2nd IRPA workshop on reasonableness in the implementation of the ALARA principle

Image quality versus patient dose: analysis of an Italian case in the implementation of ALARA in aortic CT angiography

Osvaldo Rampado, Roberto Ropolo, Marie Claire Cantone

- Medical Physics Department A.O. CITTA' DELLA SCIENZA E DELLA SALUTE DI TORINO

- UNIVERSITY OF MILAN

THE ALARA PRINCIPLE IN MEDICAL IMAGING

Donald L. Miller, M.D.
David Schauer, Sc.D., CHP

The ALARA principle, that radiation doses should be kept **as low as reasonably achievable**, social and economic factors being taken into account, is well known to medical physicists. It is perhaps less well known that the ALARA principle applies to medical exposures as well as to other sources of radiation exposure. This was not always the case.

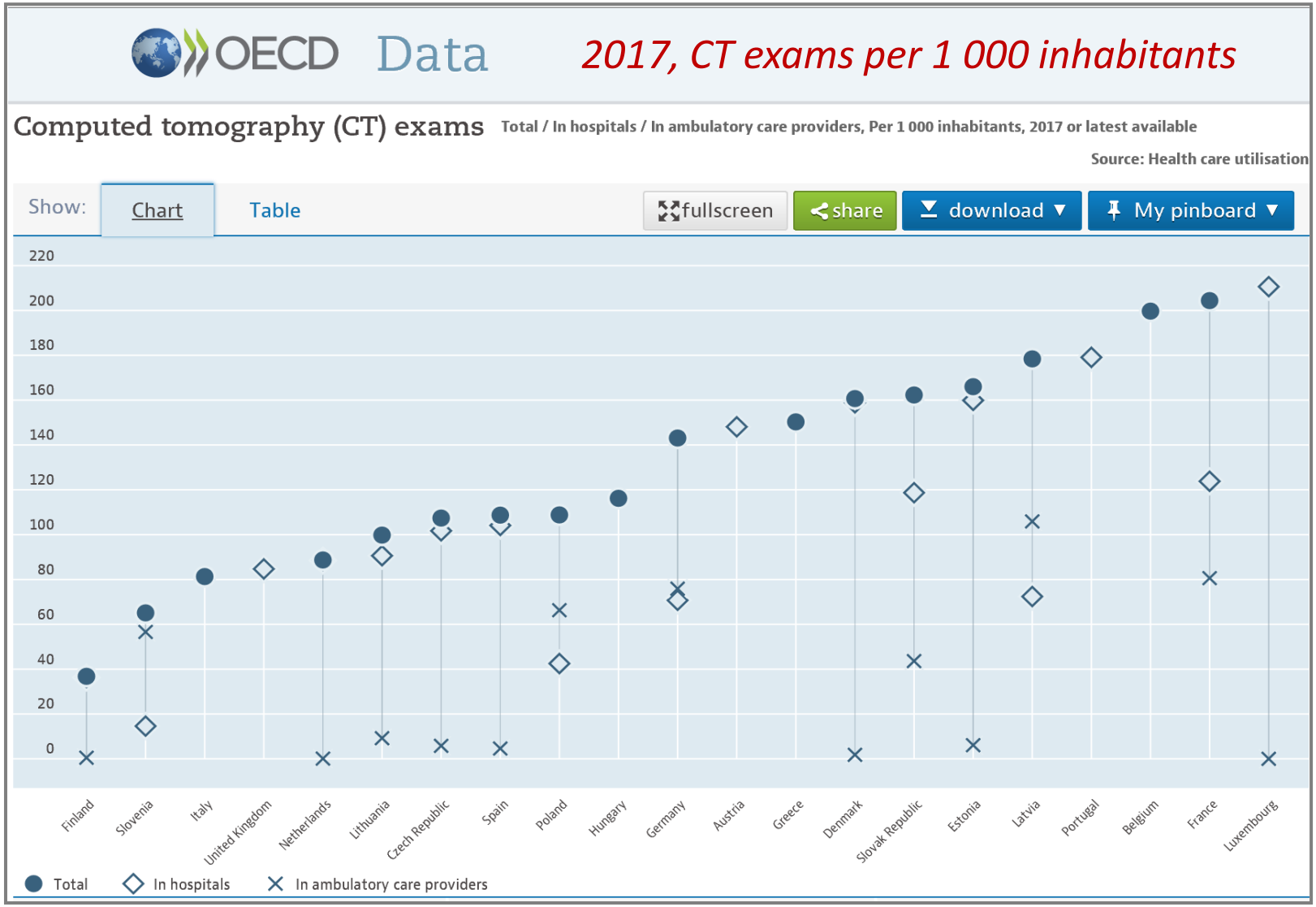
History of the ALARA Principle

ICRP Publication 105 makes the application of the ALARA principle to medical exposures explicit (paragraph 70): "The optimisation of radiological protection means keeping the doses 'as low as reasonably achievable, economic and societal factors being taken into account, and is best described as management of the radiation dose to the patient to be commensurate with the medical purpose." Publication 105 also clarifies the operational goal of the ALARA principle in medical imaging (paragraph 47): "In medicine, the requirement is to manage the radiation dose to the patient to be commensurate with the medical purpose. The goal is to use the appropriate dose to obtain the desired image or desired therapy."

AAPM newsletter volume 40 n.1, 2015

In the case of Computed Tomography….

Patient dose in CT



OECD (2018), Computed tomography (CT) exams (indicator). doi: 10.1787/3c994537-en
https://data.oecd.org/healthcare/computed-tomography-ct-exams.htm

