Ente Ospedaliero Cantonale

Radiation dose monitoring, the future

Herbstkolloquium ICKS
Schweizerische Gesellschaft Internistischer Chef- und Kaderärzte

Incontro autunnale ASIO
Associazione Svizzera dei medici primari e dei medici quadro ospedalieri

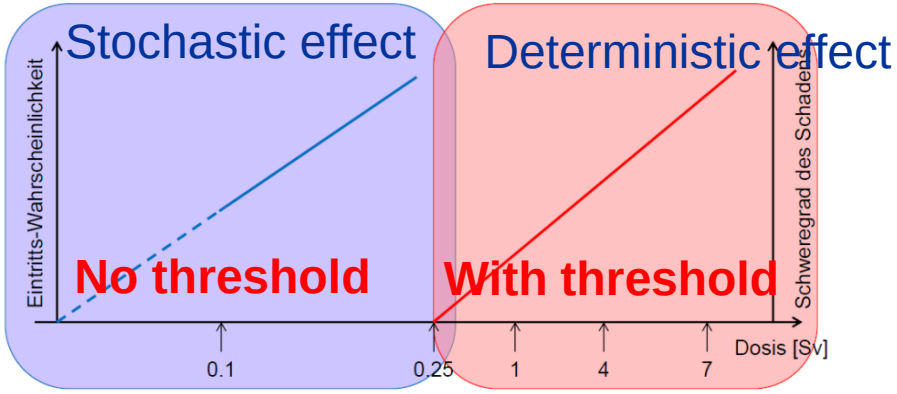
Réunion d'automne AMCIS
Association des Médecins-chefs et -cadres Internistes Hospitaliers Suisse

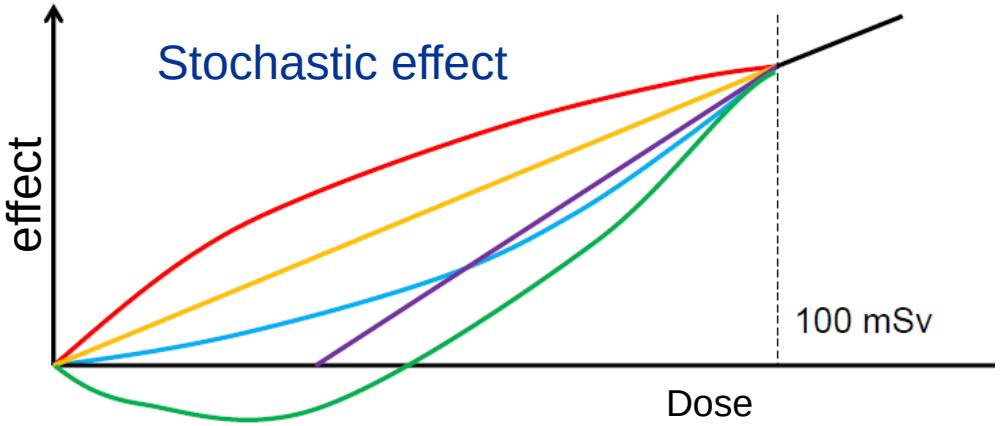
Dr. S. Presilla, Servizio di fisica medica EOC

Outline

- X-ray risk and benefits
- Why collecting dose related data
- The dose management tool
- Benefits and vision

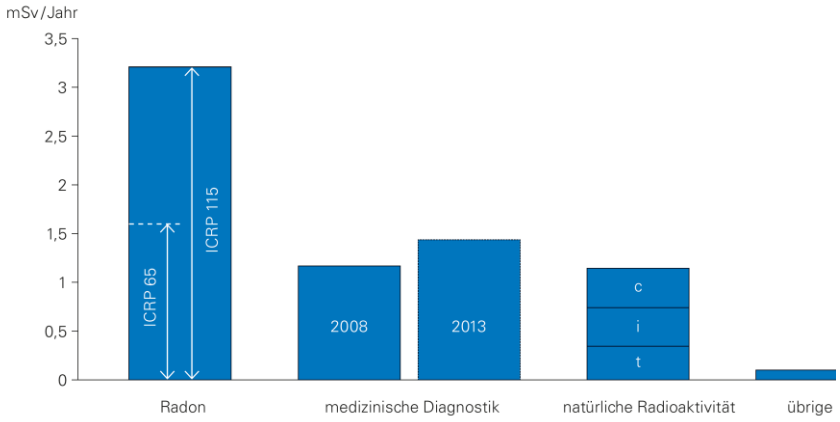
X-ray, risk and benefit





The probability for radiation induced cancer increases by 5-6% for every 1’000 mSv of dose. Cancer risk increase arising from most examinations is relatively small as compared with the risk of naturally occurring cancer which ranges between 14% and 40%.

Increasing use of X-ray



Bundesamt für Gesundheit

Table 4 Comparison of 2008 frequency and dose data with previous surveys

Year	Number of examinations/ 1000 population		N_{CT} /N_{Total}	E (mSv/caput)		E_{CT}/E_{Total}
	Total	CT	(%)	Total	CT	(%)
998	1340	46.2	3.4	1.0	0.28	28
003	1470	76.7	5.2	1.2	0.56	47
008	1680	100	6.0	1.2	0.80	68

Aroua et al. BMC Medical Imaging 2013

Table 2. Distribution of the annual number of examinations per thousand population, dose per examination and the average per inhabitant effective dose over the various radiological modalities.

Radiological modality	Number of examinations/1000 inhabitants	Frequencies (%)	Dose (mSv)	Dose (mSv)/1000 inhabitants	Contribution to the collective dose (%)
Radiography	473	38.83	0.32	151.44	10.67
Mammography (diagnostic)	20	1.66	0.36	7.30	0.51
Mammography (screening)	11	0.93	0.36	4.06	0.29
Computed tomography	117	9.61	8.54	1000.21	70.44
Dental radiology (conventional)	572	46.91	0.02	11.44	0.81
Dental radiology (cone beam CT)	6	0.45	0.20	1.10	0.08
Conventional fluoroscopy	7	0.61	8.00	59.09	4.16
Interventional fluoroscopy for diagnostic purposes:					
Coronary angiographies	6	0.47	14.00	79.59	5.61
Other angiographies	2	0.17	8.00	16.98	1.20
Interventional fluoroscopy for therapeutic purposes:					
Percutaneous transluminal coronary angioplasty	3	0.22	20.00	54.12	3.81
Other therapeutic interventional	2	0.14	20.00	34.52	2.43
Total	1219	100	—	1419.87	100.00

Le Coultre et al. 2015

Need for dose justification, optimization, limitation

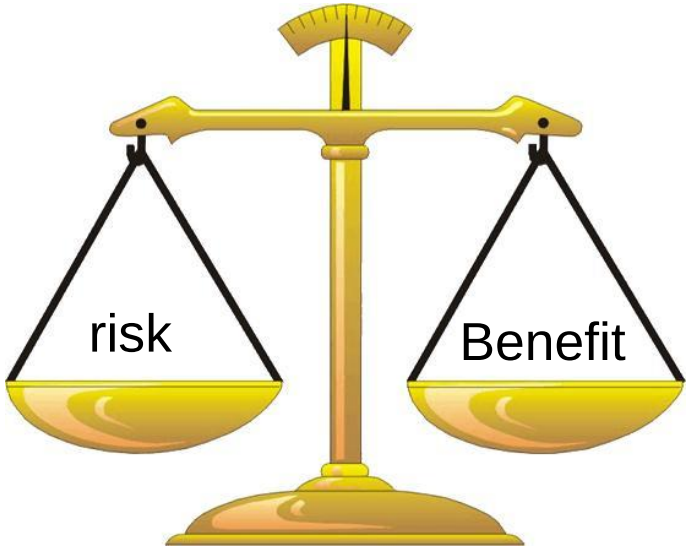
ALARA

As Low As Reasonably Achievable

(Focused only on risk)

AHARA

As Hight As Reasonably Achievable



little radiation as possible. However, this concept is one-dimensional. The primary thought in the use of the term ALARA is really only about reducing radiation risk, not recognizing benefit. It is time to consider changing our thinking to AHARA—as high as reasonably achievable—to indicate that the real goal is not just the use of as little radiation as possible but to achieve as high a benefit-to-risk ratio as possible on behalf of our patients.

EDITORIAL: Radiation Exposure in CT Scanning and Risk

Radiology: Volume 264: Number 2—August 2012 ▪ *radiology.rsna.org*

$$\text{Max.}\left(\frac{\text{Benefit}}{\text{Risk}}\right)$$

Potential for optimization

- Patient, vendor, and institutional factors influence CT radiation dose metrics, and account for approximately 50% of dose variability across imaging facilities.

- multiphase scanning is the most important predictor of median CT dose and a high-dose examination.

