- Worst Image Quality

- Wrong detector calibration

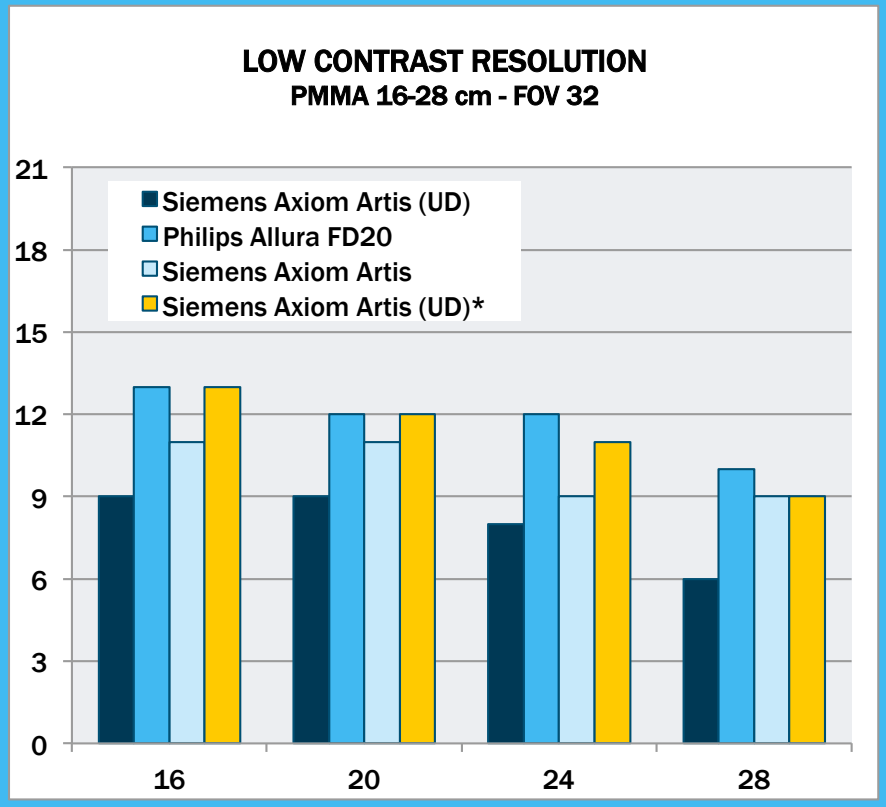


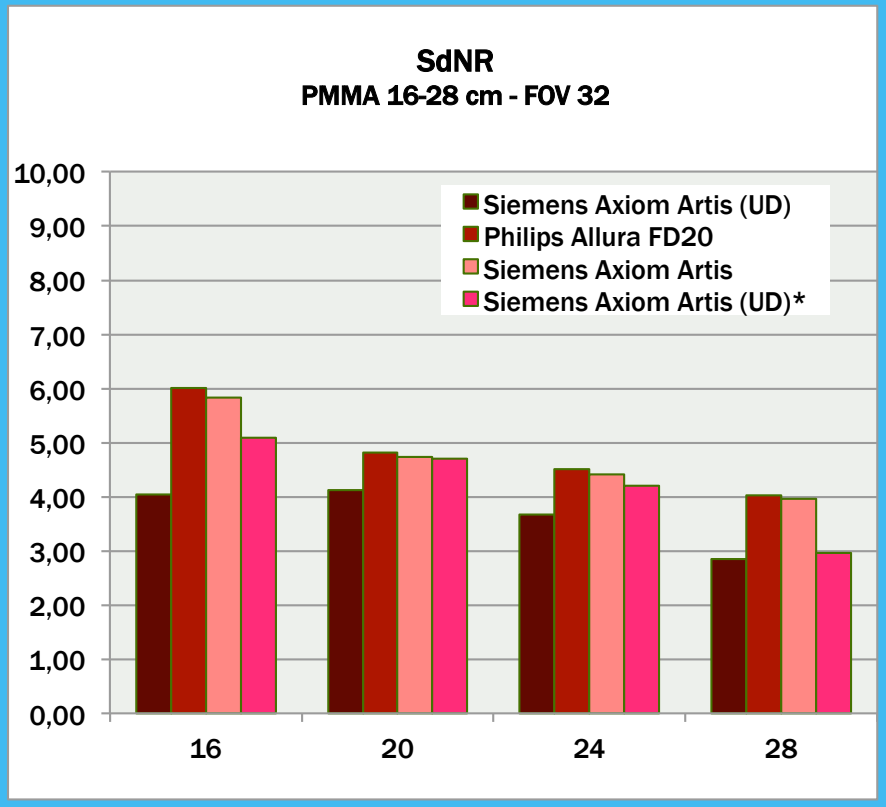




EQUIPMENT

After recalibration of FPD





EQUIPMENT

To evaluate the impact of equipment performance on FT, KAP and CK, two samples of patients who underwent liver interventions performed, respectively, before and after detector's recalibration, have been compared using Mann-Whitney non parametric test.

	Before May 2009 (144 procedures)			P	After May 2009 (98 procedures)		
	Mean	St.Dev.	Range		Mean	St.Dev.	Range
FT (min)	14.1	7.7	2 ÷ 38.6	0.04	12.0	7.1	2 ÷ 38.1
KAP (Gycm²)	215.7	139.5	24.5 ÷ 598.4	0.02	170.8	158.1	18.2 ÷ 1282..8
CK (mGy)	1136,3	767.9	123 ÷ 4729	0.03	968.5	645.4	137 ÷ 2677

TRAINING OF PHYSICIANS AND STAFF

- Physicians performing fluoroscopically-guided procedures should be trained in the safe use of fluoroscopic equipment
  - To understand dose saving features of each type of equipment on which they work
  - To understand the tools available to reduce patient dose
  - To understand the meaning of dose indicators available

→ Regular Courses:

- Basic radiation protection: 4-5 courses/year
- Advanced: every 5 years

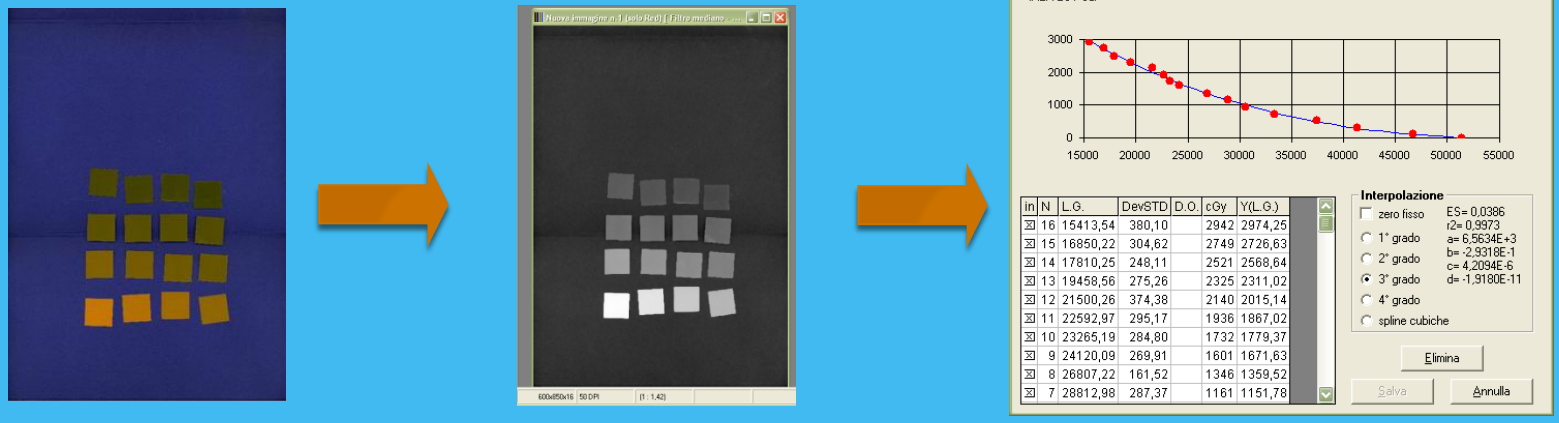
INTRA – PROCEDURE

TRIGGER LEVELS

- All equipments manufactured after June 2006 are required by law to display the Cumulative Air Kerma (CK) at the Interventional Reference Point (IRP)
- Alerting the physician when the CK reaches certain values (TRIGGER LEVELS) guarantees there are no surprises at the end of a case (skin burns)
- Decisions can be made based on medical management at each threshold