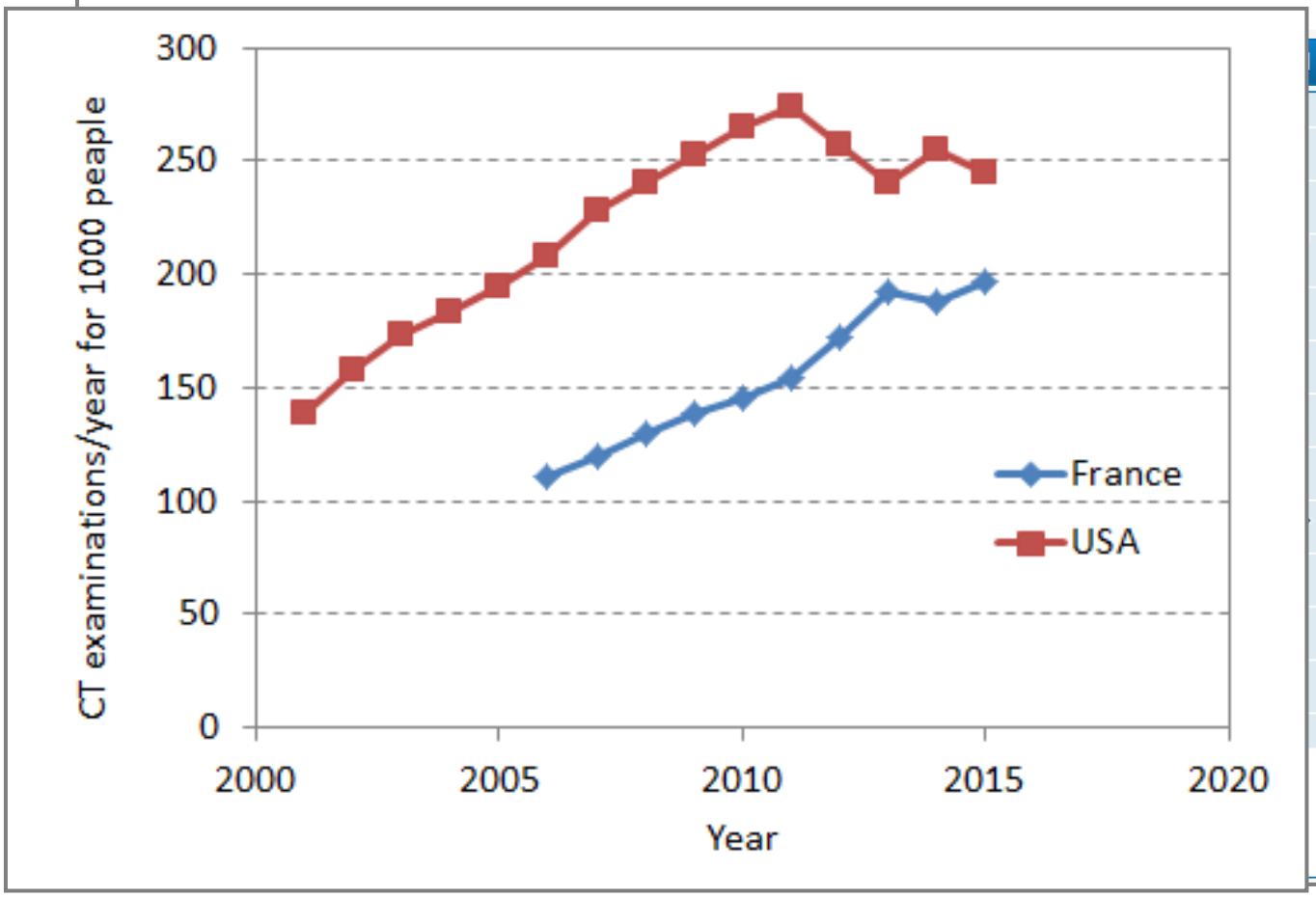
Patient dose in CT

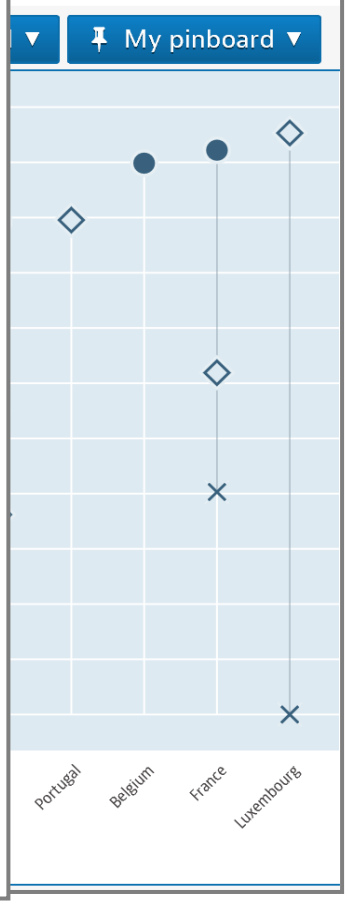
OECD Data

2017, CT exams per 1 000 inhabitants

Computed tomography (CT) exams Total / In hospitals / In ambulatory care providers, Per 1 000 inhabitants, 2017 or latest available

Source: Health care utilisation





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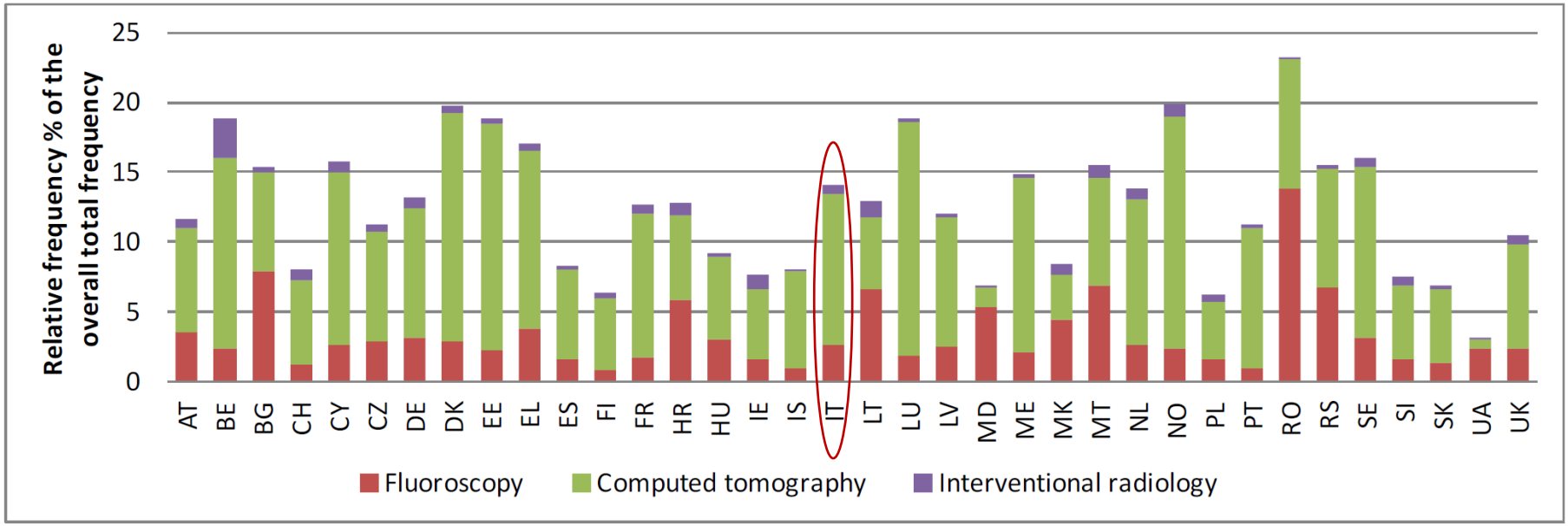
Patient dose in CT

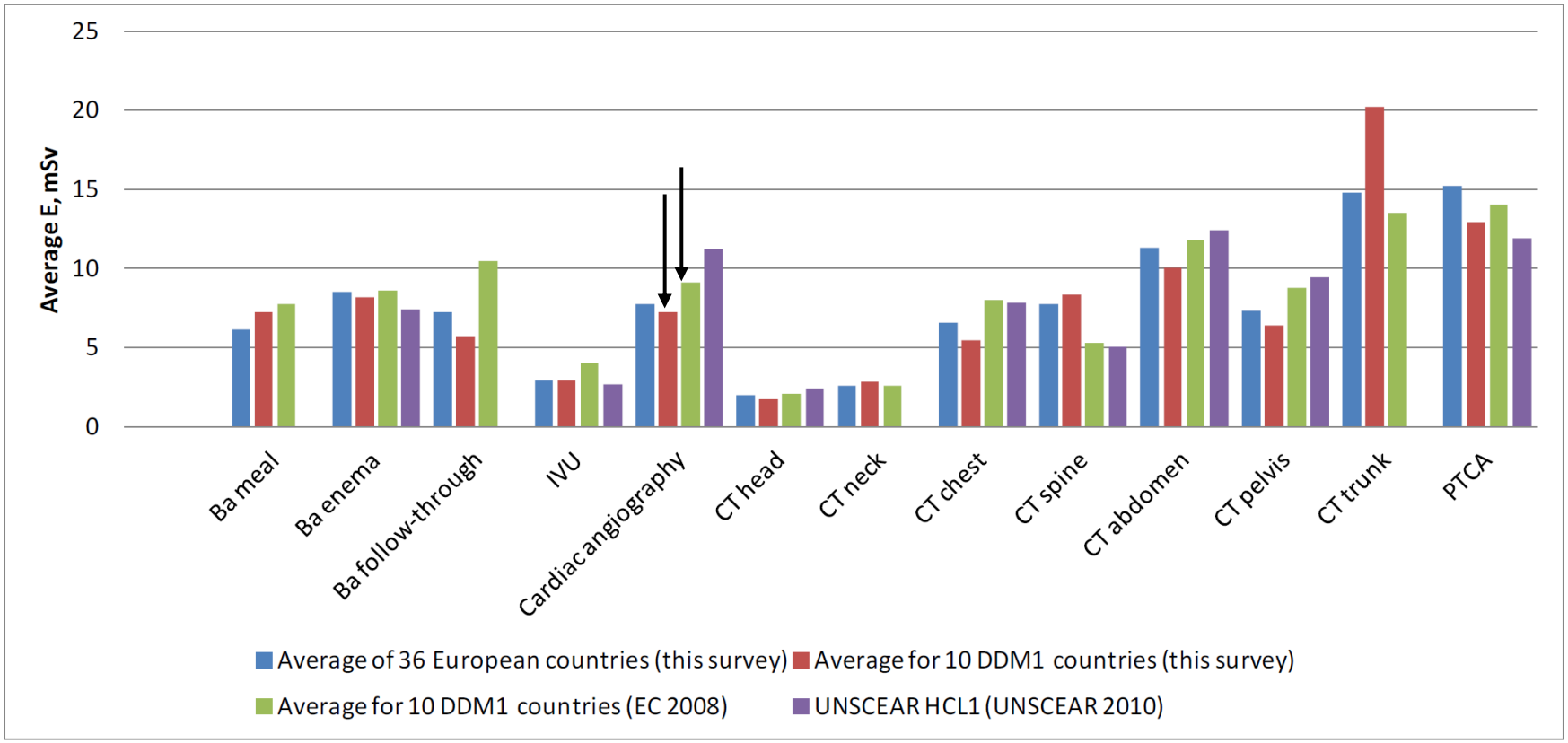


Dose Datamed 2 (DDM2)