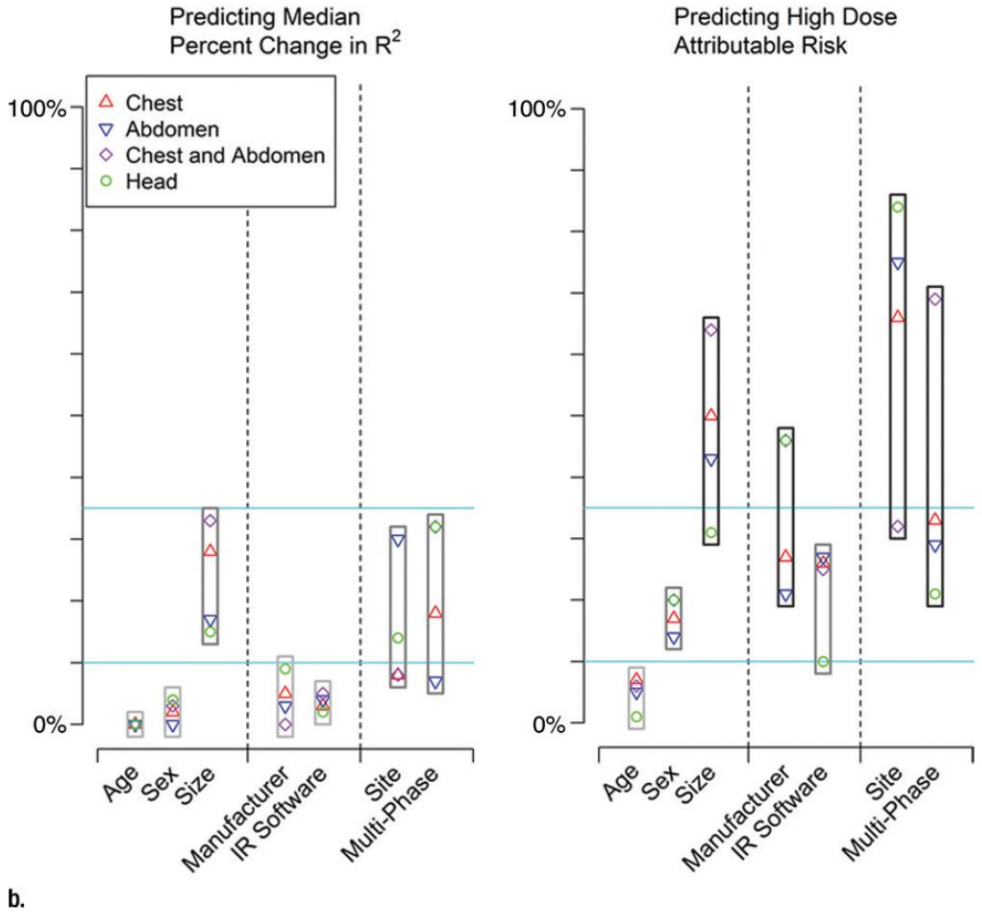
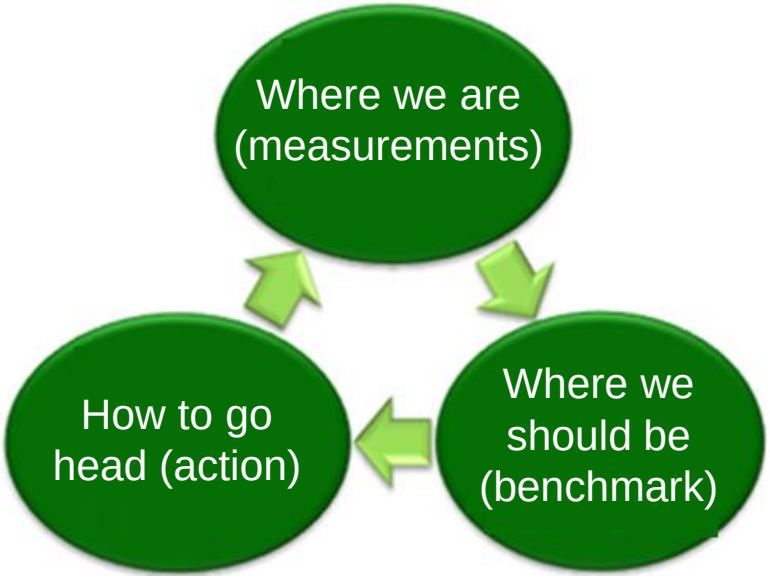


Figure 2 *(continued)*: **(b)** median effective dose, we categorized change in R^2 and attributable risk as small (<10%), moderate (10%–25%), or large (>25%). Blue lines correspond to 10% and 25% values.

Smith-Bindman et al., Radiology 2017

Optimization process: need to collect data

Data collection

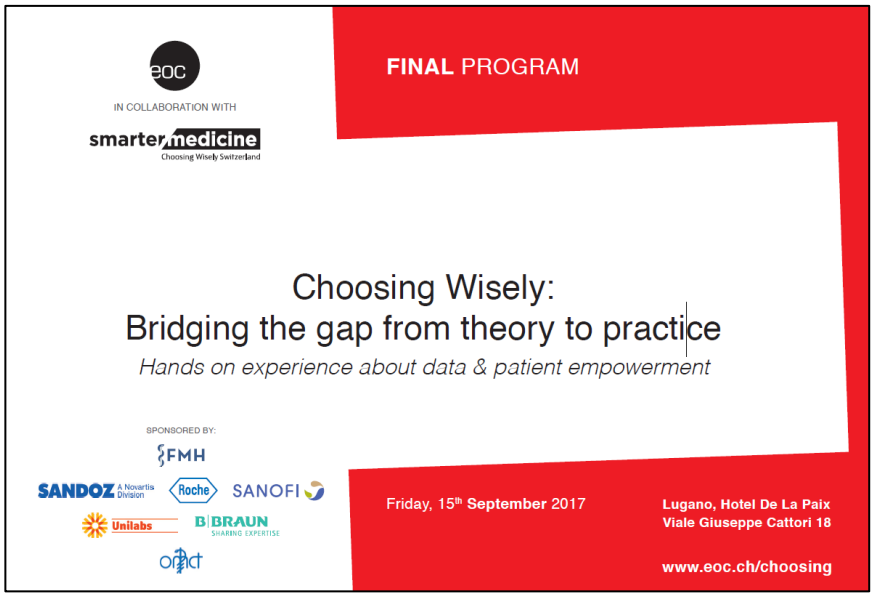


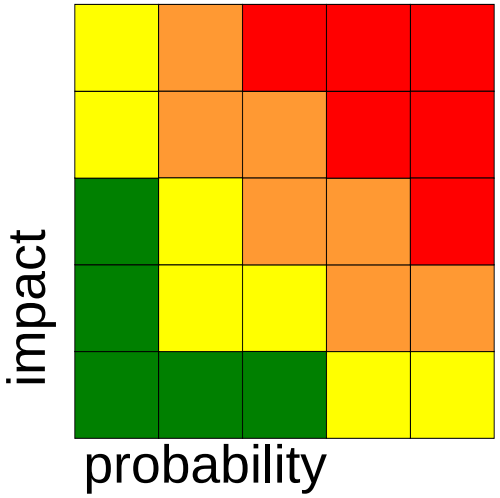
Data disaggregation for parameter optimization

Comparison with CH reference level

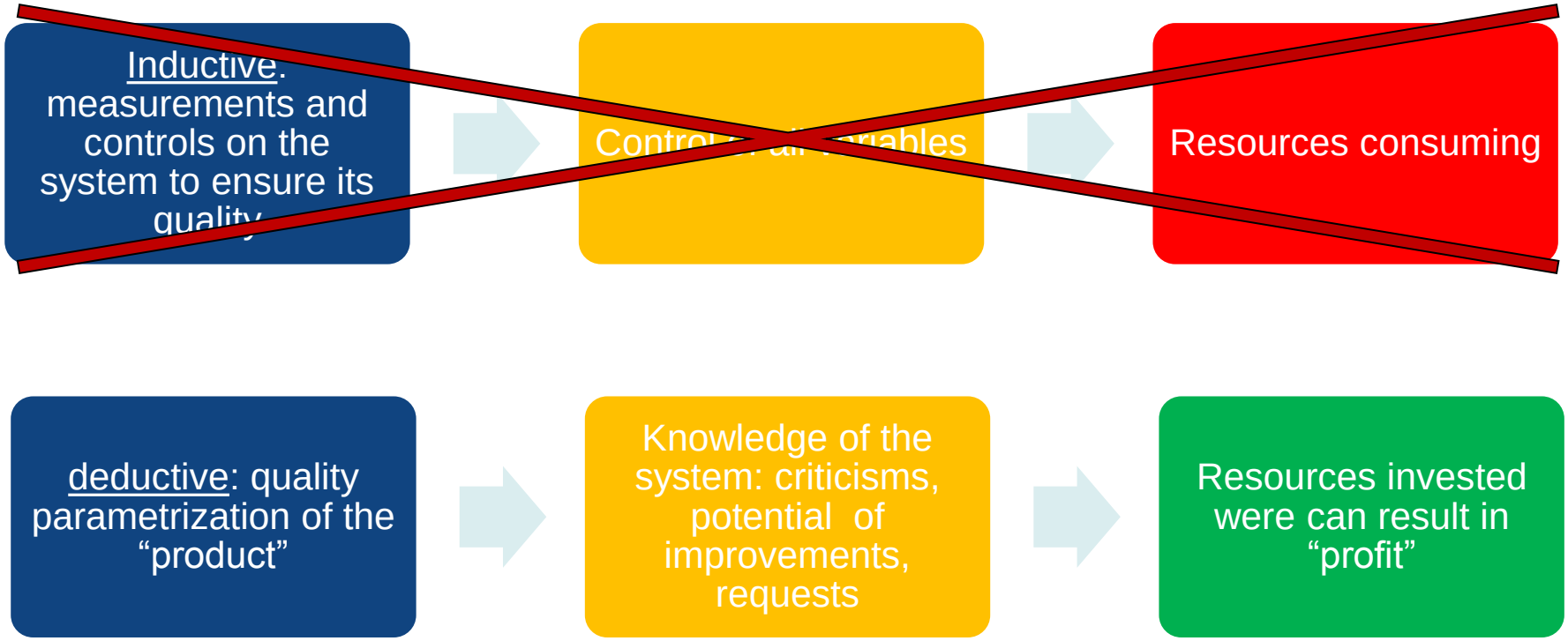
Why collecting dose data: awareness to optimize

- knowing the system
- Concentrate on issues with higher potential of improvement: Diagnostic Reference Value culture





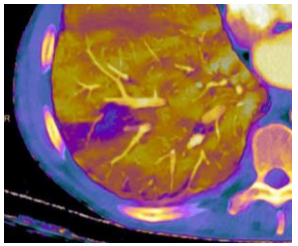
Dose monitoring tool usage: our strategy



Improve patient, operator, public radioprotection ….while maintaining (improving) the quality of cure

EOC a multisite hospital

EOC modalities: a wide spectrum



- 8 CT (1 intraoperative)
- 3 angiography room
- 1 Oarm (CT - CArm)
- 1 Hybrid operating room
- 2 Pet-CT, 1 Spect CT, 1 gamma camera
- 17 C-arms

EOC contest

multisite cantonal hospital

- 4 radiology service (in 6 hospitals)
- 1 Nuclear medicine service (in two hospitals)
- 5 operating theatre block

= enough critical mass to study general complex solutions and adapt to local reality

Radiation dose monitoring: our concept

Benchmark:

- national level
  - regional level
    - facility level

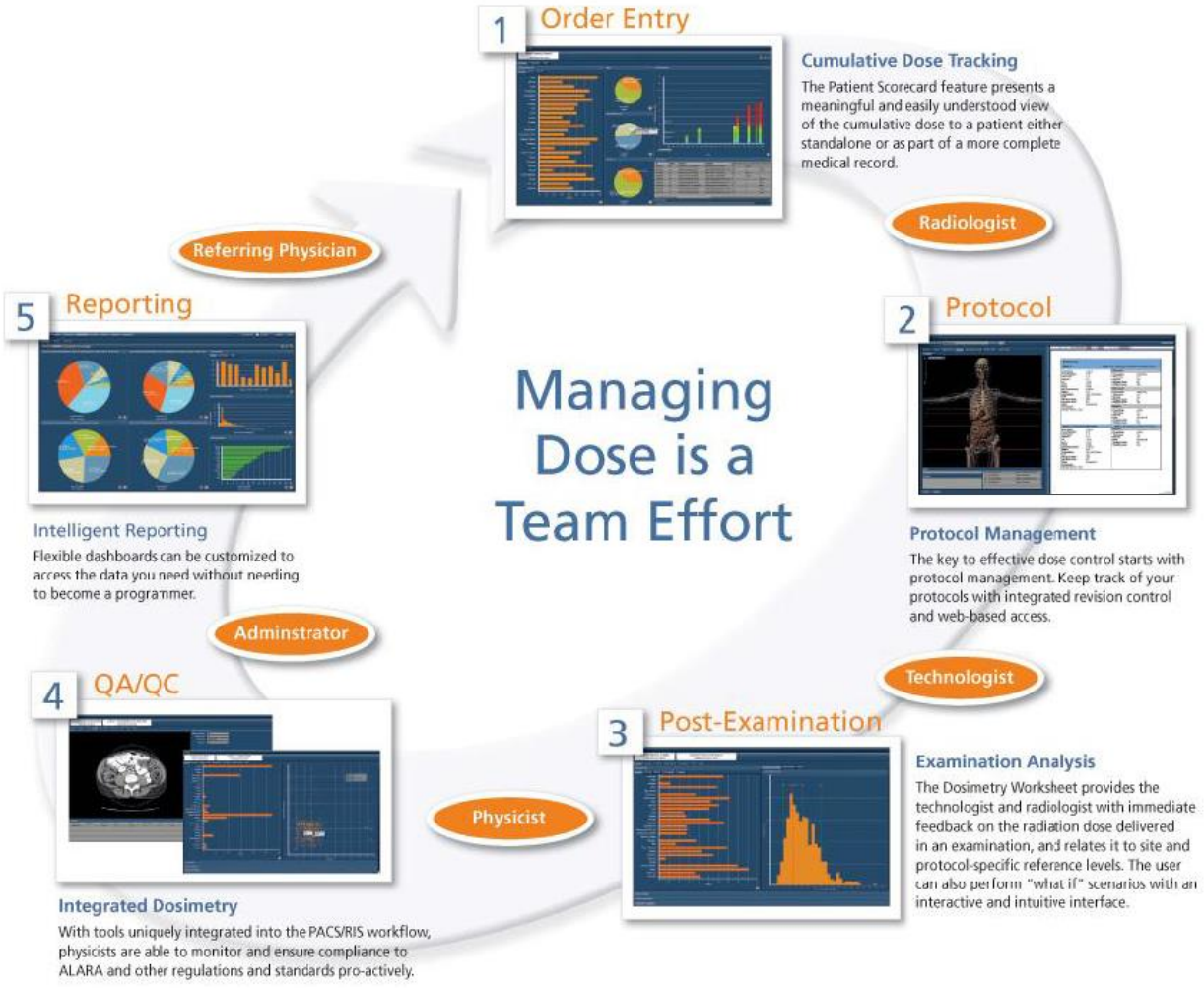
Patient risk estimation:

- for specific patient
  - correlated to each exam
    - base also on cumulative dose
- alert system
  - for each exam
    - for cumulative dose

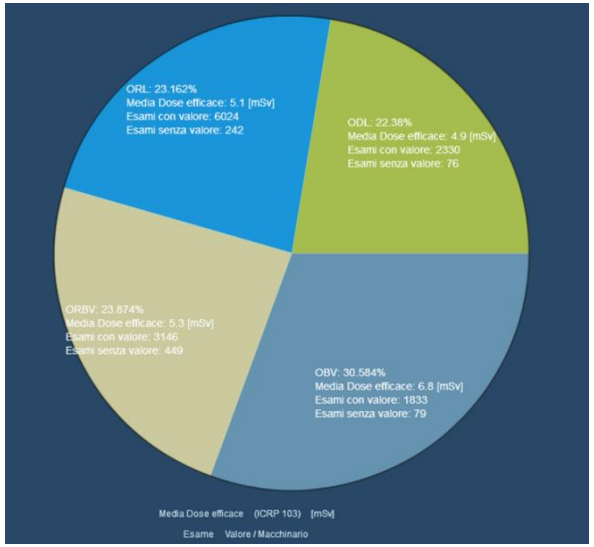
Optimization:

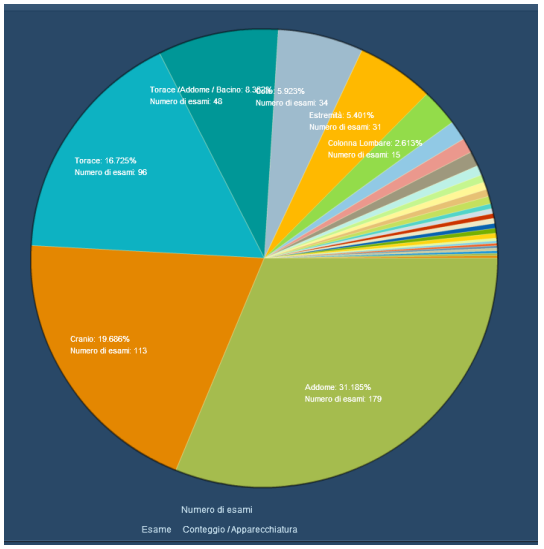
- general procedure
  - adapted to each facility
    - optimized for the specific patient

Radiation dose monitoring implementation



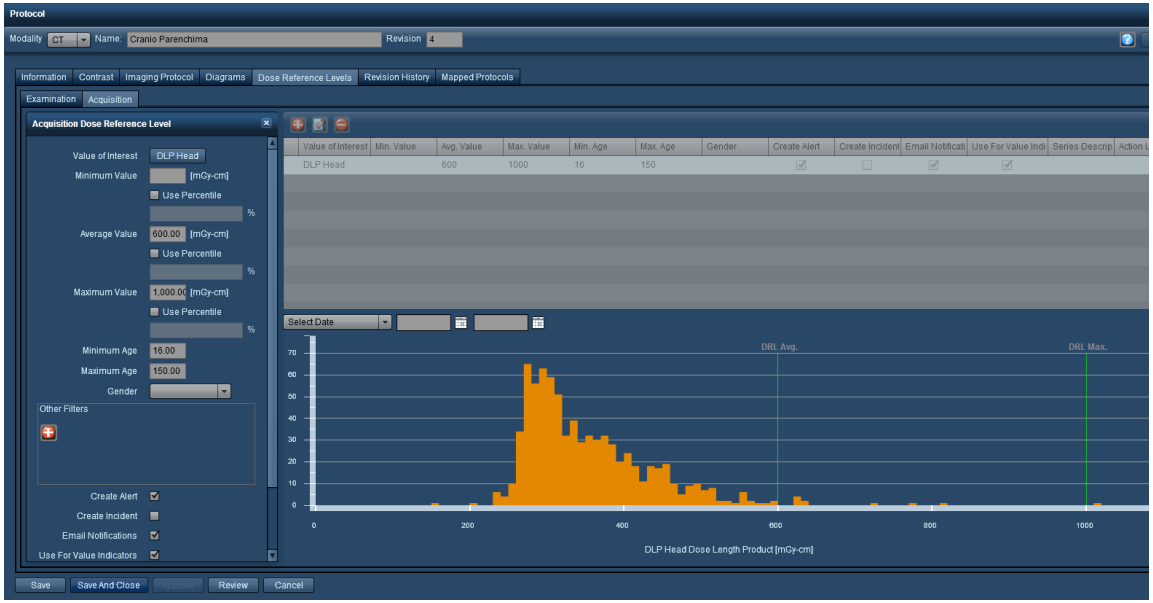
Exam and dose monitoring





all the CT examinations carried out at EOC sites and the number of examinations performed per anatomical district

Benchmark



Single protocol Vs. Swiss Reference levels

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Bundesamt für Gesundheit BAG
Direktionsbereich Verbraucherschutz

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Abteilung Strahlenschutz
www.str-rad.ch

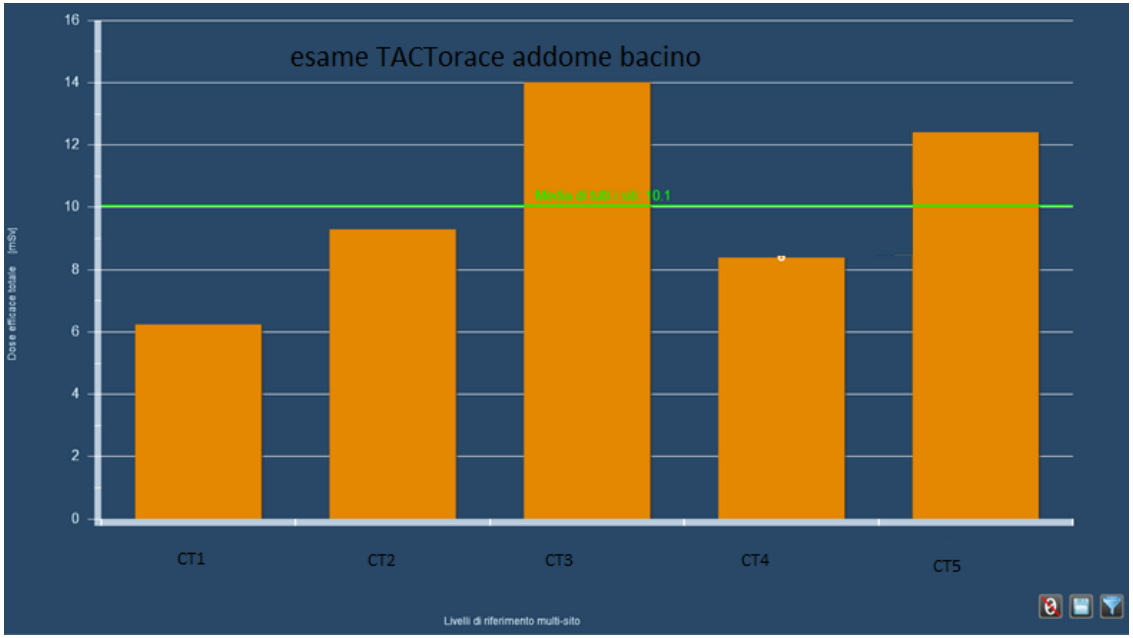
Referenz / Aktenzeichen: R-06-06md
Erstellt: 01.04.2010
Revisions-Nr.