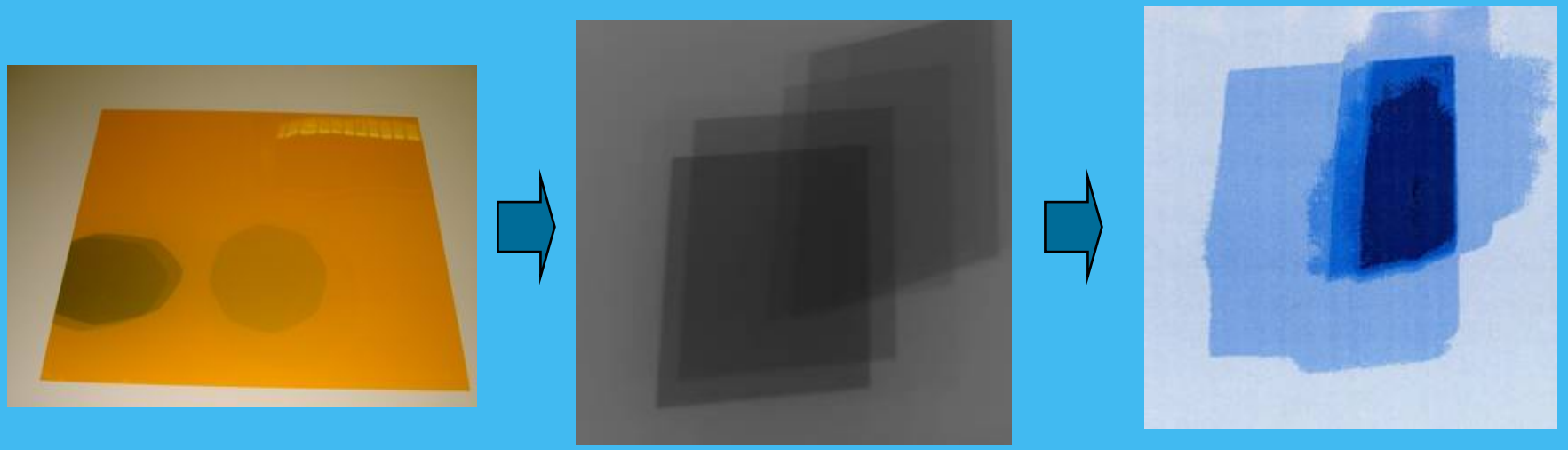
TRIGGER LEVEL ASSESSMENT

- Skin dose has been measured in a sample of patients for some high dose interventional procedures using radiochromic films (Gafchromic XR-TypeR):
  - Used in the hospital since 2004
  - Tested in a international project (IAEA CRP)
  - Proper calibration:



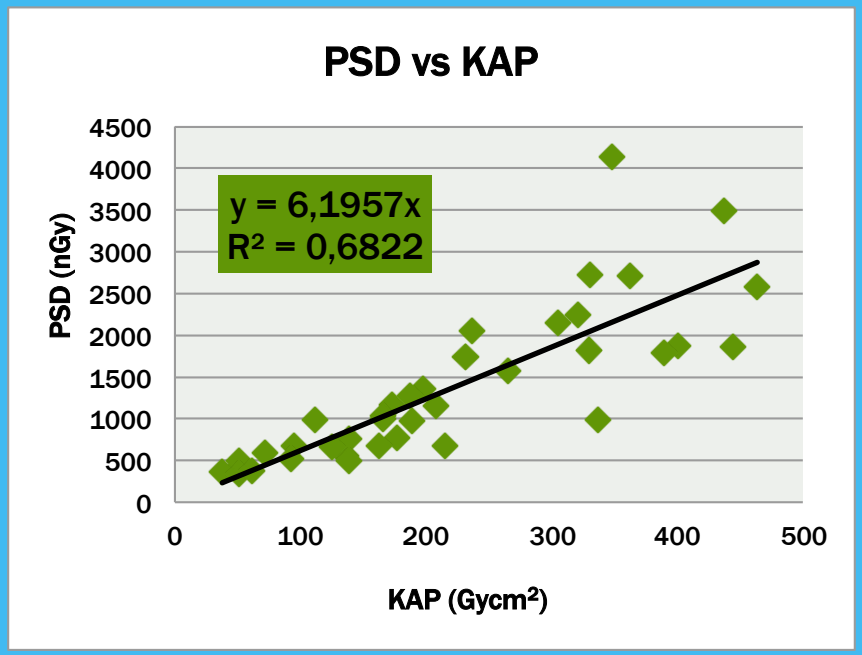
TRIGGER LEVEL ASSESSMENT

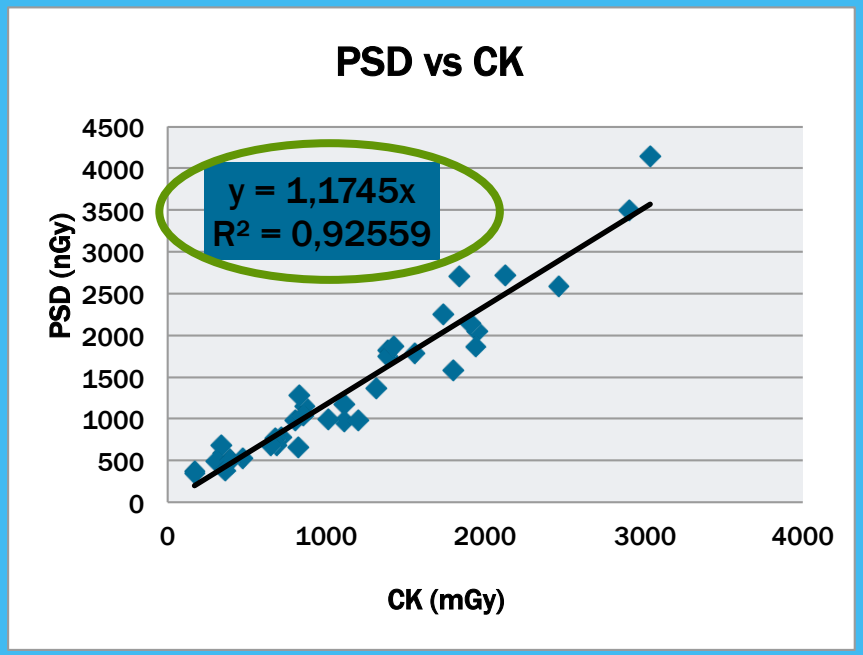
1. The patient film is acquired with the scanner in manual mode, with the parameters registered/stored in the calibration procedure.
2. The red component of the image is selected.
3. The image can be smoothed with a 5x5 filter.
4. The red levels (GL) of the extracted image is converted to entrance dose to air applying the calibration curve.



TRIGGER LEVEL ASSESSMENT

- Trigger levels based on the correlation inbetween MSD and Dosimetric indicators:





TRIGGER LEVELS

NCRP 168

TABLE 4.7–*Suggested values for first and subsequent notifications and the SRDL.*

Dose Metric	First Notification	Subsequent Notifications (increments)	SRDL
$D_{skin,max}$	2 Gy	0.5 Gy	3 Gy
$K_{a,r}$	3 Gy	1 Gy	5 Gy[a]
P_{KA}	300 Gy cm^2 [b]	100 Gy cm^2 [b]	500 Gy cm^2 [b]
Fluoroscopy time	30 min	15 min	60 min

[a]See additional discussion concerning the value 5 Gy in Section 4.3.4.2.
[b]Assuming a 100 cm^2 field at the patient's skin. For other field sizes, the P_{KA} values should be adjusted proportionally to the actual procedural field size (*e.g.*, for a field size of 50 cm^2, the SRDL value for P_{KA} would be 250 Gy cm^2).

POST - PROCEDURE

RECORD

- What?
  - All the available data privileging CK, KAP, FT and number of images
- How?
  - Hardcopy archive
  - Digital database
  - DICOM objects
- Why?
  - Practice monitoring and improvement
  - Comparison with DRL
  - Dose reconstruction: when necessary (→ over the threshold) and if possible (→ depends on data available)
  - Follow up of “high dose” patients