Relative frequencies as a percentage of the overall total frequency of all x-ray examinations, except plain radiography

European Commission - Radiation Protection N. 180, Medical Radiation Exposure of the European Population, 2014

Patient dose in CT



Dose Datamed 2 (DDM2)

Average values of typical effective doses (mSv) obtained in DDM2, compared with the early data from 10 European Countries and UNSCEAR HCL1 countries

European Commission - Radiation Protection N. 180, Medical Radiation Exposure of the European Population, 2014

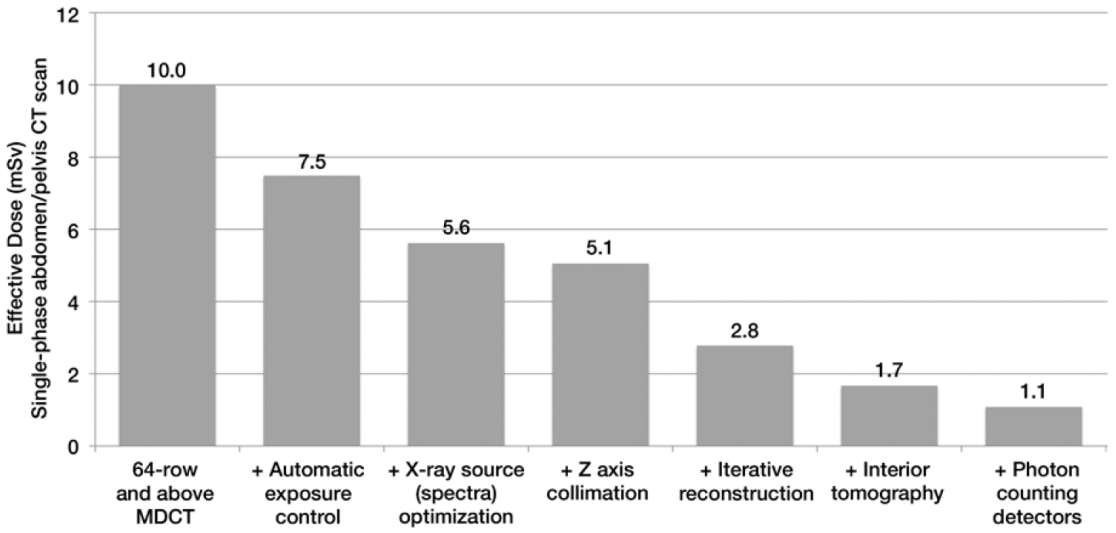
CT dose reduction devices

Dose reduction in CT is a major target for all professionals in every diagnostic department

All the CT scanner companies have developed in the last ten years several devices and techniques for dose reduction.

Achieving Routine Submillisievert CT Scanning:
Report from the Summit on Management of Radiation Dose in CT[1]

Radiology: Volume 264: Number 2—August 2012

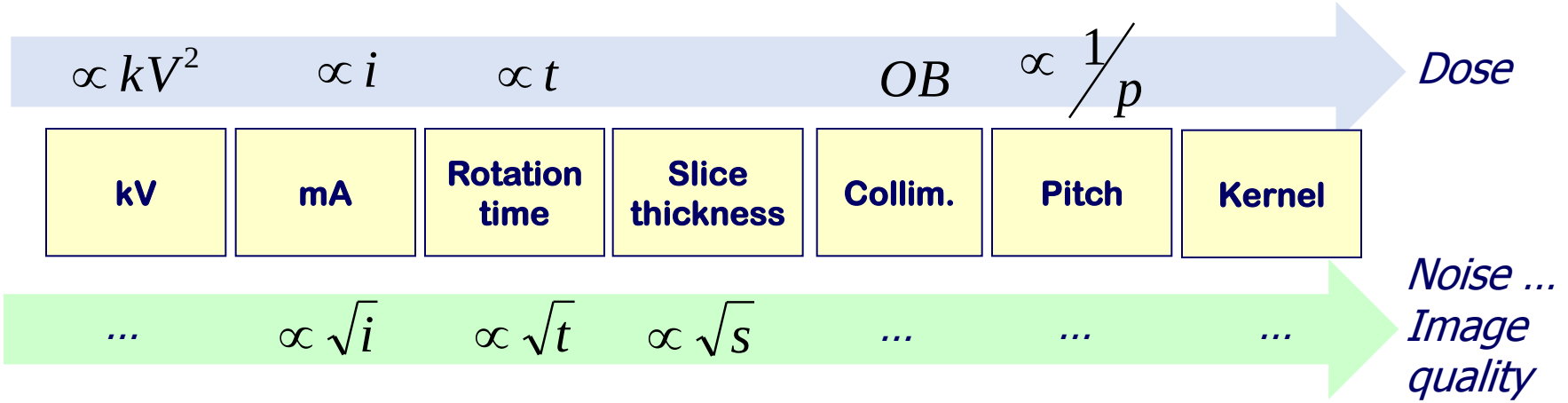


Estimated Reduction in Dose by using various approaches to MDCT system, 64-detector row, in abdomen and pelvis. Each successive dose-reduction approach is applied to the previous dose estimate.

Among other factors, tube current modulation and iterative algorithms could allow a dose reduction of about 60 %, but the exact dose saving depended strongly on the parameter choice of the user.

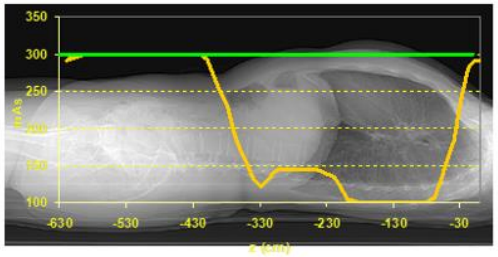
Dose reduction in CT with new dedicated devices

In the past dose reduction was achieved by straightforward modification of exposure parameters

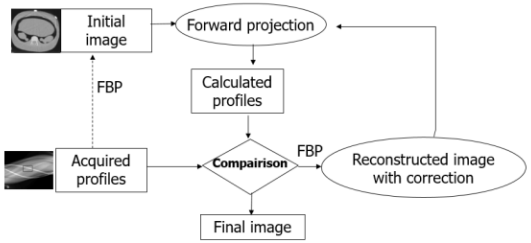


But **now it is «a must» to know the functioning** of other parameters of dedicated devices

Desirable noise (tube current modulation)



Iterative level



Tube current modulation

The modulation of tube current is based on a choice of an acceptable level of noise on the final image, which should be specifically defined for each different diagnostic objective.