Merkblatt R-06-06
Diagnostische Referenzwerte in der Computertomographie

Tabelle 1: DRW und Zielgrössen für Erwachsene

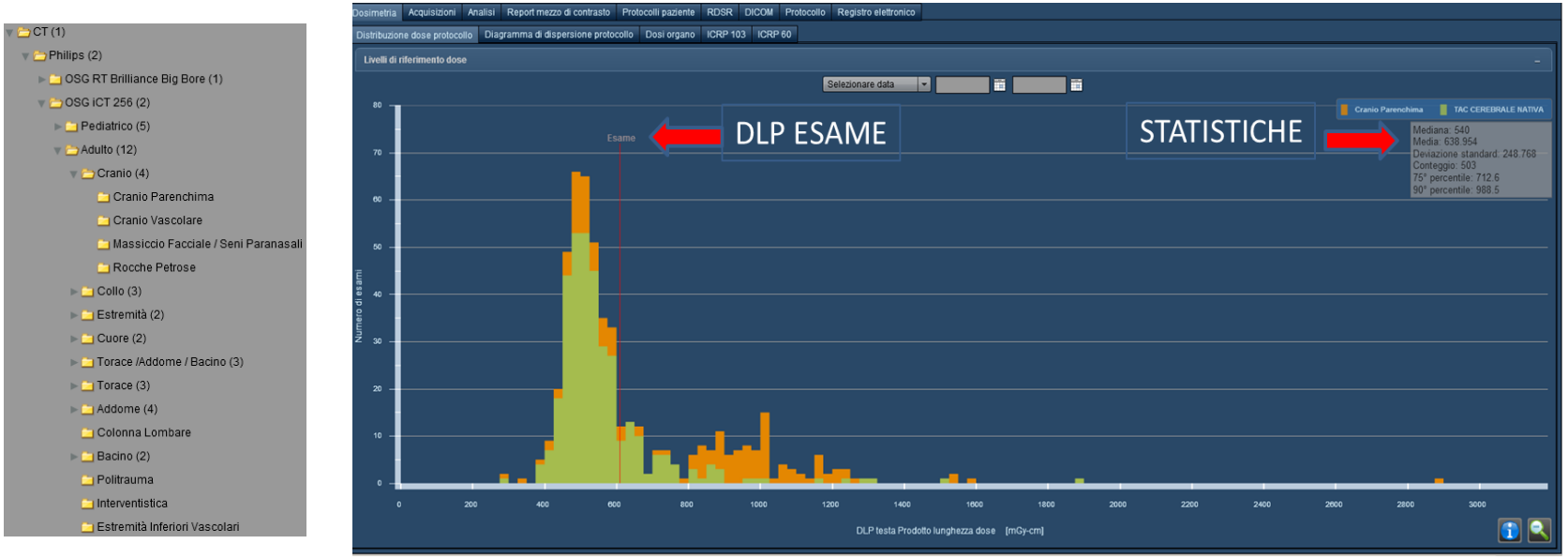
	Untersuchung / Fragestellung	DRW (75. Perzentile)		Zielgrösse (25. Perzentile)	
		$CTDI_{vol}$ [mGy]	DLP [mGy·cm]	$CTDI_{vol}$ [mGy]	DLP [mGy·cm]
1	**Schädel / Hirn** Standardabklärungen, Metastasensuche, Hirn-abszess, …	65	1000	45	600
2	**Hirn (Gefässe)** Blutungen, Aneurysmata, AVM (Arteriovenöse Malformationen), …	65	1000	45	600
3	**Gesichtsschädel, Sinus** Traumata, Sinusitis-Befund, …	25	350	10	150
4	**Schädelbasis, Felsenbeine** Traumata, Cholesteatom, …	50	250	35	200
5	**Hals, HWS (Weichteil, ossär)** Adenopathie, Abszess-Suche, …	30	600	15	250
6	**Hals (Gefässe)** CT-Angio, Vaskuläre Dissektionen, …	20	500	10	350
7	**Schulter (Weichteil, ossär)** Traumata, CT-Arthrographie, …	30	500	15	250
8	**Thorax (Gewebe, ossär, HR)** Infiltrate, Adenopathie, Herdsuche, …	10	400	5	250
9	**Thorax (Gefässe)** LE (Lungenembolie), …	15	450	10	250
10	**Thorax + Oberbauch** Lungen-CA, Meta-Suche, …	15	600	10	300
11	**Abdomen (Oberbauch)** Leber, Milz, Pankreas, Meta-Suche, …	15	400	10	200
12	**Abdomen (O'bauch, Gefässe)** Leber, Milz, Pankreas, Meta-Suche, Gefäss-pathologie, …	15	500	10	250
13	**Abdomen/Becken** Standardabklärungen, Notfall (unklares Abdomen), Abszess, retroperitoneale Lymphadenopathie, …	15	650	10	350
14	**Abdomen/Becken (Gefässe)** CT-Angio, Gefässsituation, …	15	650	10	500
15	**Becken (ossär)** Traumata, Missbildungen, …	20	500	10	300
16	**Becken (Gefässe)** CT-Angio, Gefässsituation, …	20	500	10	300
17	**Thorax / Abdomen / Becken** Traumata, Polyblessé, Aorta, …	15	1000	10	700
18	**Lendenwirbelsäule** Traumata, Frakturen, ossäre Veränderungen, …	30	850	15	300
19	**Untere Extremität (Gefässe)** Angio-CT, …	15	1000	10	700
20	**Herz (Angio-CT)** Kardiovaskuläre Abklärungen, Thoraxschmerzen, Herzinsuffizienz, …	50	1000	30	500
21	**Herz (Kardio-CT)** Calcium-Scoring	10	150	5	50

Benchmark



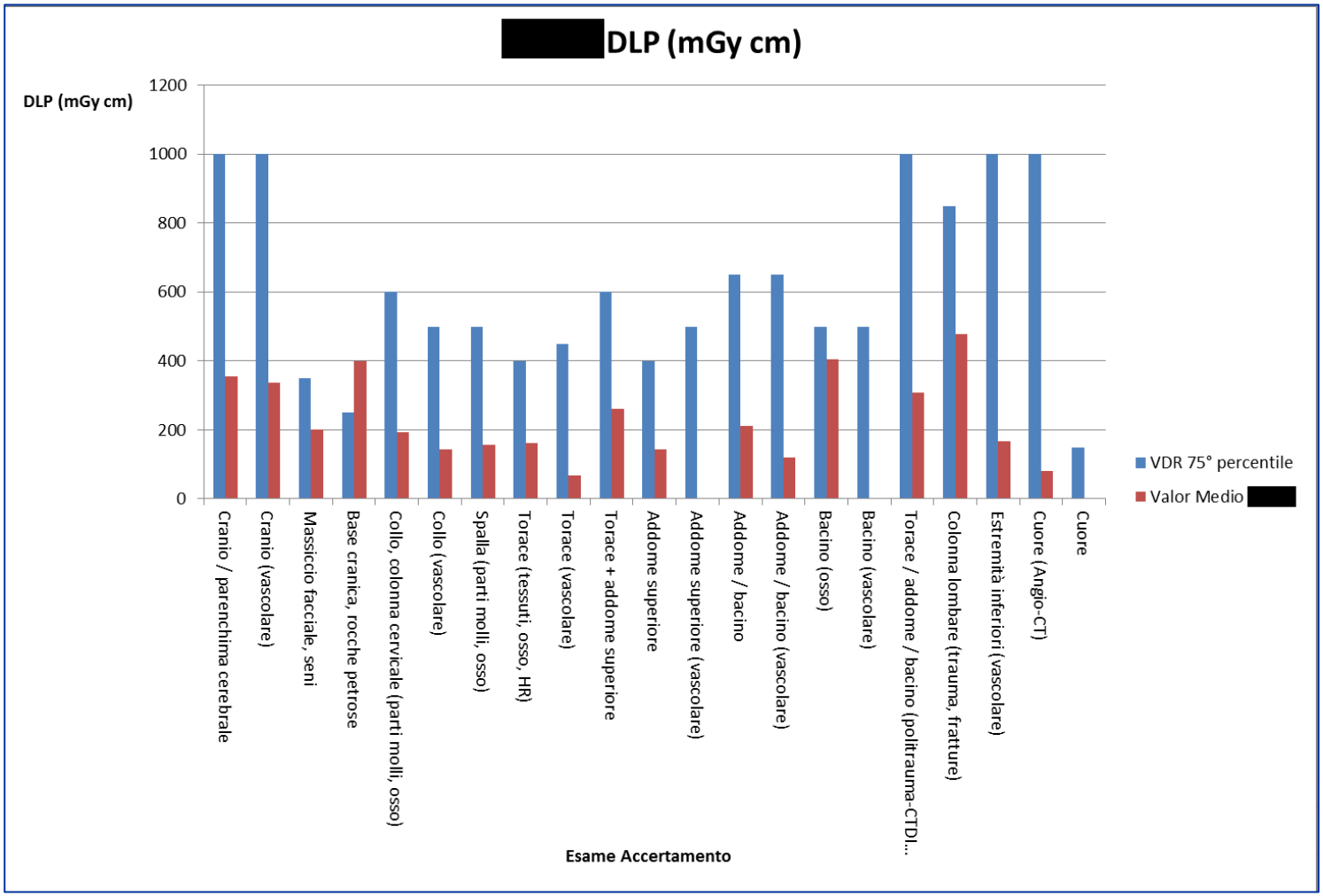
Single protocol Vs. regional distribution