HOW? → Use of DICOM Information

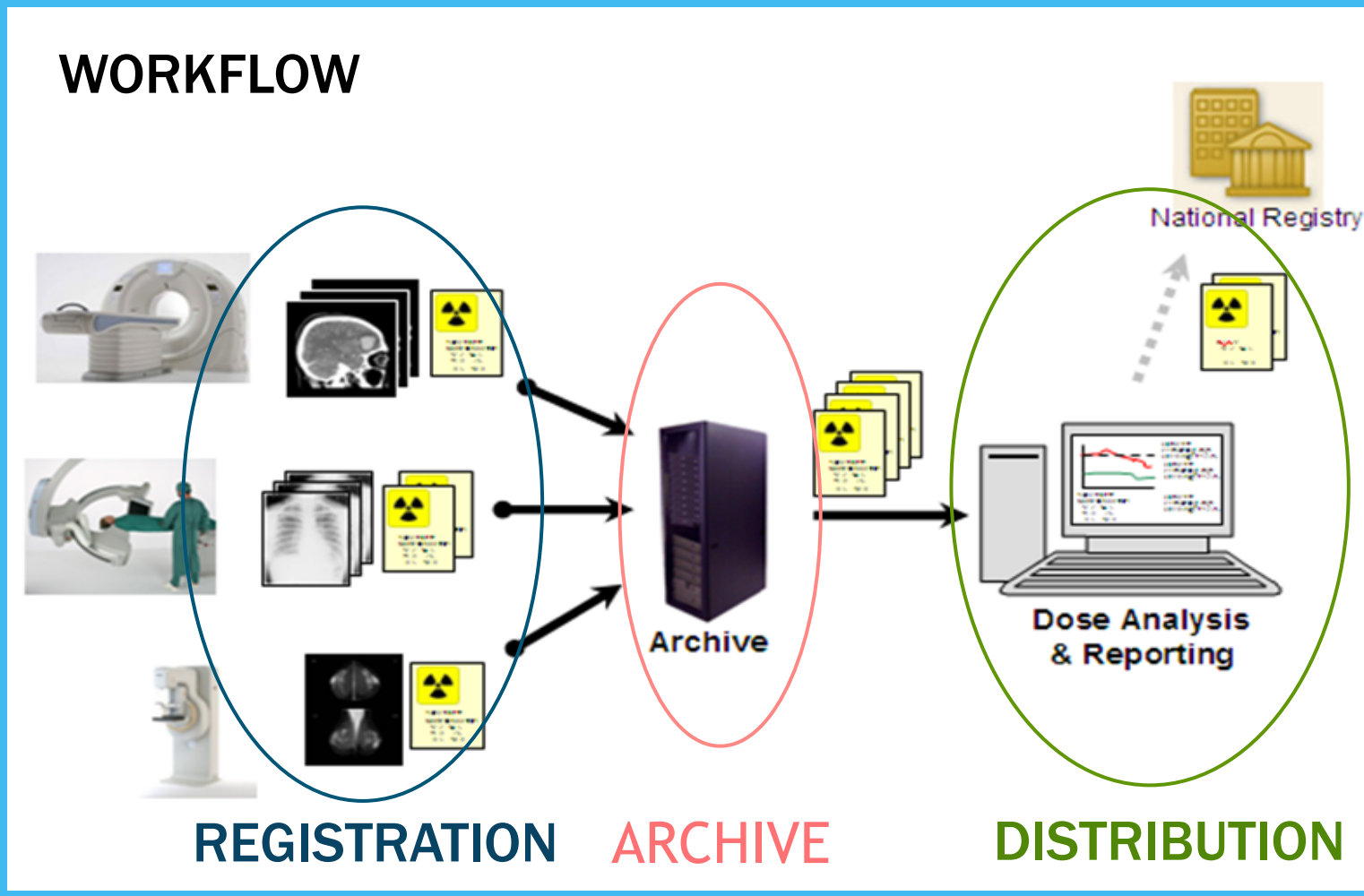
- First steps

Radiation Protection Dosimetry (2005), Vol. 117, No. 1–3, pp. 162–165
doi:10.1093/rpd/nci735 Advance Access published on February 3, 2006

ON THE USE OF DICOM CINE HEADER INFORMATION FOR OPTIMISATION: RESULTS FROM THE 2002 EUROPEAN DIMOND CARDIOLOGY SURVEY

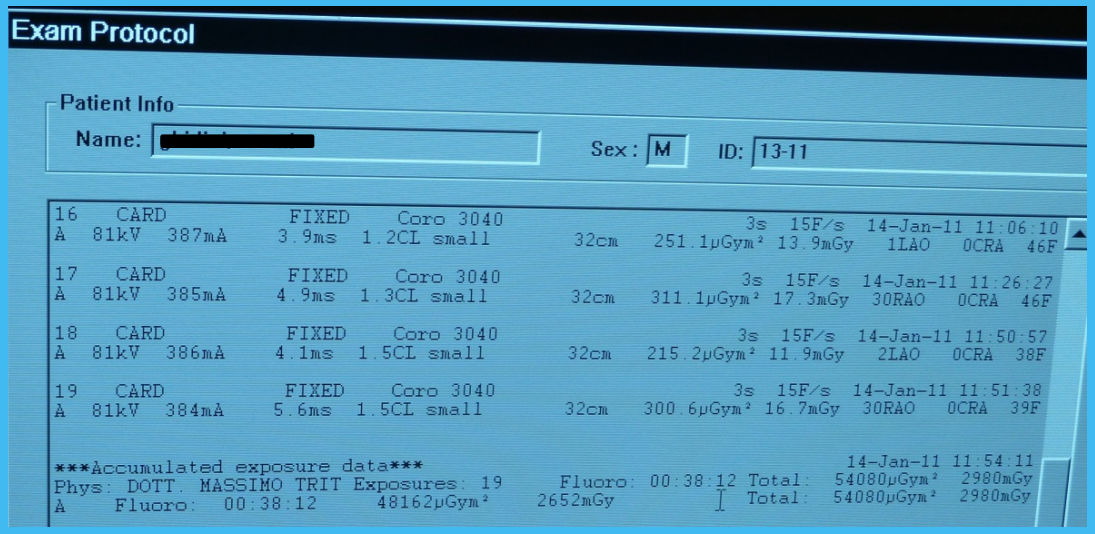
E. Vano[1,*], R. Padovani[2], G. Bernardi[2], J. I. Ten[1], A. Peterzol[2], A. Dowling[3], H. Bosmans[4], S. Kottou[5], Z. Olivari[6], K. Faulkner[7] and S. Balter[8]

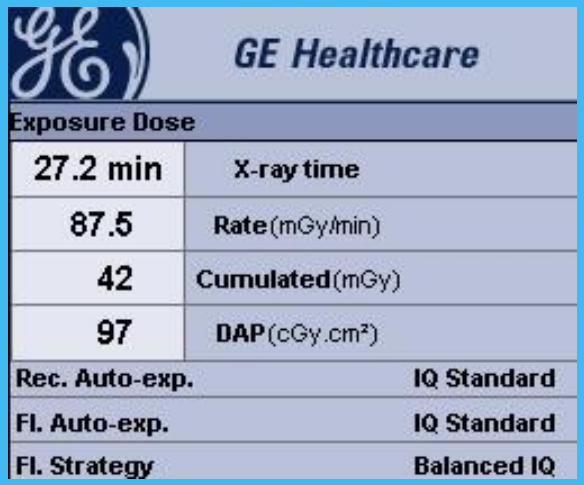
HOW? → Use of DICOM Information



HOW? → Use of DICOM Information

- **STUDY REPORT** →Text information on the display





HOW? → Use of DICOM Information

DICOM HEADER

- Text file containing different information
  - Patient data
  - Protocol data
  - Acquisition geometry info
  - Exposure data
- Information organized in groups and individuated by numerical indexes named “DICOM Tags”

First 128 bytes: unused by DICOM format
Followed by the characters 'D','I','C','M'
This preamble is followed by extra information e.g.:

0002,0000,File Meta Elements Group Len: 132
0002,0001,File Meta Info Version: 256
0002,0010,Transfer Syntax UID: 1.2.840.10008.1.2.1.
0008,0000,Identifying Group Length: 152
0008,0060,Modality: MR
0008,0070,Manufacturer: MRIcro
0018,0000,Acquisition Group Length: 28
0018,0050,Slice Thickness: 2.00
0018,1020,Software Version: 46\64\37
0028,0000,Image Presentation Group Length: 148
0028,0002,Samples Per Pixel: 1
0028,0004,Photometric Interpretation: MONOCHROME2.
0028,0008,Number of Frames: 2
0028,0010,Rows: 109
0028,0011,Columns: 91
0028,0030,Pixel Spacing: 2.00\2.00
0028,0100,Bits Allocated: 8
0028,0101,Bits Stored: 8
0028,0102,High Bit: 7
0028,0103,Pixel Representation: 0
0028,1052,Rescale Intercept: 0.00
0028,1053,Rescale Slope: 0.00392157
7FE0,0000,Pixel Data Group Length: 19850
7FE0,0010,Pixel Data: 19838

HOW? → Use of DICOM Information

DICOM HEADER

PRO

- Persistent information in PACS

CONS

- Mostly Exposure details (for interpretation)
- Information associate only with images →
  - Missing (fluoroscopy, deleted images)
  - Redundant (extra reconstructions; post-processing)
- Not complete

HOW? → Use of DICOM Information

RADIATION DOSE STRUCTURED REPORT

- DOSE KEY INDICATORS

AND

- Full Patient / Order / Study Details
- Unique ID for each Irradiation Event
- Equipment ID

- Patient Position, Anatomy imaged
- Imaging Geometry (projection), Collimation, X-Ray Filters, Anode Target Material, Calibration, Phantom, Dosimeter