Anatomical district

Diagnostic task

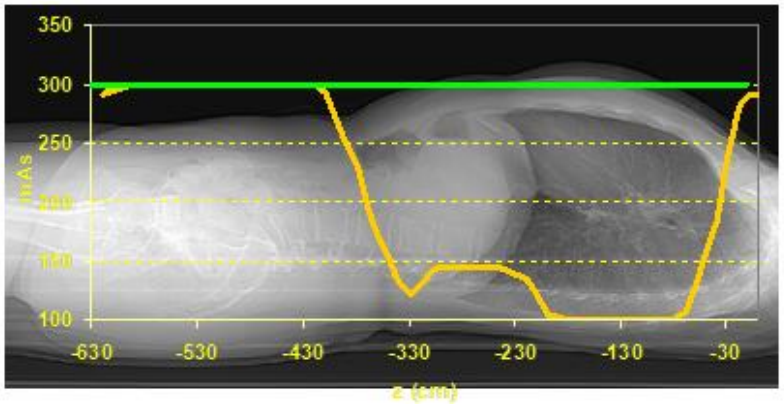
Desired image quality (noise index)

⇨

Patient topogram

⇨

Automatic tube current modulation



Without modulation 13 mSv

With modulation 8 mSv

Iterative CT algorithms: advantages

Iterative reconstruction methods in CT were implemented in the last ten years with several potential benefits:

→ Noise reduction with resolution maintenance (in some cases better)

→ Reduction of artifacts associated with traditional filtered back projection (FBP) methods

→ Possibility of dose reduction with various strategies (reducing the beam intensity with lower tube current, reducing the number of projections,…)

→ Possibility of using small focus and reduced kV even on large patients

Filtered back projection *Iterative Reconstruction*

Beister et al 2012

CT aorta examination optimization: an Italian experience

Multislice CT can be used to diagnose various abnormalities of the aorta, such as aortic aneurysms, aortic dissection, traumatic aortic transection, and congenital malformations.

Fig. 3—70-year-old man with diffuse abdominal pain. Three-dimensional volume rendering of contrast-enhanced CT scan shows fusiform aneurysm of distal abdominal aorta without extension into iliac arteries. Note narrowing of right common iliac artery (*arrow*). Atherosclerotic plaque is highlighted in blue and contrast-opacified lumen in pink.

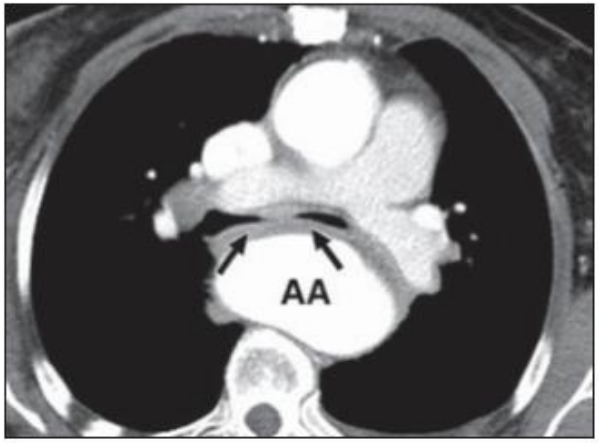


Fig. 4—70-year-old woman with shortness of breath. Contrast-enhanced CT image shows large fusiform descending aortic aneurysm (AA) causing extrinsic compression of adjacent bronchi with luminal narrowing (*arrows*).

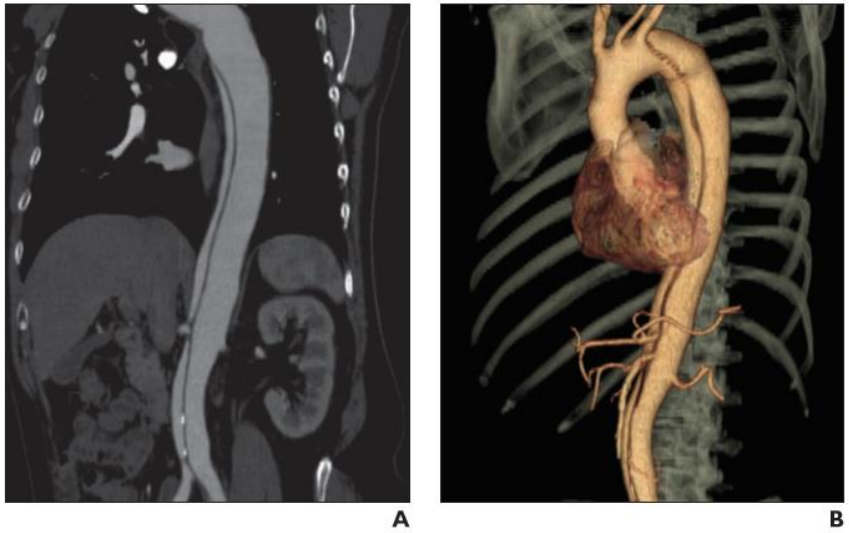


Fig. 13—58-year-old man with chest pain.
A and **B**, Curved multiplanar reconstruction (**A**) and 3D volume rendering (**B**) of contrast-enhanced CT show type B dissection originating just distal to left subclavian artery, continuing into left common iliac artery.

Litmanovich et al. (2009)

Due to the <u>multiple scan performed for each CT aorta examination</u> (basal, contrast and late phase) and to the need of thin slices with acceptable noise, <u>patient dose can reach tens of mSv for each exam.</u>

CT aorta examination optimization: an Italian experience

Radiol med (2016) 121:291–300
DOI 10.1007/s11547-015-0611-4

CrossMark

COMPUTED TOMOGRAPHY

Aortic CT angiography dose reduction: investigation of optimal noise index and iterative algorithm strength in combination with low kV

Osvaldo Rampado[1] · Stefania Busso[1] · Domenica Garabello[2] · Ezio Marengo[2] · Marco Valerio[2] · Simona Capello[2] · Simona Veglia[2] · Ottavio Davini[2] · Roberto Ropolo[1]

The aim of this study is to optimize an aorta angiographic CT protocol, by investigation of the best combination of tube current modulation, iterative algorithm strength and kV reduction for patients of different sizes.

CT aorta examination optimization: an Italian experience

Table 3 Comparison of optimisation studies about aortic CT

Main results of published optimisation

Reference	CT manufacturer	Reference protocol	Optimized protocol	Dose reduction	Finale average CTDI (mGy)
Cornfeld [22]	GE	120 kV, TCM NI 11, 3.75 mm no iterative	120 kV, TCM NI 13.75, 3.75 mm, ASIR 40 %	−29 %	15.6
Fanous [7]	Toshiba	120 kV, 350 mA, 0.5 s, 1 mm, no iterative	100 kV, 350 mA, 0.5 s, 1 mm, no iterative	−37 %	12.5
Yu [6]	Siemens	120 kV, TCM, no iterative, 0.6 mm	80 or 100 kV, 0.6 mm, TCM, no iterative	−36 %	11.2
Schindera [9]	Siemens	100 kV, TCM ref 160 mAs, 1.5 mm	80 kV, TCM ref 260 mAs, 1.5 mm	−23 %	5.2
Pontana [12]	Siemens	120 or 100 kV, TCM, 1 mm, no iterative	100 or 80 kV, TCM, 1 mm, iterative Safire Strength 3	−50 %	1.2

Rampado et al. 2016 - After the adoption of optimised protocol:

100 kV for small sized patient a dose reduction of 47% , CTDI of 2.7 mGy
100 kV for medium sized patient a dose reduction of 47% , CTDI of 5.9 mGy
120 kV for large sized patient a dose reduction of 49% , CTDI of 10.1 mGy

CT aorta examination optimization: an Italian experience

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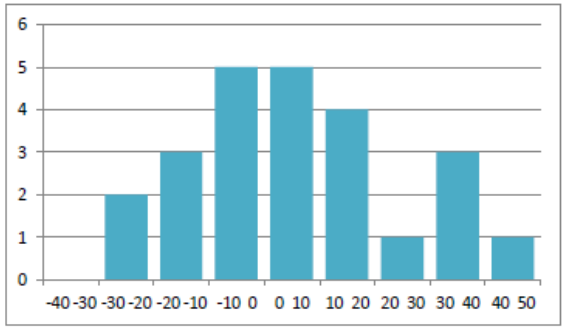
To our knowledge, this is the first phantom study for CT angiography that has considered the complex interplay between:

- different phantom sizes, - kV reduction,- tube current modulation
- iterative algorithms,
with objective and subjective image quality evaluations.