Benchmark

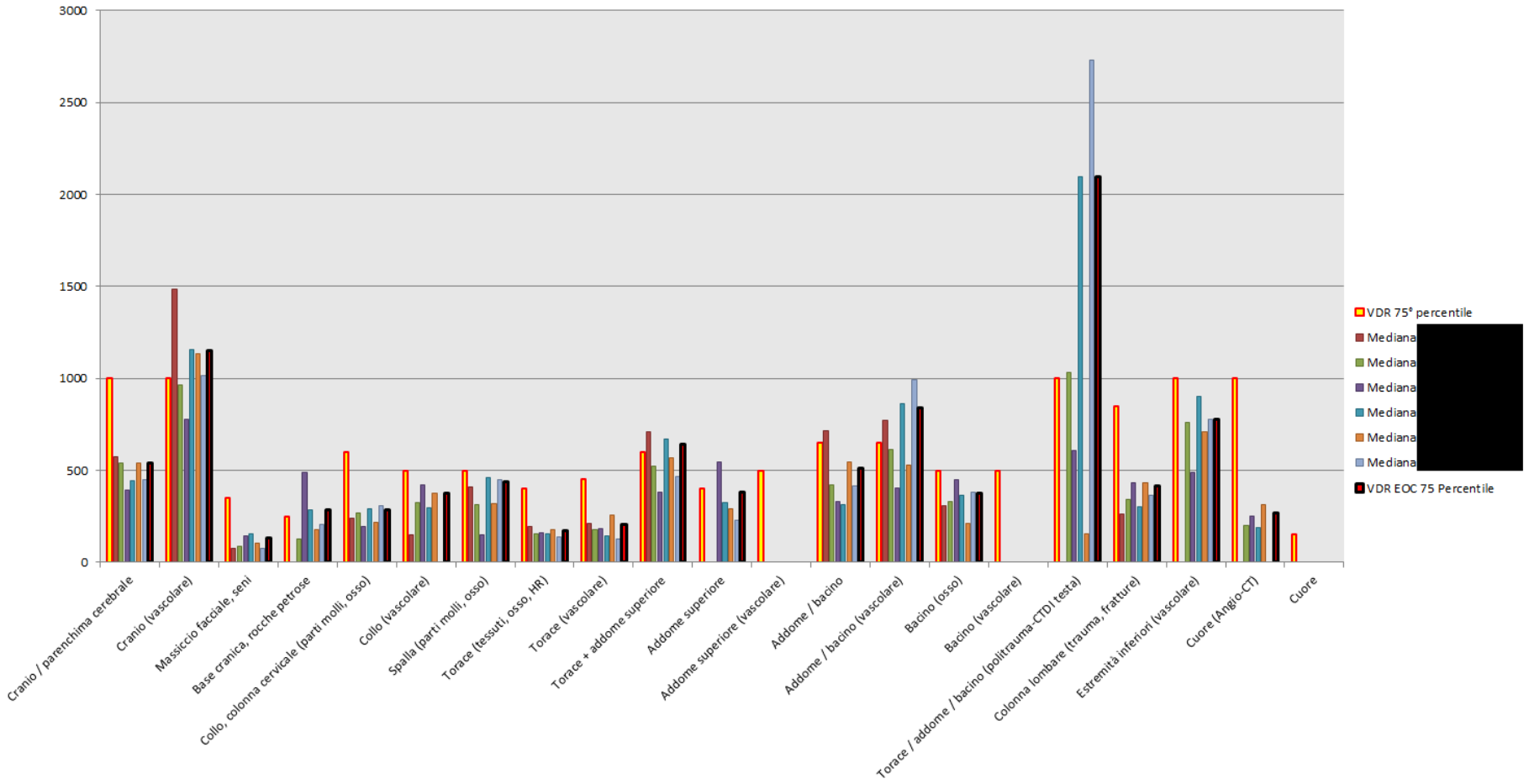


Single exam Vs. local population

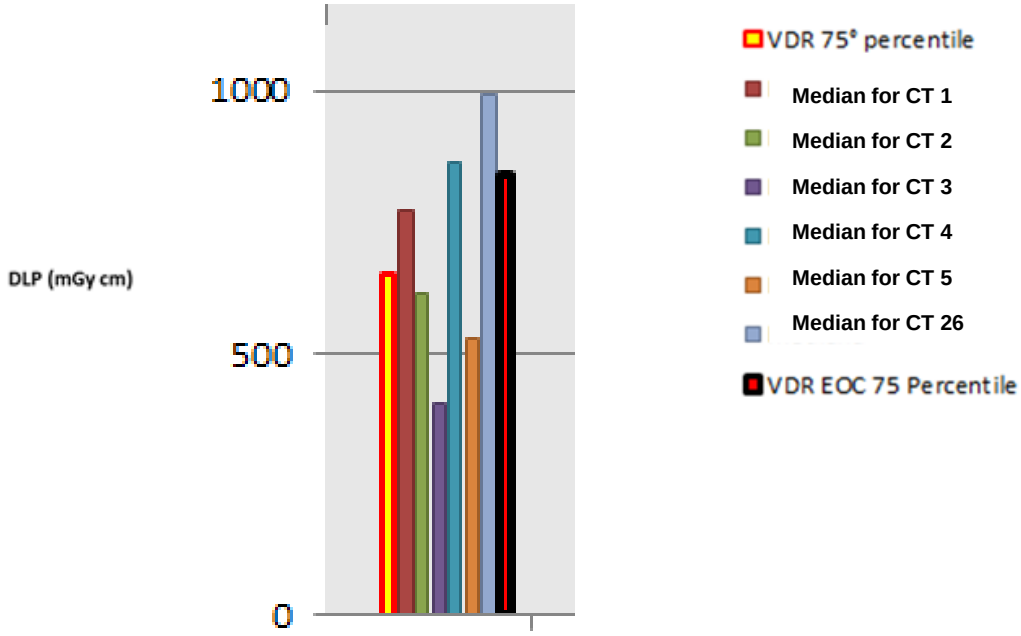
benchmark


[redacted] DLP (mGy cm)
DLP (mGy cm)
1200
1000
800
600
400
200
0
Cranio / parenchima cerebrale
Cranio (vascolare)
Massiccio facciale, seni
Base cranica, rocche petrose
Collo, colonna cervicale (parti molli, osso)
Collo (vascolare)
Spalla (parti molli, osso)
Torace (tessuti, osso, HR)
Torace (vascolare)
Torace + addome superiore
Addome superiore
Addome superiore (vascolare)
Addome / bacino
Addome / bacino (vascolare)
Bacino (osso)
Bacino (vascolare)
Torace / addome / bacino (politrauma-CTDI...
Colonna lombare (trauma, fratture)
Estremità inferiori (vascolare)
Cuore (Angio-CT)
Cuore
Esame Accertamento
VDR 75° percentile
Valor Medio [redacted]

benchmark

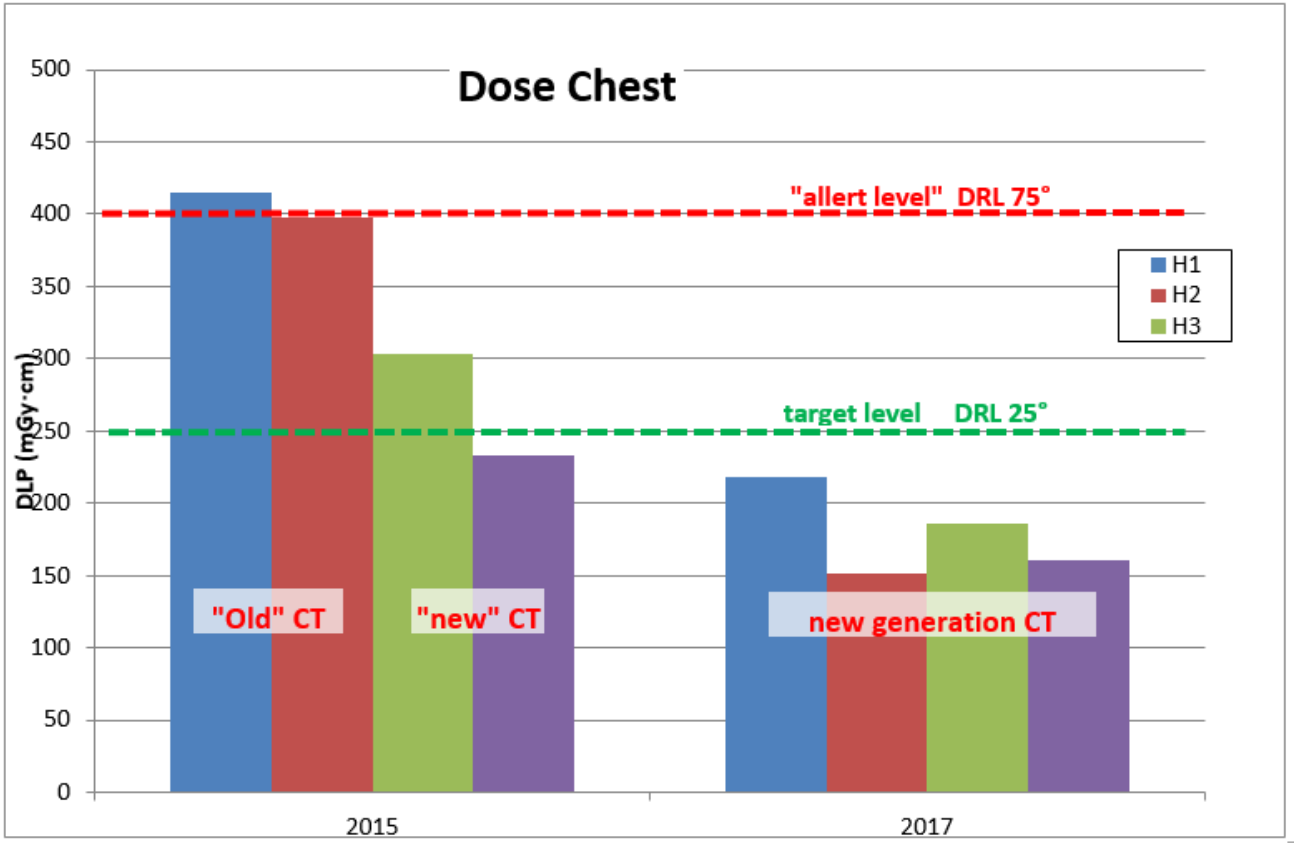

3000
2500
2000
1500
1000
500
0
Cranio / parenchima cerebrale
Cranio (vascolare)
Massiccio facciale, seni
Base cranica, rocche petrose
Collo, colonna cervicale (parti molli, osso)
Collo (vascolare)
Spalla (parti molli, osso)
Torace (tessuti, osso, HR)
Torace (vascolare)
Torace + addome superiore
Addome superiore
Addome superiore (vascolare)
Addome / bacino
Addome / bacino (vascolare)
Bacino (osso)
Bacino (vascolare)
Torace / addome / bacino (politrauma-CTDI testa)
Colonna lombare (trauma, fratture)
Estremità inferiori (vascolare)
Cuore (Angio-CT)
Cuore
VDR 75° percentile
Mediana
Mediana
Mediana
Mediana
Mediana
Mediana
VDR EOC 75 Percentile