HOW? → Use of DICOM Information

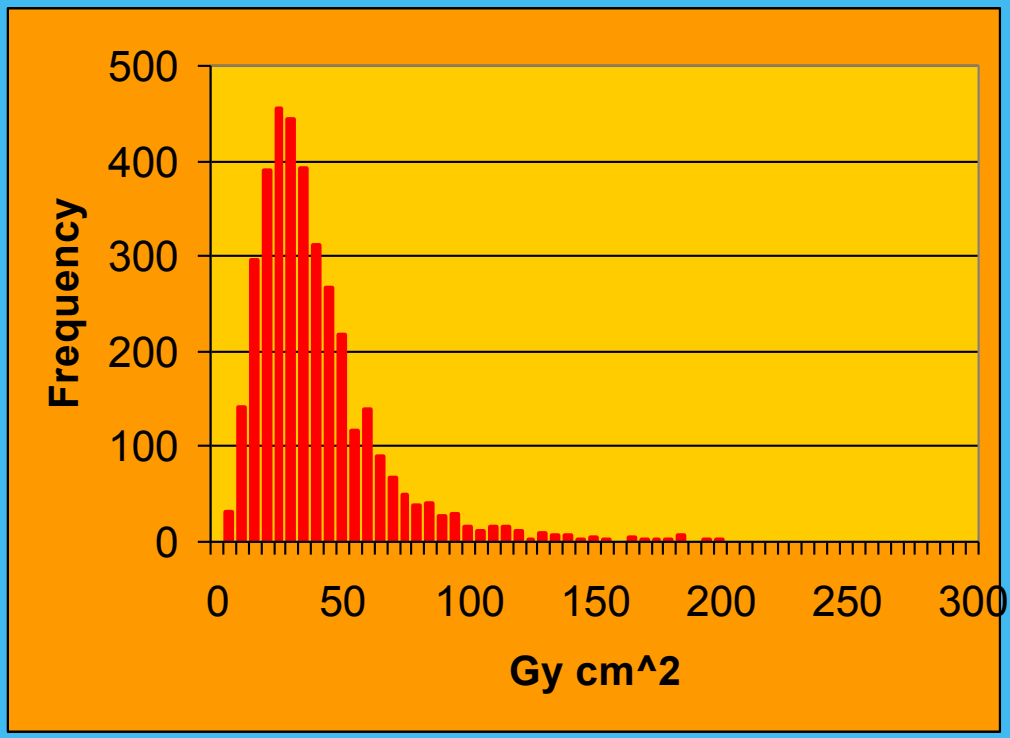
RADIATION DOSE STRUCTURED REPORT

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			CONTAINER	EV (113819, DCM, "CT Acquisition")	1	M		
2	>	CONTAINS	TEXT	EV (125203, DCM, "Acquisition Protocol")	1	U		
3	>	CONTAINS	CODE	EV (123014 , DCM, "Target Region")	1	M		DCID (4030) CT and MR Anatomy Imaged
4	>	CONTAINS	CODE	EV (113820, DCM, "CT Acquisition Type")	1	M		DCID (10013) CT Acquisition Types
5	>	CONTAINS	CODE	EV (~~G-C232~~G-C32C, SRT, "Procedure Context")	1	U		DCID (10014) Contrast Imaging Technique
6	>	CONTAINS	UIDREF	EV (113769, DCM, "Irradiation Event UID")	1	M		
7	>	CONTAINS	NUM	EV (113821, DCM, "X-ray Filter Aluminium Equivalent")	1	U		Units = EV (mm, UCUM, "mm")
8	>	CONTAINS	CONTAINER	EV (113822, DCM, "CT Acquisition Parameters")	1	M		
9	>>	CONTAINS	NUM	EV (113824, DCM,	1	M		Units = EV (s, UCUM, "s")

WHY? → Practice Monitoring

CA AND DIAGNOSTIC PROCEDURES

No. of procedures	3674
Mean DAP	37.5 Gycm^2
Median DAP	31.2 Gycm^2
No. of procedures with DAP>300Gycm^2	1

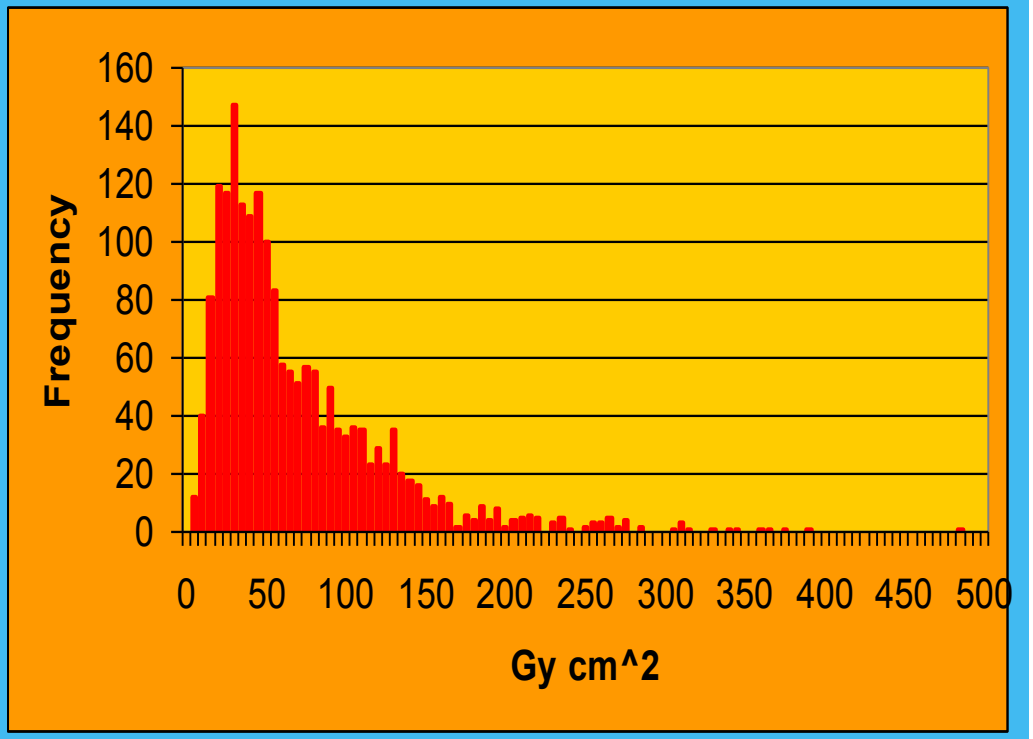


DAP distribution of CA procedures

WHY? → Practice Monitoring

PTCA PROCEDURES

No. of procedures	1843
Mean DAP	66.1 Gycm^2
Median DAP	48.3 Gycm^2
No. procedures with DAP>300Gycm^2	13 (0.7%)



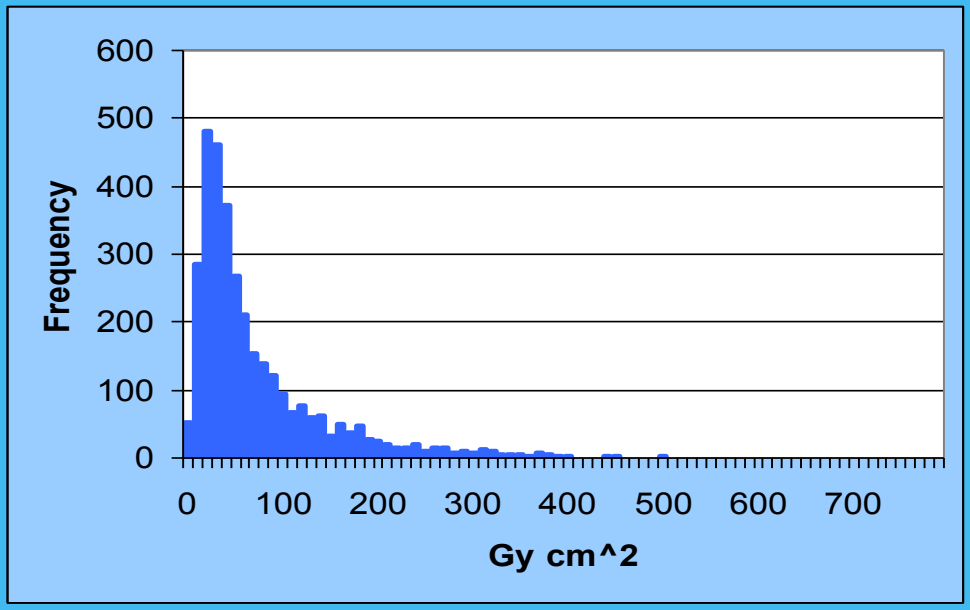
DAP distribution of PTCA procedures

WHY? → Practice Monitoring

REPEATED PROCEDURES

No. of procedures per patient	1	2	3	4	5	6	7	>7
No. of patients	1967	940	194	138	41	29	14	9