Following the introduction of the new protocol…

ROI noise difference

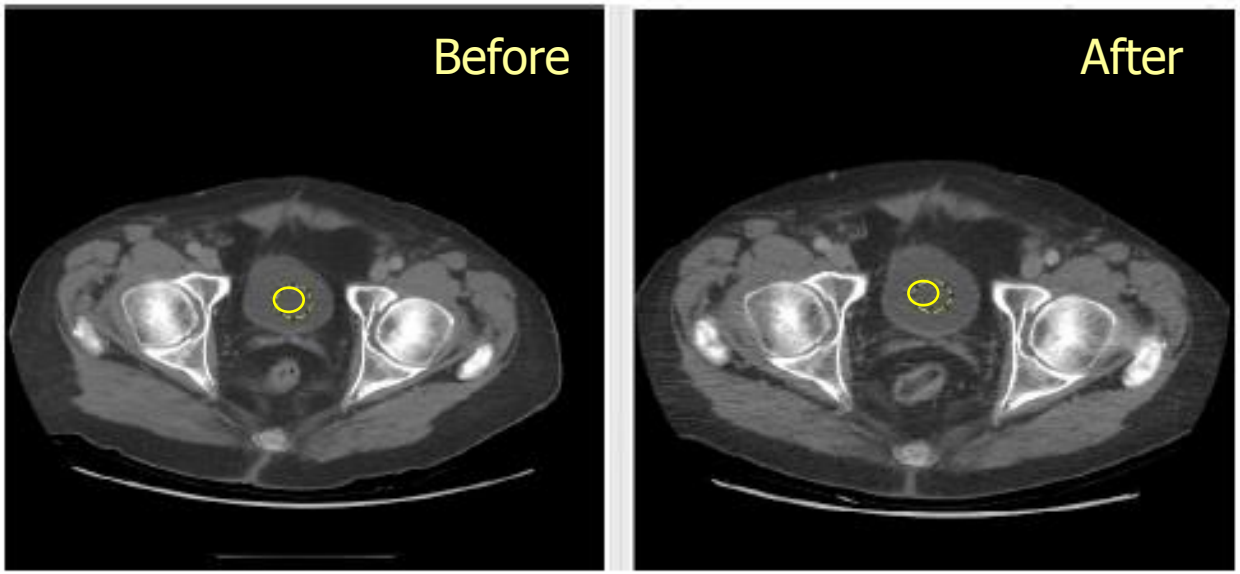


< 20% in 70% of cases

After implementing the optimized protocol, 20 patients were identified who performed a CT before optimization to compare the images acquired with the two modalities.

Subjective evaluation of image quality was good in all cases, even with a reduction of dose near to 50%

Abdominal aortic aneurysm



Following the introduction of the new protocol…

When different dose reduction parameters are available, anthropomorphic phantoms of different sizes help to find the optimal combination.

For aorta studies, 100 kV with relative high values of noise indexes and iterative levels provides the best balance between dose reduction and image quality, the approach used with multiple anthropomorphic phantoms allowed to investigate dose reduction possibilities for different sized patients.

An optimized protocol was established, with a dose reduction of 47 % from the previous protocol.

This result was possible after the definition of a "best equilibrium" between different dose reduction possibilities based on kV choice, noise index and iterative post processing level.

Staff training ...

TECHNICAL PARAMETERS AND SYSTEMS FOR THE REDUCTION OF DOSE

MODALITA' DI ISCRIZIONE

PER GLI INTERNI A.O.U. CITTÀ DELLA SALUTE

1.Collegarsi ed entrare con la propria password nel sito ECM Regione Piemonte www.ecmpiemonte.it
2.Cliccare su "Offerta formativa"
3.Scegliere il corso
4.Cliccare sull'icona per iscriversi
5.Scegliere l'edizione e cliccare sull'icona
6.Confermare la preiscrizione con "OK"
7. Verificare l'avvenuta approvazione della pre-iscrizione da parte del Coordinatore/Referente formativo
8.Verificare la CONFERMA dell'iscrizione: potrà essere visualizzata in piattaforma almeno 20 giorni prima del corso, nella sezione riepilogo iscrizioni, SOLO dopo la definitiva accettazione dell'iscrizione da parte della segreteria organizzativa

FORMAZIONE FAD

I partecipanti, dovranno scaricare **singolarmente il giorno di inizio del percorso FAD** utilizzando il proprio account da www.ecmpiemonte.it - home page - "materiale didattico" ***PENA LA NON ASSEGNAZIONE DEI CREDITI ECM,*** la documentazione prevista dai docenti leggerla e studiarla prima dell'inizio del percorso residenziale. La valutazione del percorso FaD sarà conteplata nella valutazione finale del corso

SEGRETERIA ORGANIZZATIVA

Rita GENTILE CASAGRANDE
mail *rgentilecasagrande@cittadellasalute.to.it*
tel. 011-6333209 – FAX 011-6335116

DESTINATARI

20 partecipanti:

- Tecnici Sanitari Radiologia Medica
- Fisici Sanitari

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Modulo 007_RES - LOCANDINA
Revisione n. 3
Data di emissione : 1 settembre 2017
Approvato ed emesso in originale

S.S. FORMAZIONE PERMANENTE E AGGIORNAMENTO

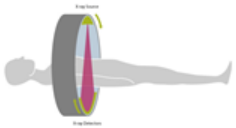
Progetto Formativo Aziendale - BLENDED

CORSO DI PERFEZIONAMENTO IN TC:

I PARAMETRI TECNICI E I SISTEMI PER LA RIDUZIONE DELLA DOSE

DATE

Ediz.1: **11, 19 Aprile 2018**



ORARIO

Dalle ore 14 alle ore 18

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AULA GIALLA
ISTITUTO ROSMINI
Via Rosmini 4 - Torino

ECM REGIONE PIEMONTE

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ALARA experience from CT aorta examination

→ The implementation of the ALARA principle in modern CT equipment with dose reduction devices is rather complex and it should be set up with phantom measurements and visual assessments by radiologists or model observers

→ It is important to know the basic principles of the used iterative algorithm and to consider the physical characterizations with the proper figures of merit (Receiver operating characteristic studies, Task Transfer function, Noise power spectrum)

→ Different CT technologies (with different cost) allow to reach different patient dose levels.

→ Staff training and cooperation are a key element for ALARA in modern imaging diagnostics

"In hospitals, standard, optimized and uniform protocols are used throughout the country for optimal use of radiological equipment ".

The various professionals involved (. . .) share objectives and methods, to guarantee the assisted person the best imaging or treatment response limiting the health detriment deriving from exposure (ALARA principle)

quotidianosanità.it

Lettere al direttore

Rischio radiazioni. Per limitarlo al massimo serve impegno di tutte le professioni coinvolte

04 NOV - *Gentile direttore*,
con un articolo di recente pubblicazione si ricorda come negli ultimi 30 anni sia aumentata in modo rilevante l'esposizione delle persone alle radiazioni mediche e che solo in Italia si effettuano ogni anno oltre 40 milioni di esami radiologici. Sarebbe interessante, a nostro avviso, limitarsi all'analisi dei dati relativi agli ultimi 16 anni, al fine di valutare la discutibile efficacia e il trascurabile impatto avuto dal D.Lgs. 187/2000, quale recepimento della direttiva 97/43/Euratom, in materia di protezione sanitaria delle persone contro i pericoli delle radiazioni ionizzanti connesse ad esposizioni mediche.

E', invece, nostra intenzione sottoscrivere segnatamente l'appello che l'Associazione Italiana di Fisica Medica (AIFM) ha lanciato in occasione della quarta Giornata Internazionale della Fisica Medica proclamata il 7 novembre dalla International Organization for Medical Physics: "Negli ospedali servono protocolli standard, ottimizzati e uniformi su tutto il territorio nazionale per l'utilizzo ottimale delle apparecchiature radiologiche".