benchmark



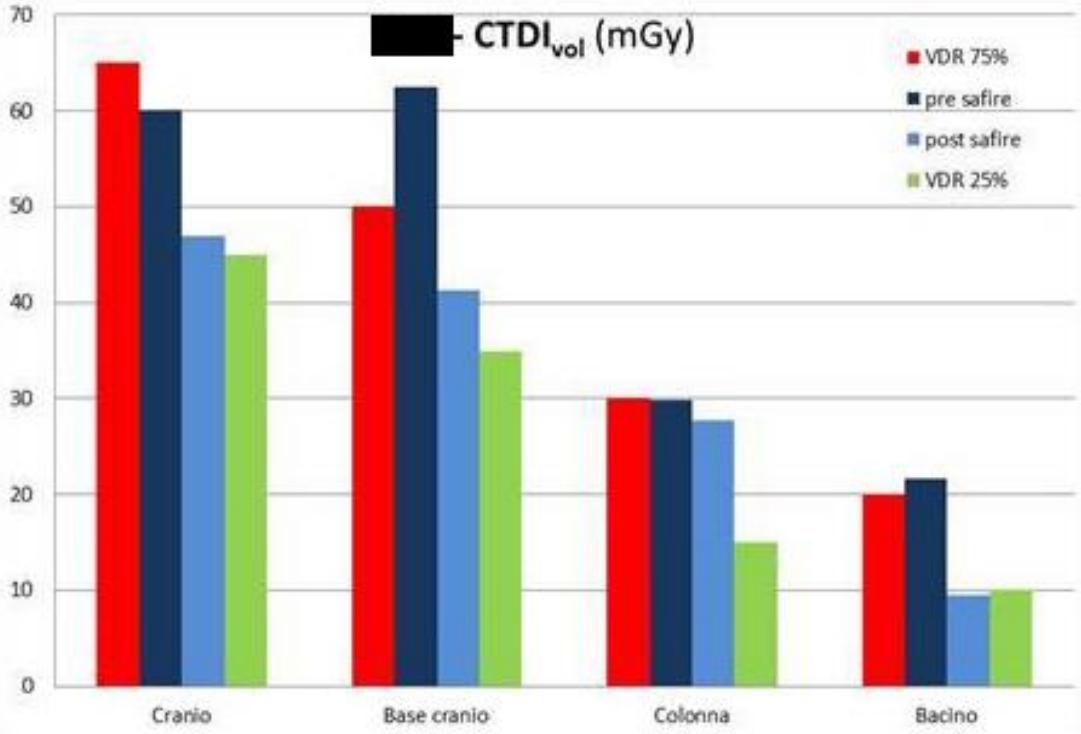
Dose for the total exam

Monitoring action impact



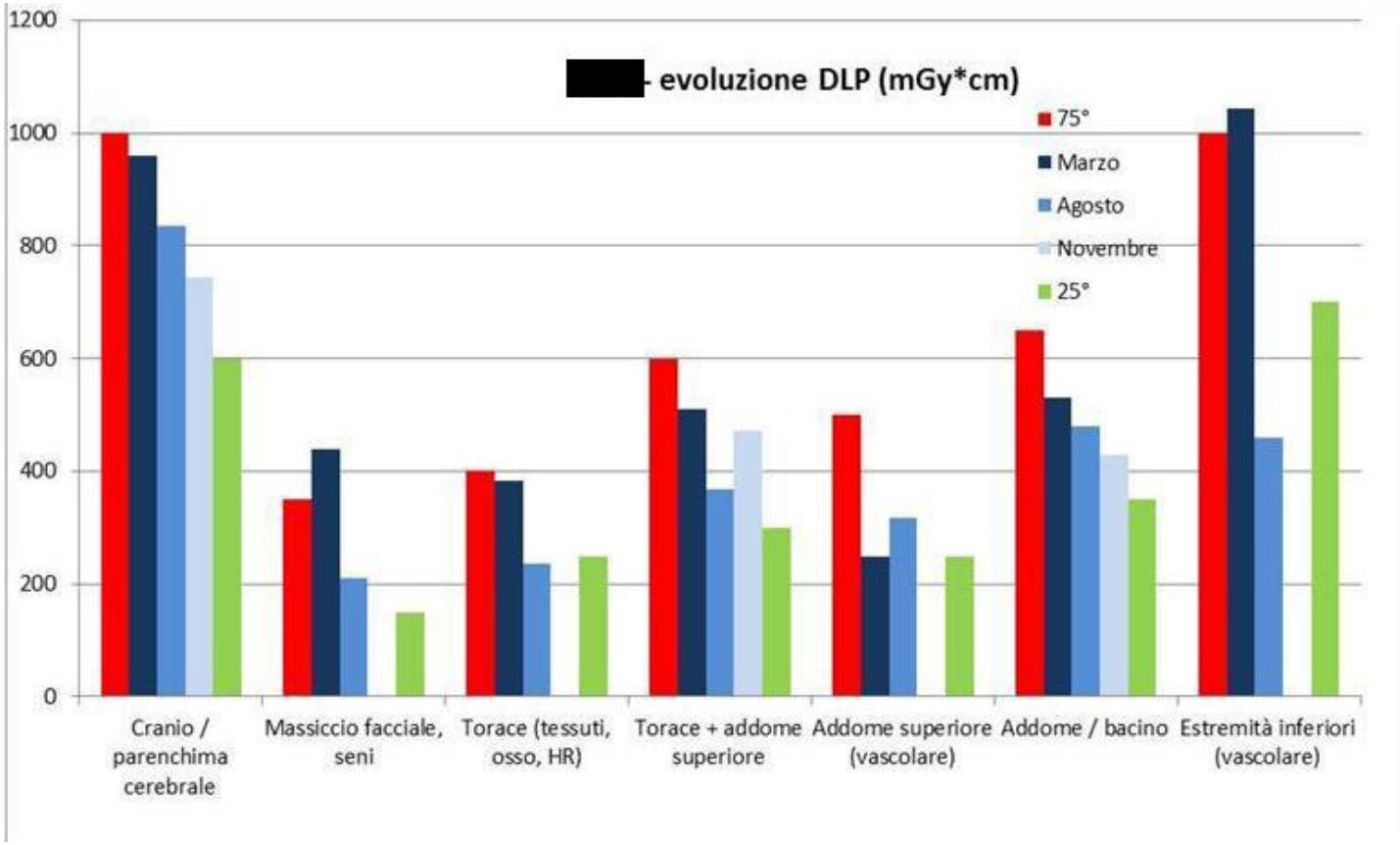
Impact of technologies changes

Monitoring action impact



Impact of software changes

Monitoring action impact



Impact of protocol changes

Single exam dose evaluation

Examination dose Vs. threshold value for the specific patient

Need to adapt to the single patient

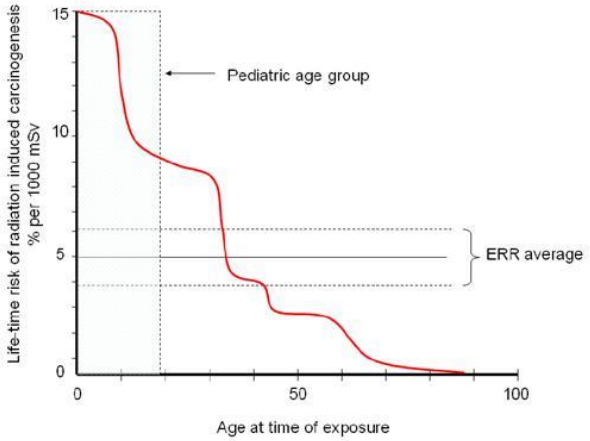
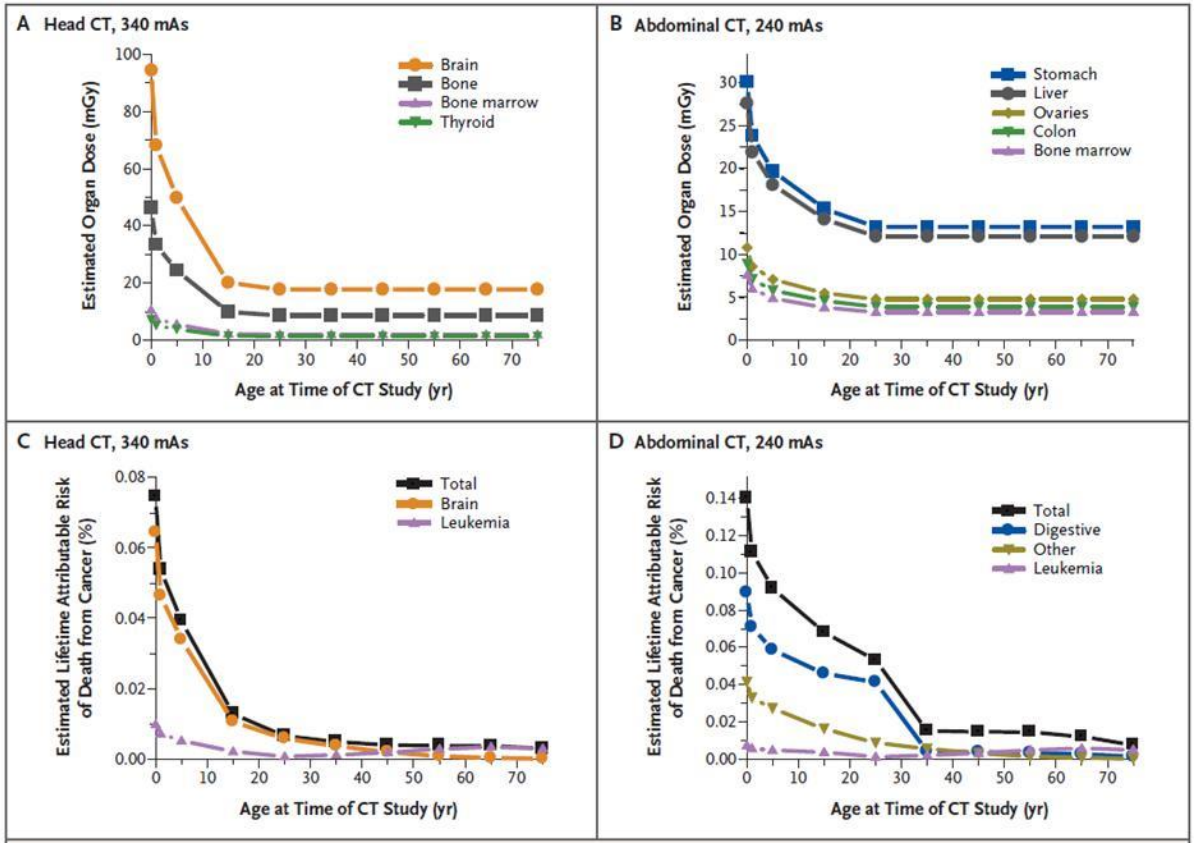
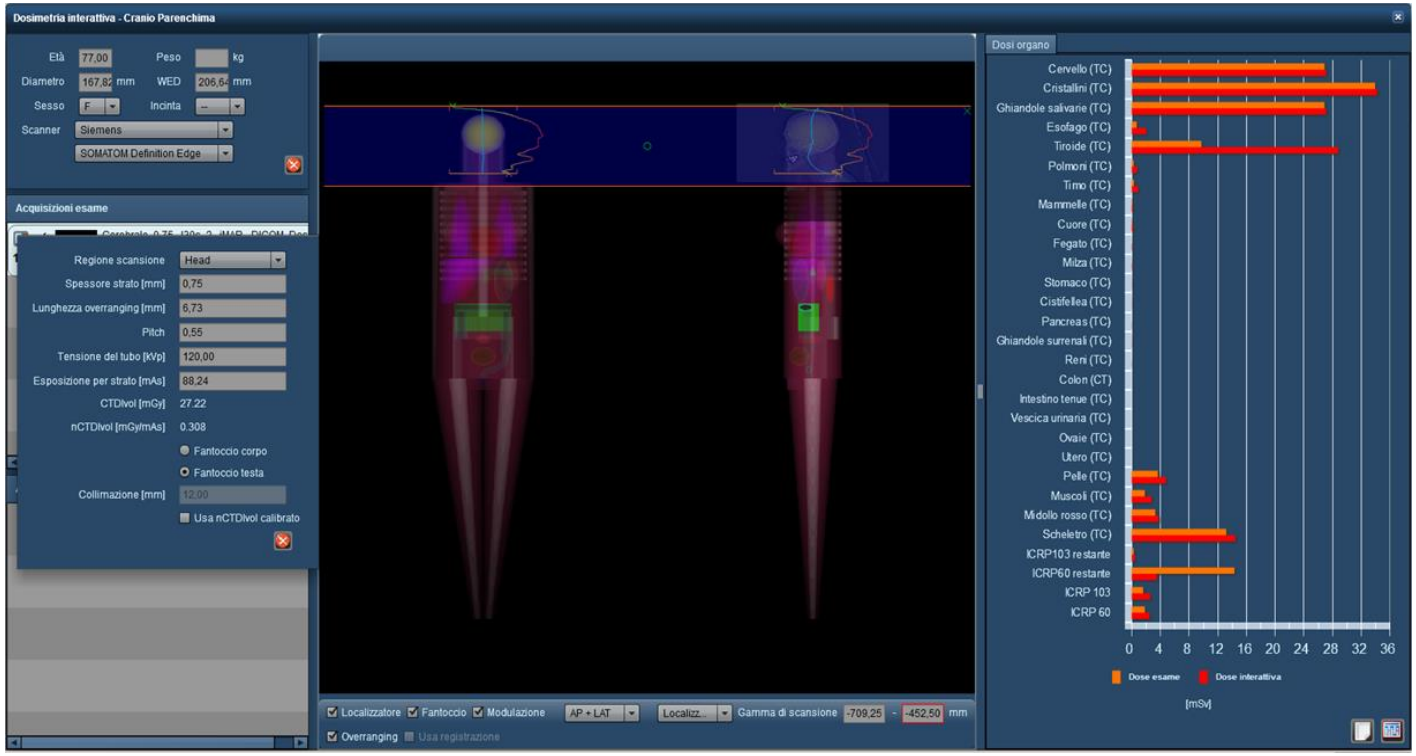