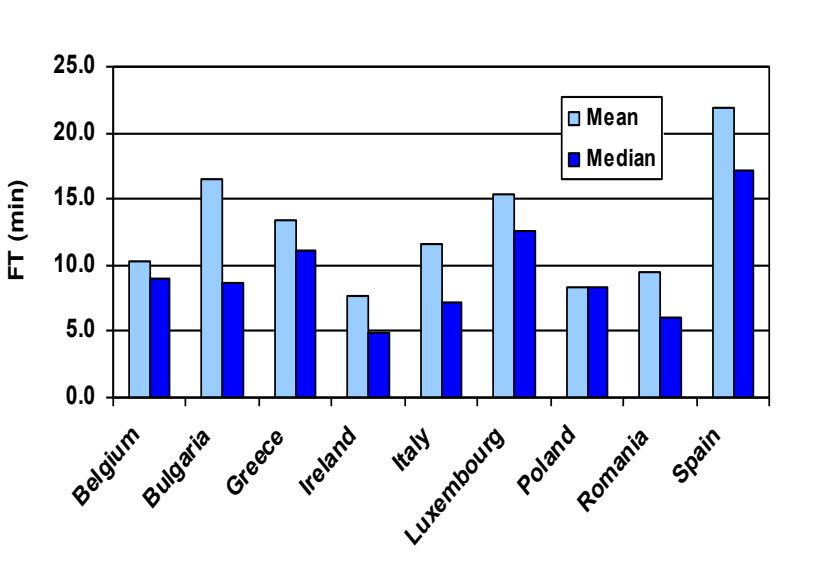
No. of patients	3332
Mean DAP	78.6 Gycm^2
Median DAP	50.6 Gycm^2
No. of patients with DAP>300Gycm^2	87 (2.6%)

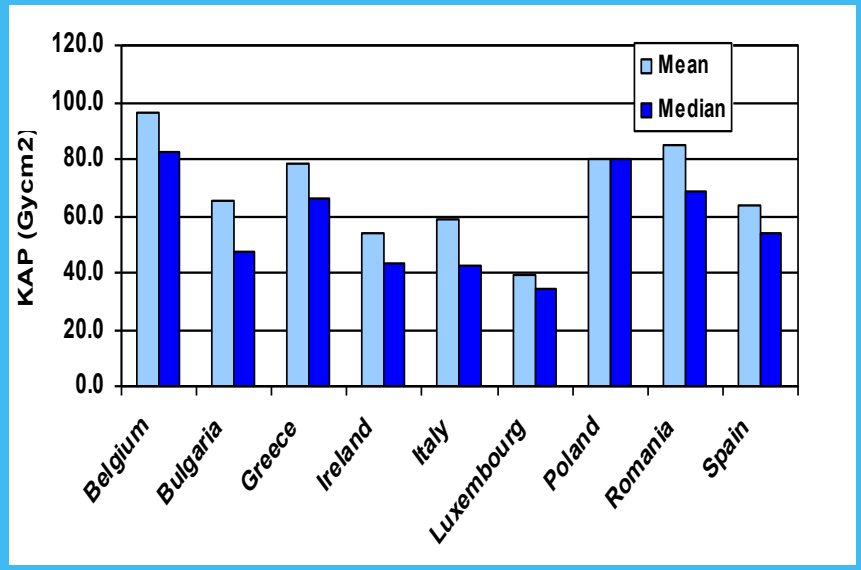


WHY? → Practice Monitoring

COMPARISON WITH OTHER CENTRES

- FT: median values in a range from 5 to 13 (factor 2.5)
- KAP: median values in a range from 35 to 85 (factor 2.5)





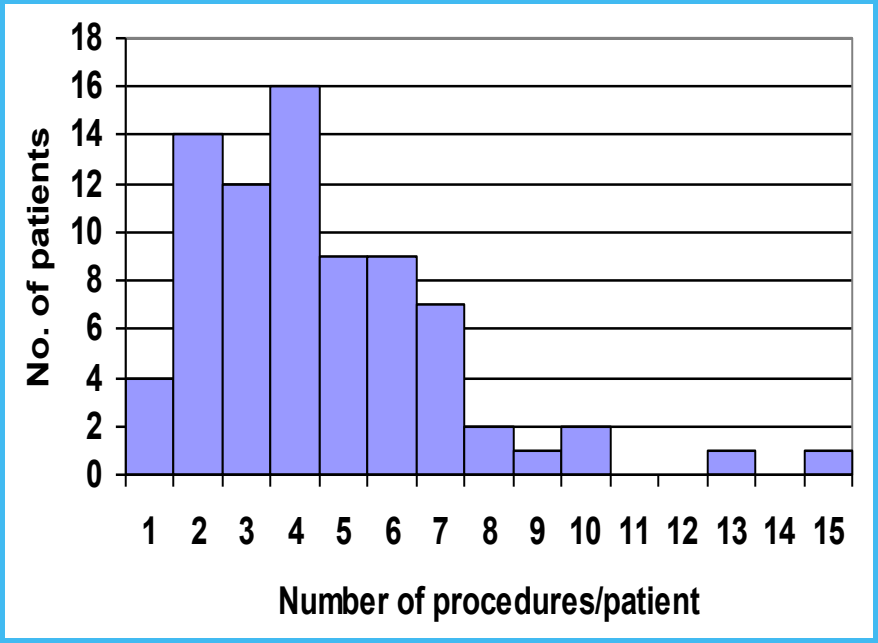
WHY? → Practice Monitoring

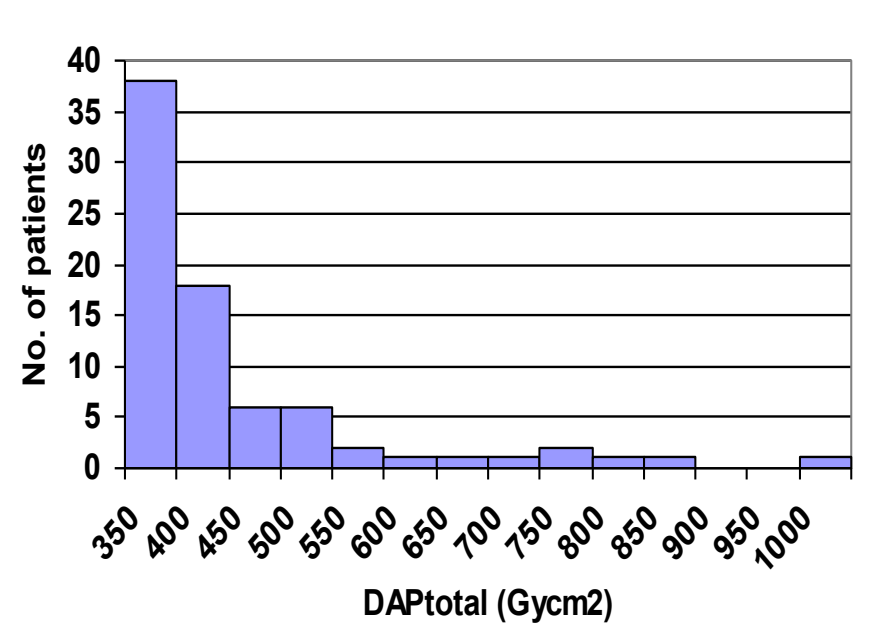
RETROSPECTIVE EVALUATION OF SKIN INJURIES ON PATIENTS OF UDINE CARDIAC CENTRE

- Methodology:
  - Analyze database of patients submitted to diagnostic and therapeutic procedures in a 4 years period
  - Detect patients with highest cumulative DAPs (due to repeated procedures) selecting an appropriate DAP trigger value
  - Evaluate maximum local skin dose
  - Submit selected patients to a clinical evaluation to detect possible skin injuries

WHY? → Practice Monitoring

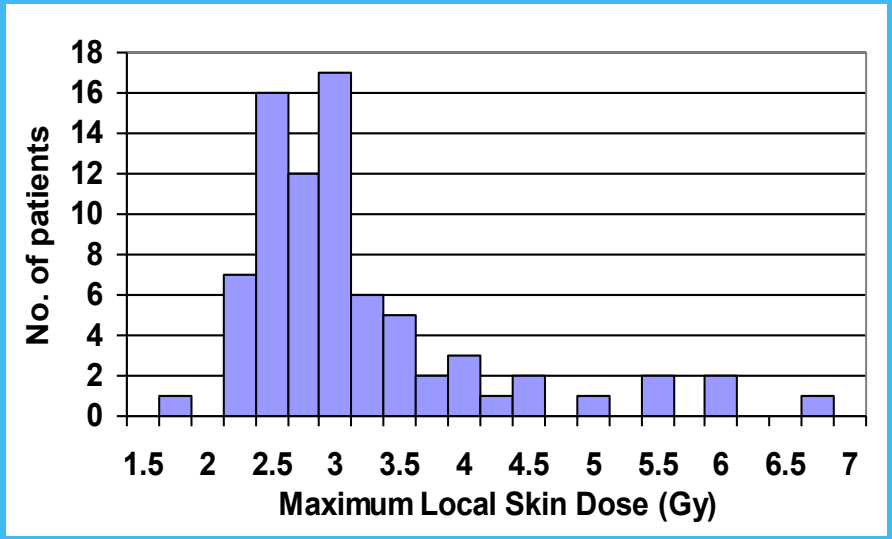
- 79 patients with a cumulative DAP>300 Gycm^2 extracted from the database
- Distribution of number of procedures performed and cumulative DAP