Per massimizzare l'efficacia del principio di ottimizzazione occorre necessariamente che le diverse professionalità coinvolte (Medici specialisti, Fisici medici e Tecnici sanitari di radiologia medica) condividano preventivamente obiettivi e modalità, al fine di garantire alla persona assistita la migliore risposta iconografica o di trattamento, limitando al massimo il detrimento sanitario derivante dall'esposizione (principio A.L.A.R.A)

.....

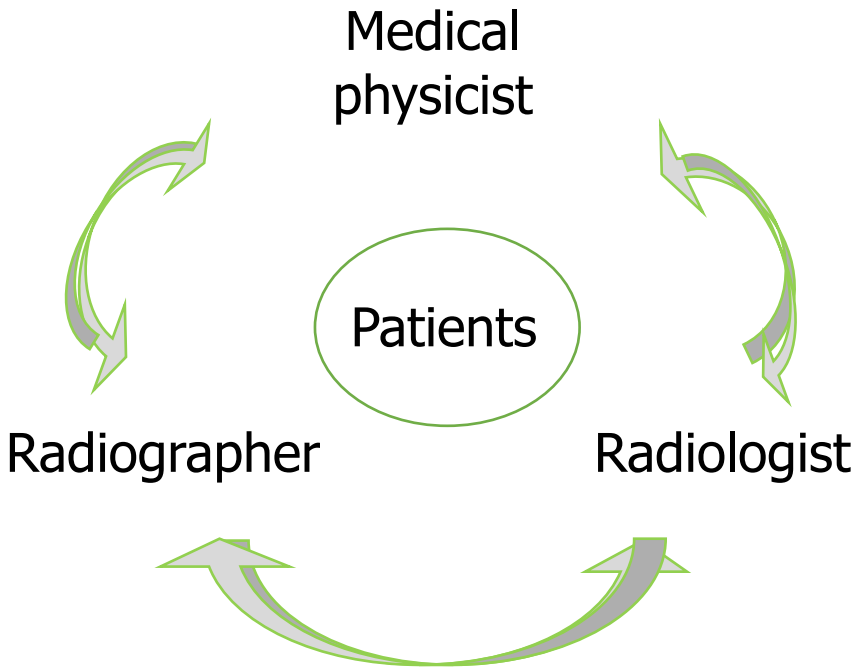
.....

Comitato Centrale
Federazione nazionale Collegi professionali tecnici sanitari di radiologia medica

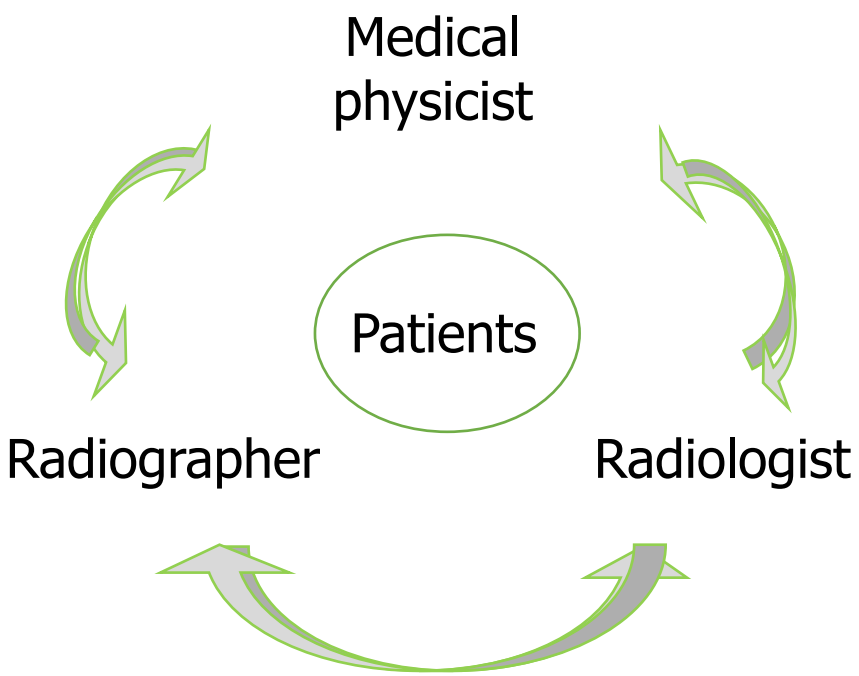
04 novembre 2016

http://www.quotidianosanita.it/lettere-al-direttore/articolo.php?articolo_id=44714

ALARA experience from CT aorta examination



ALARA experience from CT aorta examination



Science

Technical development

Manufactors

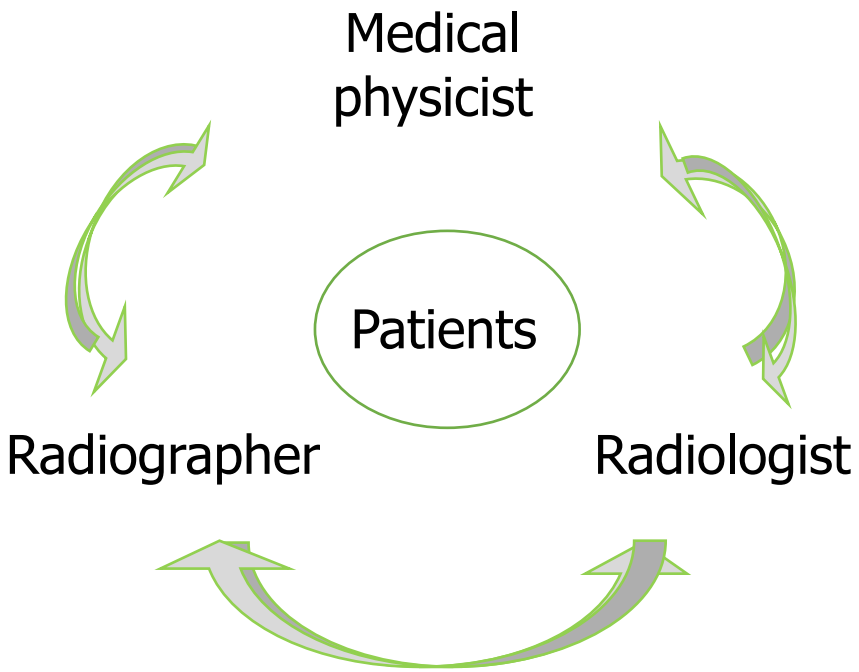
Other professionals

ALARA experience from CT aorta examination

Ethics in the practice

Culture, awareness

Education and training



Science

Technical development

Manufactors

Other professionals

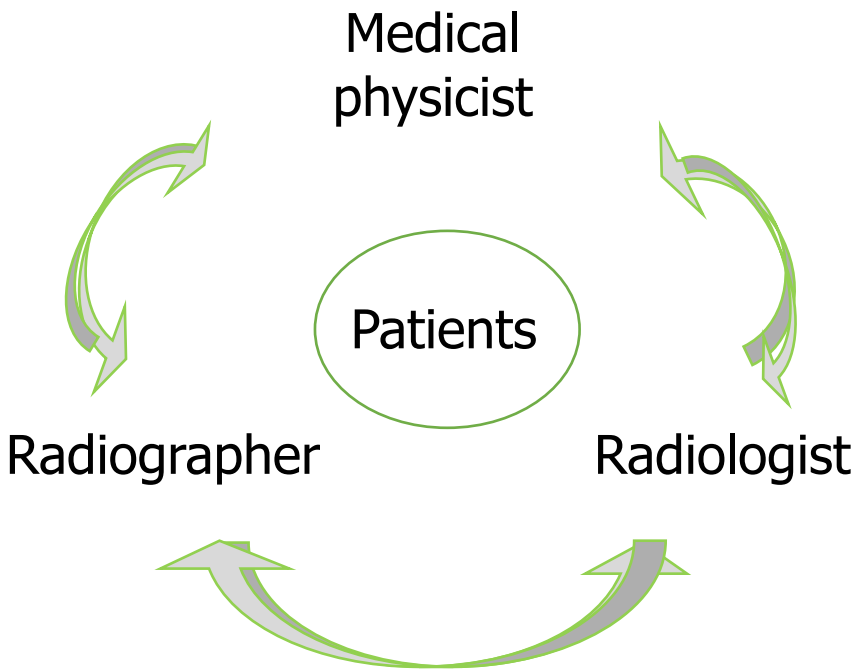
ALARA experience from CT aorta examination