Figure 2 Adapted from ICRP Publication 60 (1990)



N Engl J Med; 2007;357:2277-84; CT - An increasing source of radiation exposure

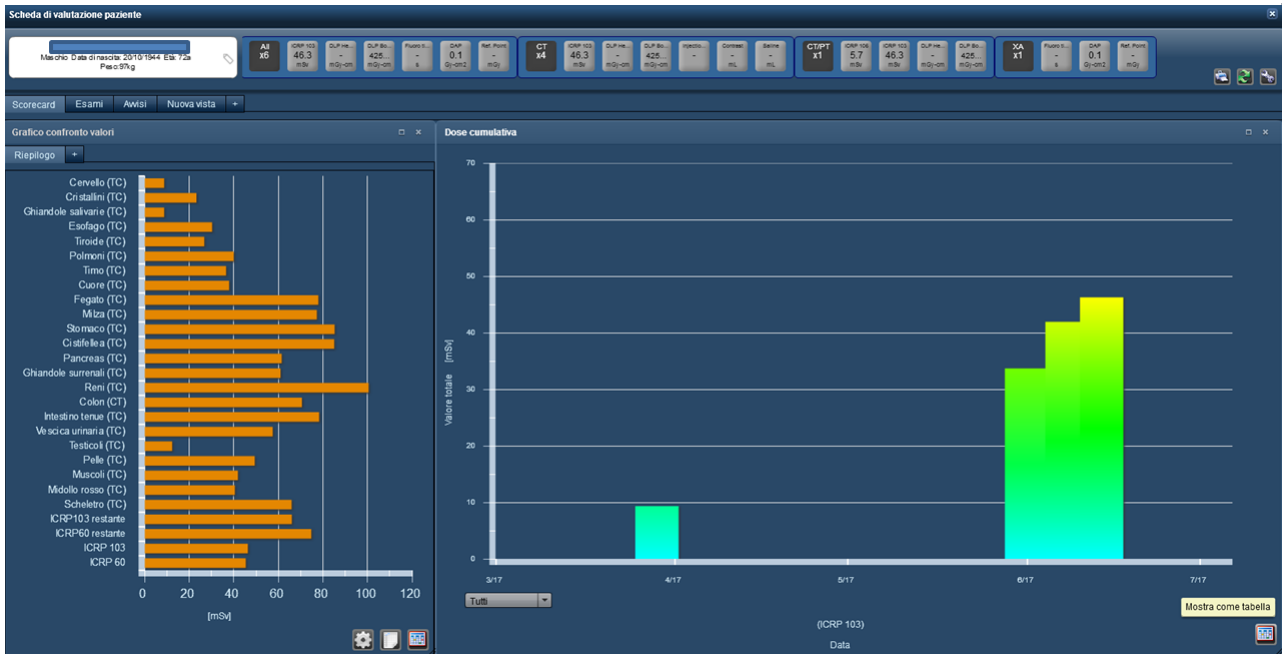
Patient dose distribution



Dose estimation of the individual organ of each specific patient for the specific TAC examination.

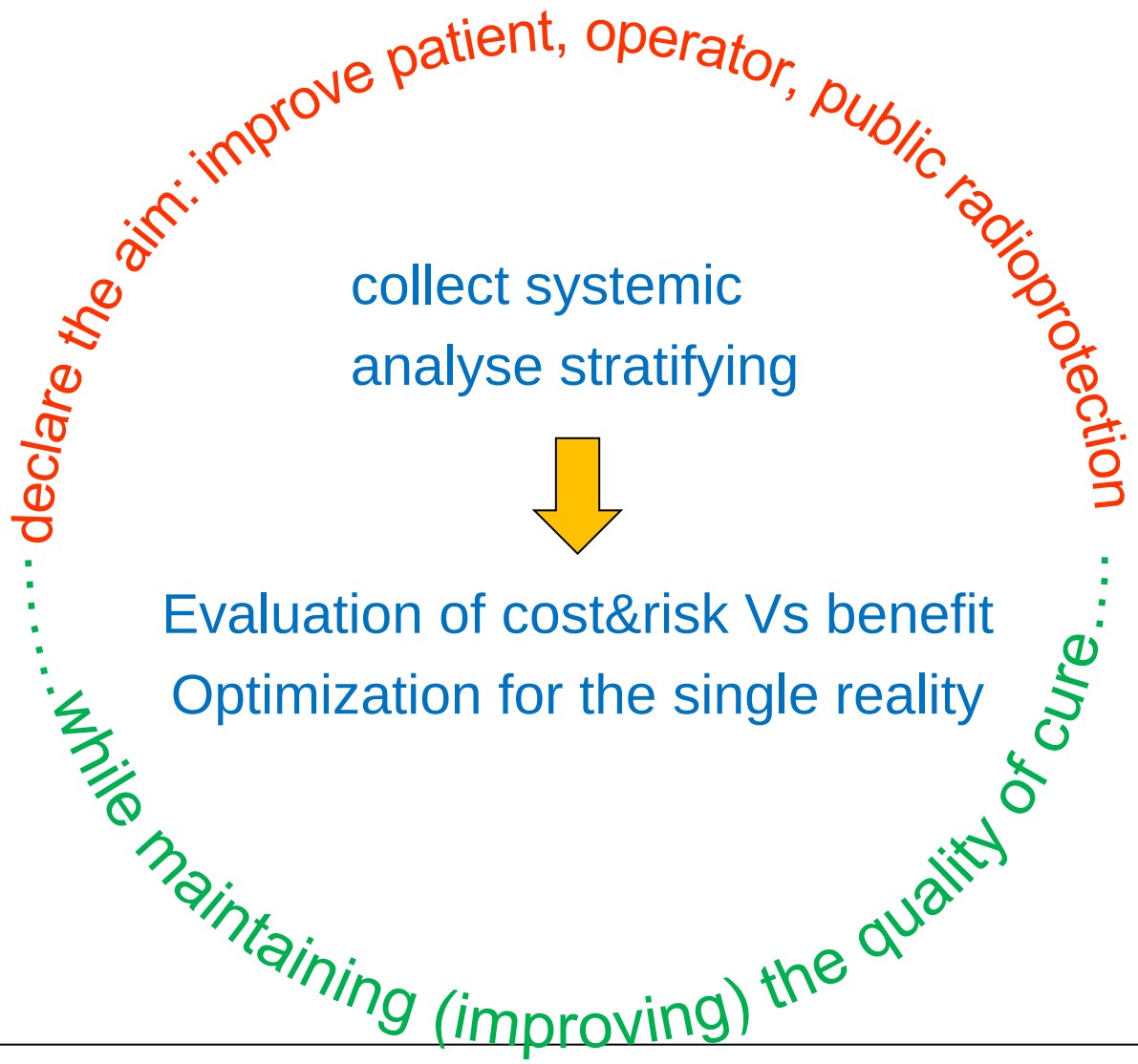
We can make a risk assessment considering also the age, gender, and size of the patient

Patient “dosimetric history”