WHY? → Practice Monitoring

- Maximum local skin dose evaluated



- medical examination for 56 patients → no skin lesions

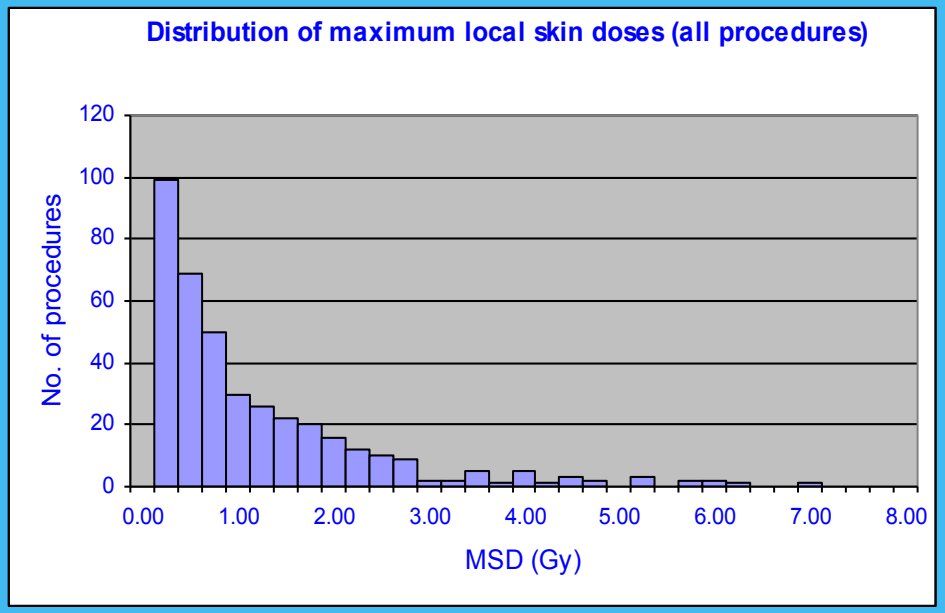
→if proper quality assurance and radiation protection programme is established, the frequency of skin injuries can be very low also when repeated procedures are taken into account

WHY? → Practice Monitoring

MONITORING OF SKIN DOSE IN HIGH DOSE PROCEDURES (IAEA CRP)

- Radiochromic films used to measure patient skin dose in a sample of 392 interventional procedures
- Results:

  PSK>2Gy in 52 proc.
  PSK>4Gy in 15 proc.
  maximum PSK was 6.6 Gy;
  38 PTCA, 6 RF ablation, 1 neuro-embolisation and 6 hepatic
- 39 occurred at two hospitals !



WHY? → Practice Improvements

WHY? → Reference Levels

- Assessment of reference levels in interventional cardiology
  - DIMOND & SENTINEL European projects
  - IAEA CRP project
- SENTINEL survey
  - Reference levels have been derived as the rounded values of the 3rd quartile of the frequency distributions

Dose or dose analogue	Procedures		
	CA	PTCA	EFO
KAP (Gycm^2)	45	85	35
Effective dose (mSv)	8	15	6
CD at IRP (mGy)	650	1500	-
Fluoroscopy time (min)	6.5	15.5	21
No. of cine images	700	1000	-
Entrance surface air kerma rate	Fluoroscopy low: 13 (mGy/min) Image acquisition: 100 (μGy/frame)		

WHY? → Reference Levels

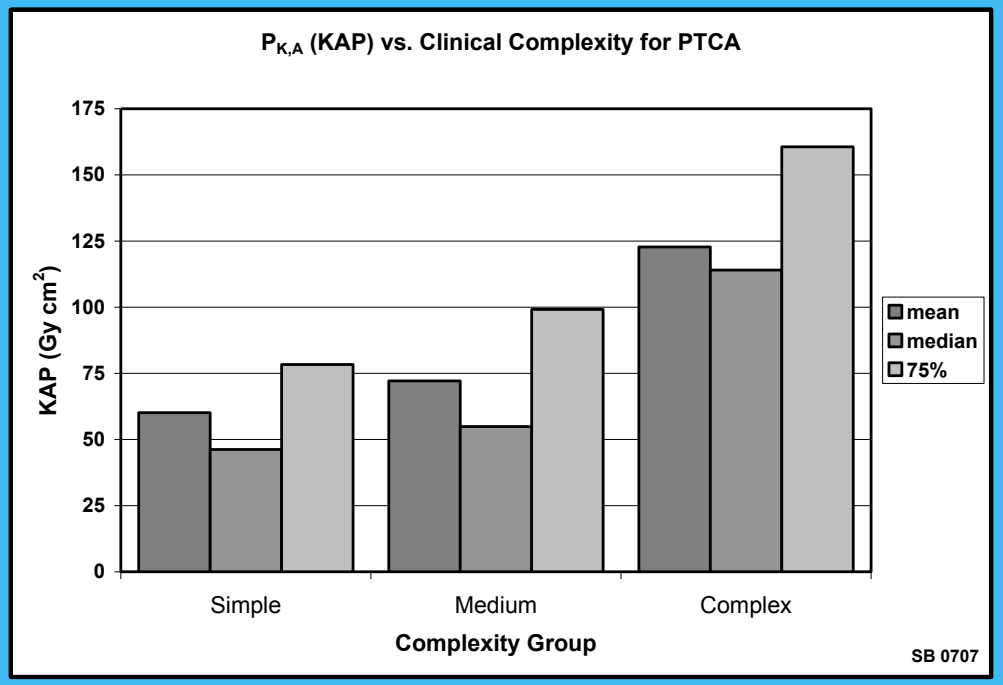
- The concept of reference (guidance) levels refers to “common examinations” done on large numbers of patients in a relatively standardized manner.
- Extending this concept to fluoroscopically guided interventions raises several problems:
  - In addition to technical variables (patient size, equipment performance and operational technique), procedures are usually non-standard for clinical reasons.
  - The complexity of a procedure is affected by factors related to the patient’s anatomy and to the severity of the treated pathology.

→ Complexity is an important factor in setting guidance levels

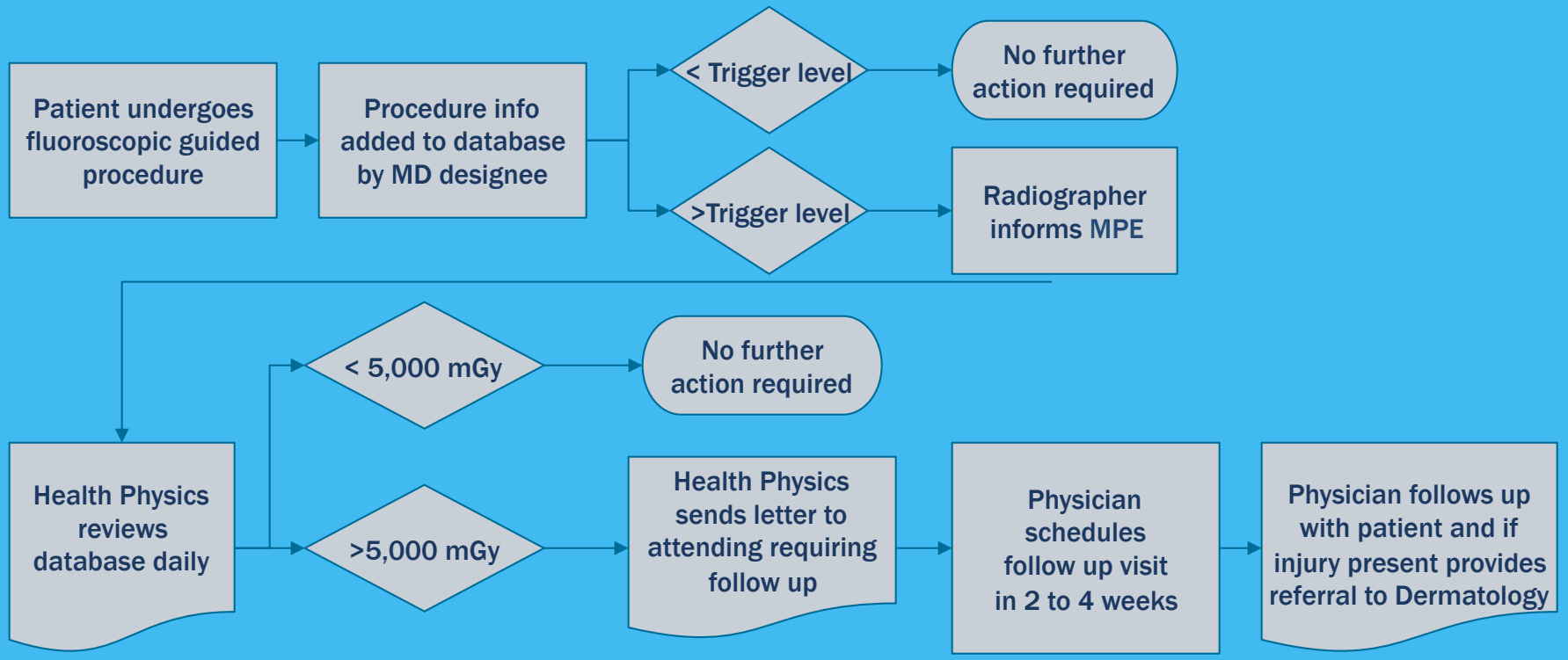
WHY? → Reference Levels

IAEA CRP study, 2006

- More 1000 PTCA procedures analysed
- Determinants for complexity of procedures identified
- Procedures grouped according to the level of complexity (Complexity Index)
- Reference levels assessed as a function of CI