Economy

Ethics in the practice

Culture, awareness

Education and training



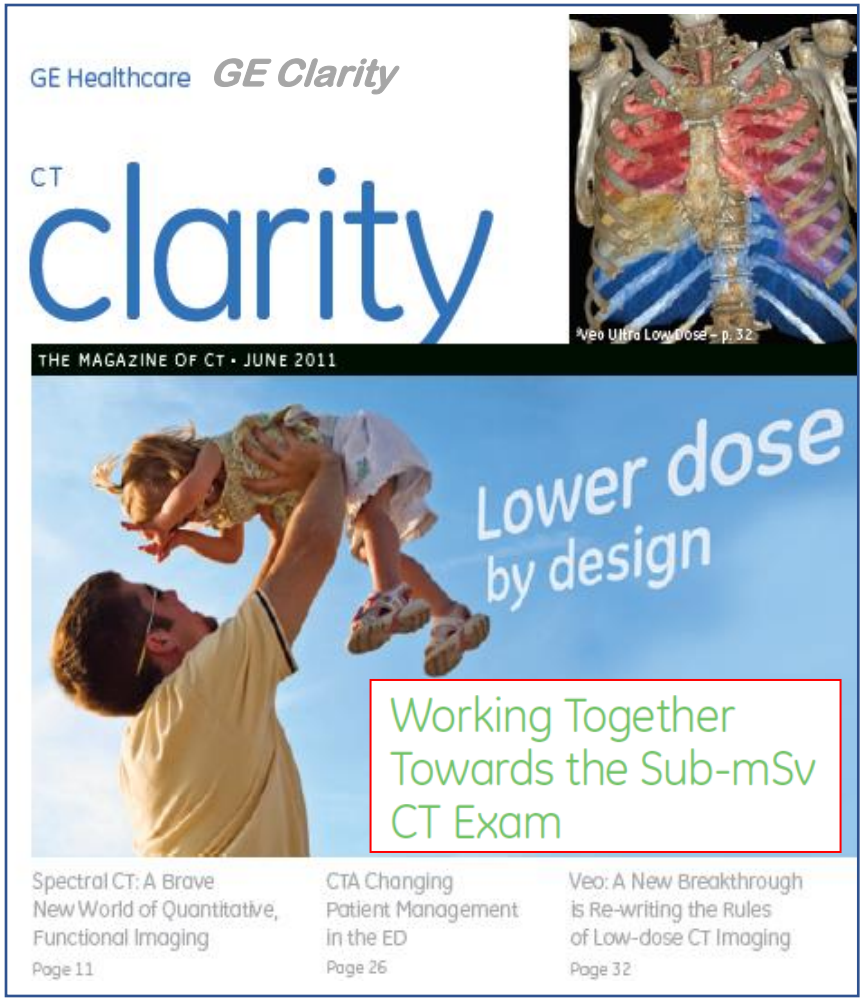
Science

Technical development

Manufactors

Other professionals

"The war of the doses"



Dose reduction has become an element of strong competition among CT manufacturers in recent years.

"The war of the doses"

GE Healthcare *GE Clarity*

CT

THE M

Spectr
New W
Functi

Page 11

Dose reduction has become an element of strong competition among CT manufacturers in recent years.

Philips iDose white paper

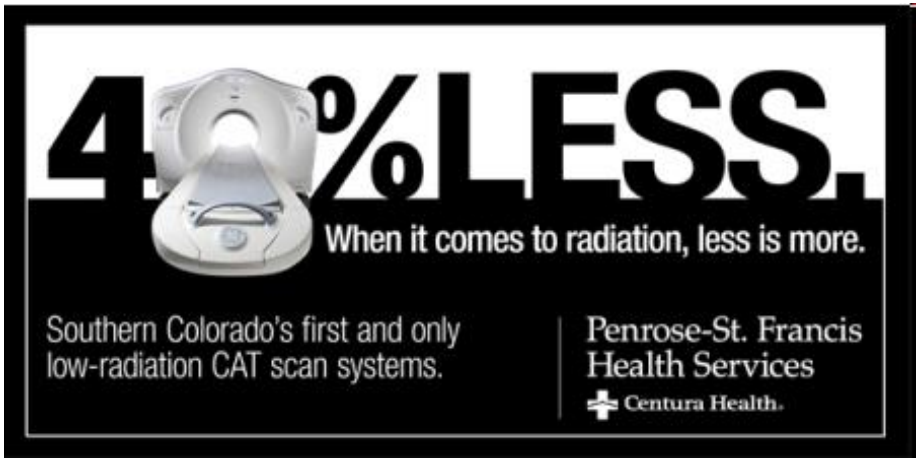
Cardiac CTA (Philips)

Helical scan without DoseRight Cardiac	20mSv
Helical scan with mild DR-C 40-75%	12mSv
Helical scan with aggressive DR-C 75% only	8mSv
120 kV S&SC scan with 5% tolerance	3.5mSv
100 kV S&SC scan with 5% tolerance	2.1mSv
100 kV S&SC scan with 3% tolerance	1.7mSv
100 kV S&SC scan without tolerance	1-1.3mSv
100 kV S&SC scan without tolerance + **iDose⁴**	0.8-1mSv
80 kV S&SC scan without tolerance	0.7mSv
80 kV S&SC scan without tolerance + **iDose⁴**	0.25 – 0.5mSv

Cardiac catheterization
5mSv (= 25 chest X-rays)

Natural background exposure (annual)
2-3mSv (= 10 chest X-rays)

Chest X-Ray
0.2mSv



RAVENNATODAY Sezioni Salute ACCEDI

Salute / Lugo

All'ospedale di Lugo la "Ferrari" delle Tac che riduce le radiazioni dell'80%

Il dottor Orzincolo ha inoltre annunciato che di qui a poche settimane entrerà in funzione una nuova apparecchiatura diagnostica, un telecomandato digitale del valore di 200mila euro

Redazione
06 LUGLIO 2018 15:18

I più letti di oggi

Practical management of different technological levels

To what extent should the potential dose reduction be reflected in the evaluation of the renewal of the health company's fleet and of the budget needed for new devices **?**

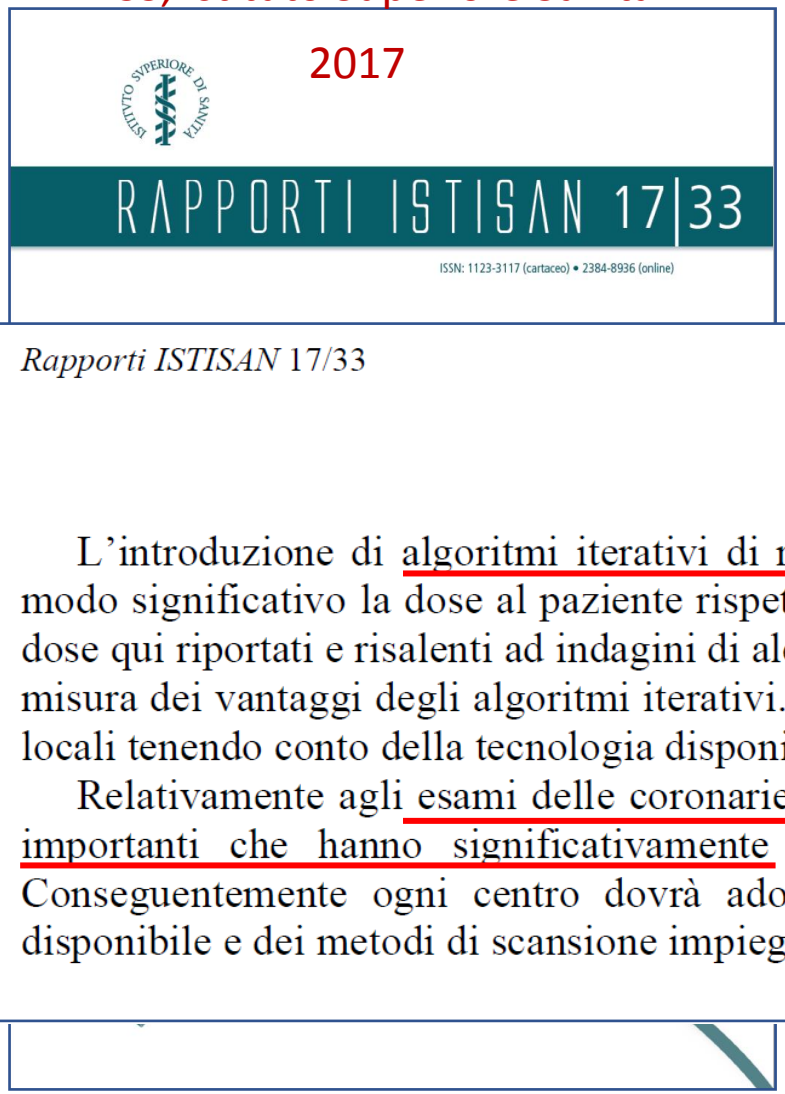
The question "how low can we go" often occurs in publications.