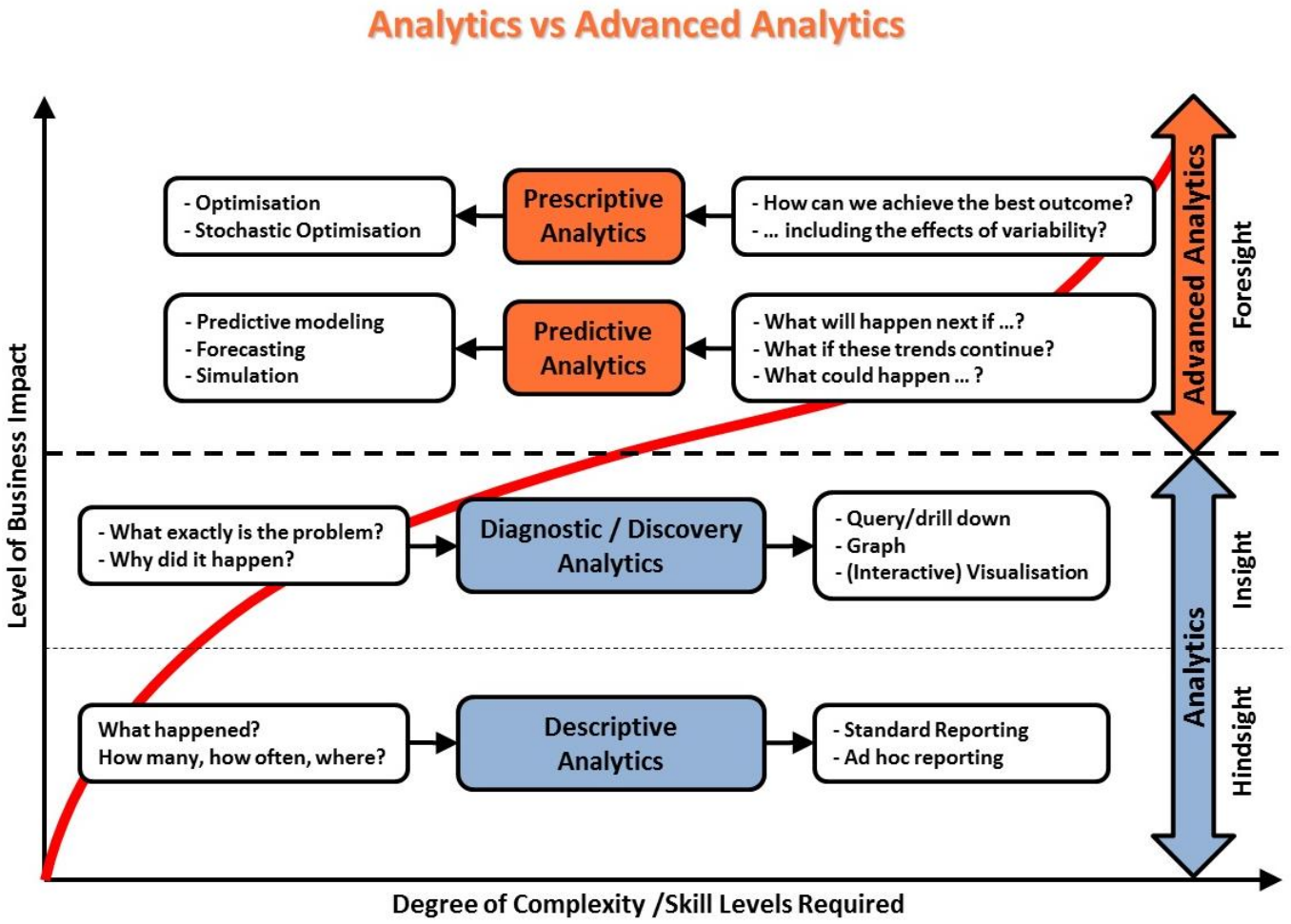


Cumulative dose as adding for each run of a new exam with x-ray

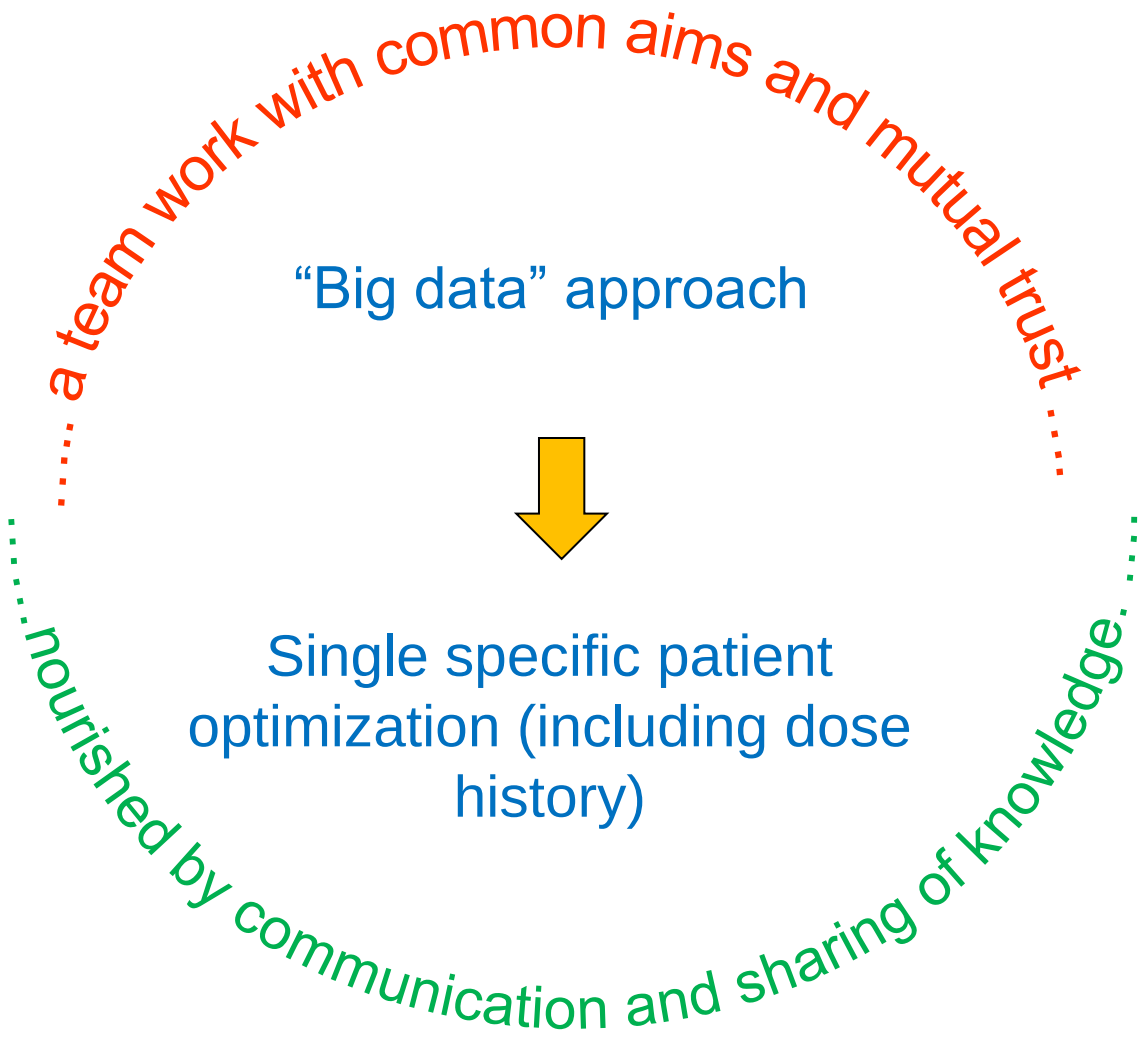
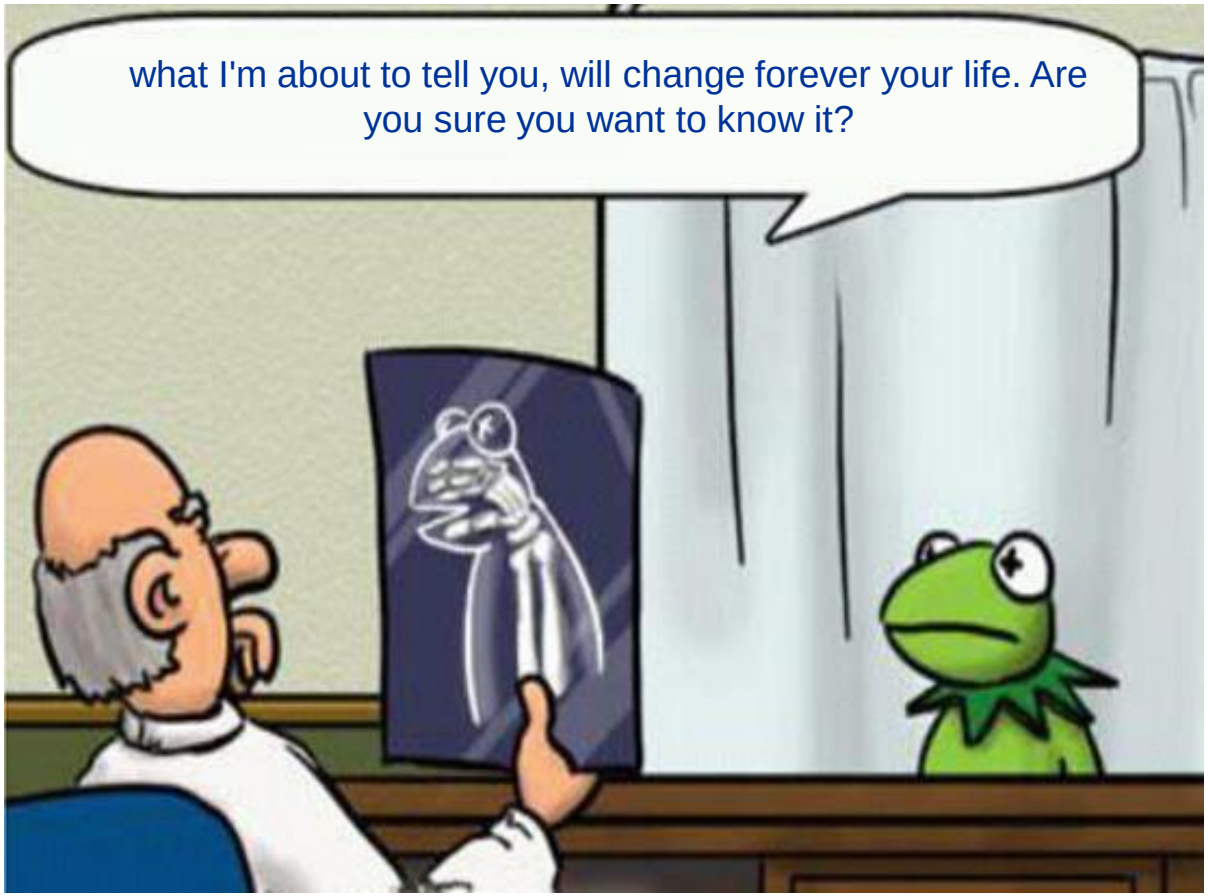
Dose monitoring in our hospital network



our Vision


Analytics vs Advanced Analytics
Level of Business Impact
Degree of Complexity /Skill Levels Required
- Optimisation
- Stochastic Optimisation
Prescriptive Analytics
- How can we achieve the best outcome?
- … including the effects of variability?
- Predictive modeling
- Forecasting
- Simulation
Predictive Analytics
- What will happen next if …?
- What if these trends continue?
- What could happen … ?
- What exactly is the problem?
- Why did it happen?
Diagnostic / Discovery Analytics
- Query/drill down
- Graph
- (Interactive) Visualisation
What happened?
How many, how often, where?
Descriptive Analytics
- Standard Reporting
- Ad hoc reporting
Advanced Analytics
Foresight
Analytics
Insight
Hindsight

Vision for dose monitoring in our hospital network



In our experience: awareness as feeding for optimization