WHY? → Follow Up



WHY? → Follow Up

ICRP No. 85

SCHEDA RACCOLTA DATI per FOLLOW UP Procedure di Chemioembolizzazione		
DATI PAZIENTE (a cura del TRM)		
Codice Paziente		
Cognome e Nome		
Data di nascita		
Peso		
Altezza		
1° Ingresso	SÌ	NO
Medico richiedente l'esame		
LIVELLI DI ATTENZIONE	**2500 mGy (1^ procedura) 850 mGy (procedure successive)**	
DATI PROCEDURA (a cura del TRM)		
Primo operatore		
Sala angiografica		
Tempo di Fluoroscopia		
KAP (μGym^2)		
Dose Cumulativa (mGy)		
Indicare l'area della cute maggiormente investita dal fascio di radiazione		
IL TRM		
VISITA DI CONTROLLO POST-PROCEDURA (a cura del medico di reparto)		
Presenza di aree eritematose nella sede indicata	SÌ	NO
IL MEDICO		

RESEARCH ACTIVITIES

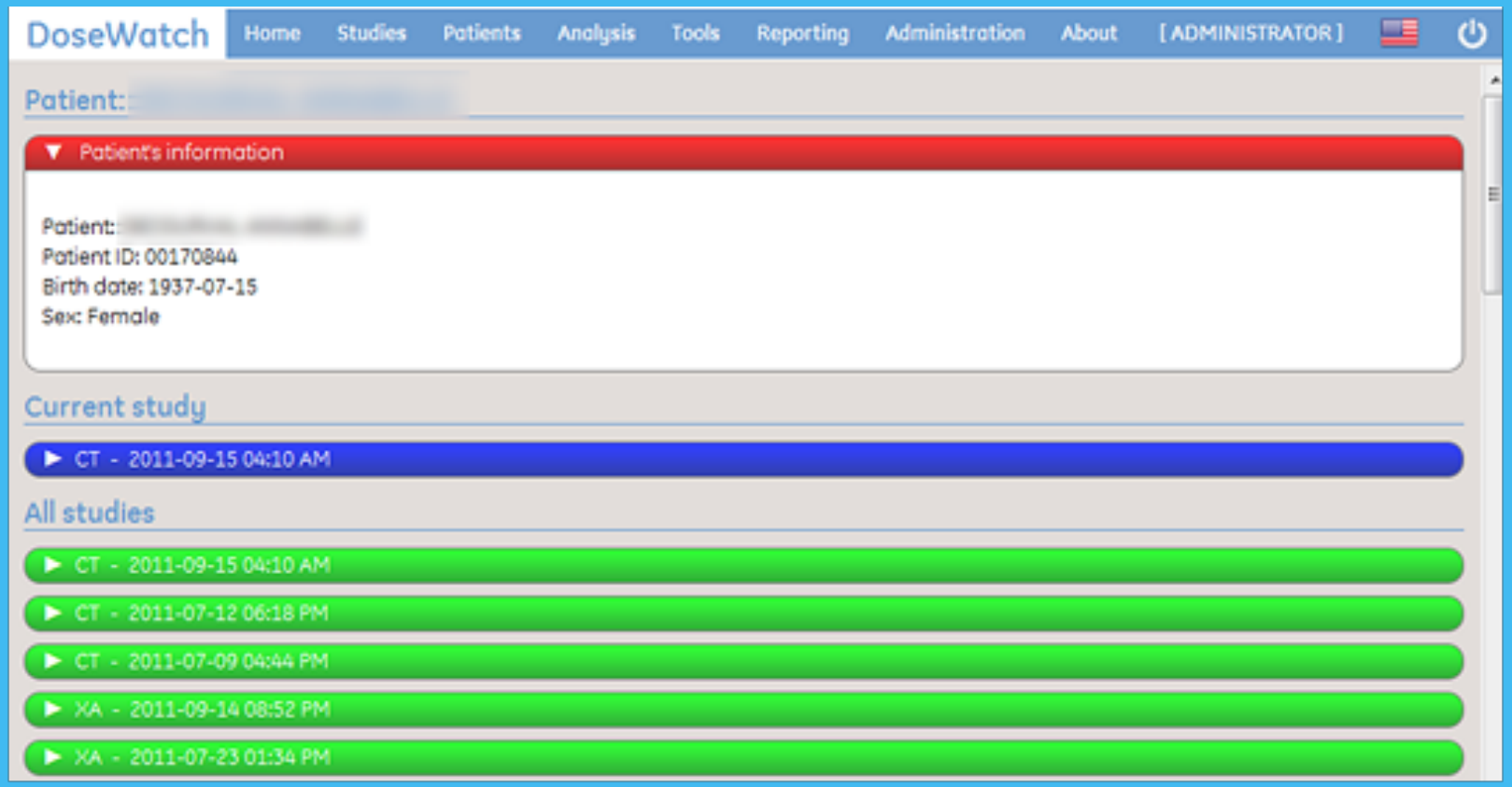
EUROPEAN TRIGGER LEVELS

- EURADOS WG12 → European alert thresholds definition
- The project:
  - 8 European countries involved
  - 3 measurement tools (gaf, TLD)
  - Different interventional procedures

- First results discussed at AAPM 55th Annual Meeting, Indianapolis, August 4-8, 3013:
  - Trianni et al. *Eurados WG12 alert thresholds*
- Draft of paper by the end of this year

DOSE TRACKING SOFTWARE

DOSE WATCH (GE Healthcare)



DOSE TRACKING SOFTWARE

- TRACKING AND ARCHIVING OF DOSIMETRIC DATA
  - Multi-modality, multi-manufacturer data collection
  - Compatible with dose data in DICOM SR and DICOM MPPS format files
- CONNECTION WITH RIS & PACS
  - Dose information included in patient report
  - Retrieve the worklist
  - Retrieve older exams to complete patient history
- INTEGRATED STATISTICAL ANALYSIS
  - High dose level studies
  - Generate analyses by device, by operator or protocol
  - Complete database export in Excel format
  - Automated and embedded monthly reports sent by email

DOSE TRACKING SOFTWARE

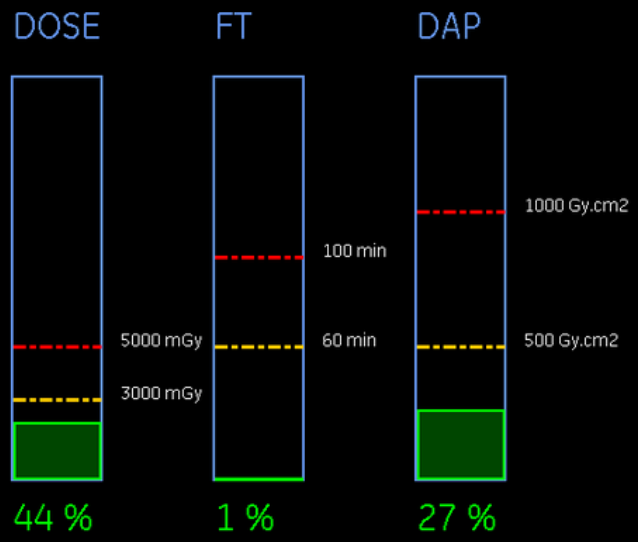
- MANAGE RISK AND HELP IMPROVE PATIENT CARE
  - automated dose alerts
  - E-mail sent when dose exceeds defined thresholds
- X-RAY HISTORY
  - Multi-modality X-Ray history
  - Detailed acquisition parameters
  - Maintain record of Body Mass Index (BMI)
- CUMULATIVE DOSE HISTORY
  - View dose history by patient, anatomical region and modality
- DOSE MAPPING
  - Distribution of dose at IRP distance depending on projection angle

DOSE TRACKING SOFTWARE

Protocol	Dose Pref.	Acquisition Mode	Frame Rate	# of Runs	Time (min)	DAP (mGy.cm²)	Dose (RPAK, mGy)
FL Angio		FLUORO	0.00 fps	90	1	214815.00	1505.5399
		RECORD	0.00 fps	10	0	51074.00	672.8
			Total	100	1	265889.00	2178.3403

Exam Levels

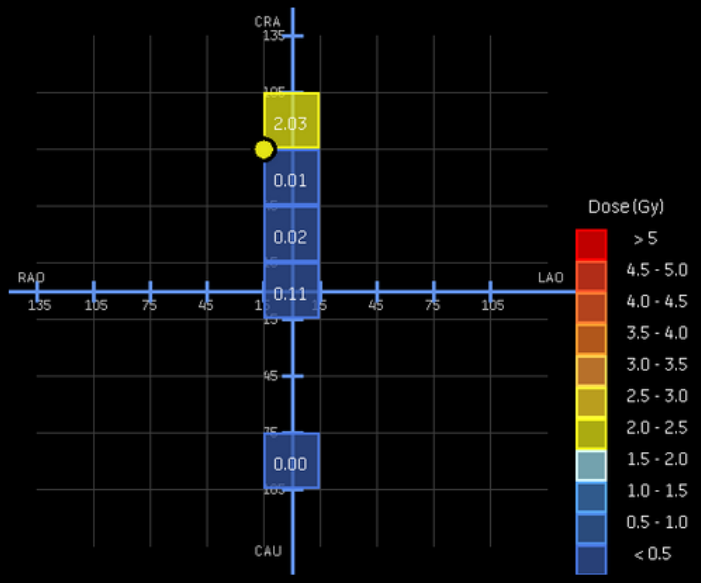
RPAK : 2178.39 mGy



Cumulative Dose (RPAK) Incidence Map (Gy)

Worst RPAK : 2041 mGy

15.0° RAO / -75.0° CRA



DOSE TRACKING SOFTWARE

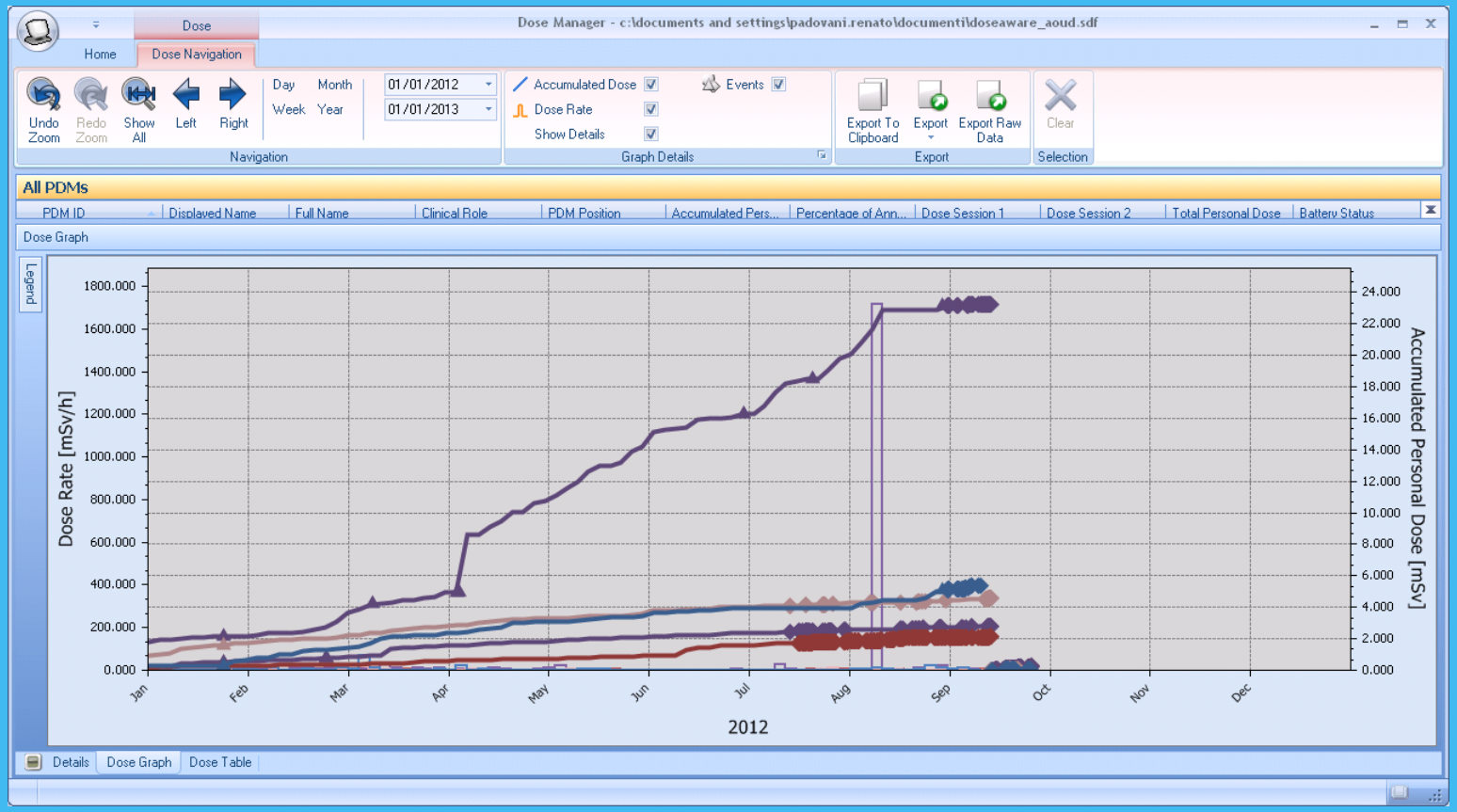
Udine Experience

- Installed in March 2013
- Connected via MPPS and RDSR → with MPPS limited information
- Connection not possibile with our PACS → no retrospective analysis
- Nomenclature not standardized → almost impossible to create samples of different procedures
- Dose maps:
  - Mistake in projection angle identification
  - Actually Air Kerma maps → to be corrected by distance, table absorption, f-factor
  - Angular sectors too large → over-estimates skin dose (comparison with gafchromic flims measurements)

STAFF

ACTIVE DOSIMETERS

DOSE AWARE (RaySafe - Philips Healthcare)



COMBINE PATIENT AND STAFF DOSES

- No standard available (under evaluation by DICOM standardisation body)

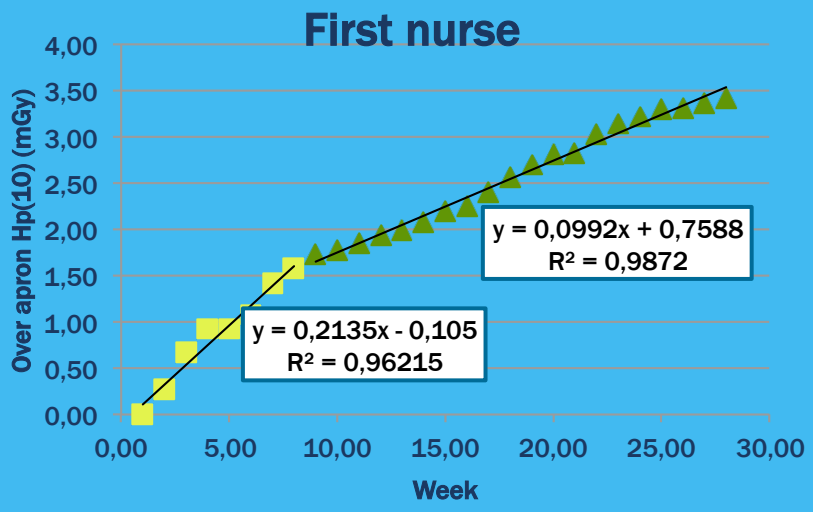
- In house development combining:
  - Patient dosimetry report sent by e-mail (Philips Allura)
  - Staff doses from active dosimeters collected and available in the hospital network

	KAP (Gycm2)	CK (mGy)	Scatter C-arm (uGy)	IC A (uSv)	IC B (uSv)	IC C (uSv)	Nurse (uSv)
Mean	69.0	893	158.8	27.3	0.6	44.5	3.8
SD	53.5	693	135.7	11.9	0.2	12.6	5.0

IMPACT OF ACTIVE DOSIMETERS

DOSE AWARE (Philips Healthcare)

- Nurses of a interventional cardiology room
  - Dose in the blind use:
    - Hp(10) = 0.2 mSv/week
  - Dose in normal use
    - Hp(01) = 0.1 mSv/week



- Positive impact of the active real time dosimetry on the behaviour of the workers

THANK YOU