It is important to keep in mind that the main objective of a CT examination remains the correct and accurate diagnosis, which is carried out by operators often with different levels of experience and preparation within the same team. Therefore, it is important to always guarantee a level of image quality that guarantees the right level of reliability for all radiologists appointed to report. It is important to follow low-dose protocols, that are always robust enough to give full evidence of all the diagnostic details for each question.

ISS, Istituto Superiore Sanità

L'ottimizzazione della protezione del paziente in radiologia diagnostica, medicina nucleare diagnostica o procedure interventistiche guidate da immagini a raggi X richiede l'applicazione di protocolli specifici personalizzati per l'età e la corporatura del paziente, la regione anatomica interessata e l'indicazione clinica al fine di garantire che la dose al paziente sia al livello più basso ragionevolmente ottenibile (*As Low As Reasonable Achievable*, ALARA).

ISS, Istituto Superiore Sanità



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L'introduzione di algoritmi iterativi di ricostruzione delle immagini consente di ridurre in modo significativo la dose al paziente rispetto alla tecnica di retroproiezione filtrata. I valori di dose qui riportati e risalenti ad indagini di alcuni anni orsono risentono probabilmente in minima misura dei vantaggi degli algoritmi iterativi. Conseguentemente ogni centro potrà adottare LDR locali tenendo conto della tecnologia disponibile.

Relativamente agli esami delle coronarie con TC, la metodica ha avuto sviluppi tecnologici importanti che hanno significativamente modificato i livelli medi di dose al paziente. Conseguentemente ogni centro dovrà adottare LDR locali tenendo conto della tecnologia disponibile e dei metodi di scansione impiegati.

Practical management of different technological levels

The introduction of iterative reconstruction algorithms for better dose optimisation in children

Pediatr Radiol
DOI 10.1007/s00247-014-3201-z

ORIGINAL ARTICLE

Radiation dose from multidetector CT studies in children: results from the first Italian nationwide survey

Claudio Granata · Daniela Origgi · Federica Palorini · Domenica Matranga · Sergio Salerno

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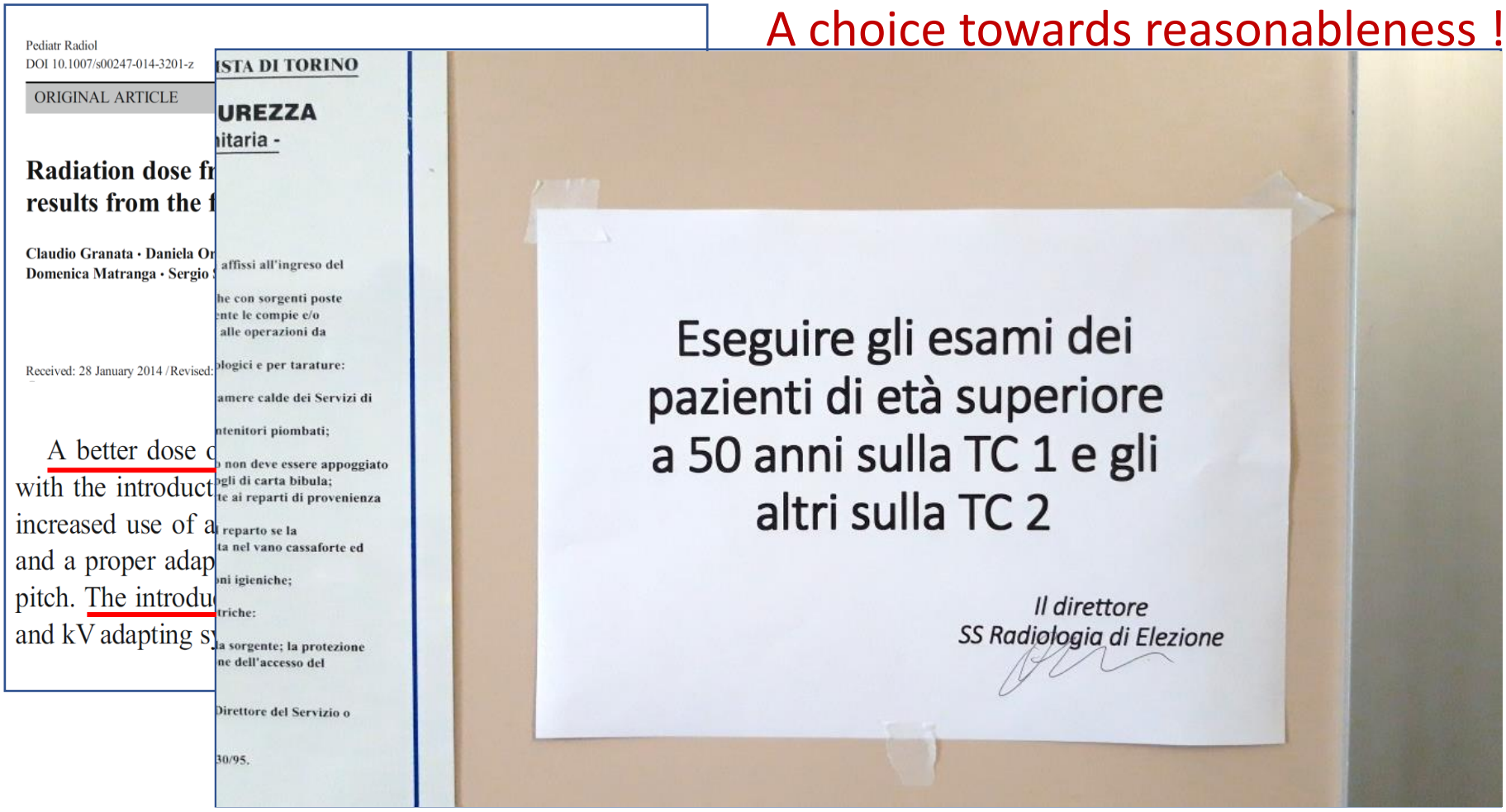
A better dose optimisation in children could be achieved with the introduction of size-specific CT protocols, with an increased use of automatic tube current modulation systems and a proper adaptation of CT settings, in particular kV and pitch. The introduction of iterative reconstruction algorithms and kV adapting systems could help in this task.

Practical management of different technological levels

The introduction of iterative reconstruction algorithms for better dose optimisation in children

A choice towards reasonableness !



What is ‘reasonable’

What is 'reasonable' changes with time.

What is reasonable today depends on the most current technology available, that will gradually give us even more advanced devices and perhaps at lower costs.

The ethical and societal aspects help us in our choices (*our→ professionals, patient, families of patients, . . .*).

What is reasonable or not is related to our feeling and evaluation of today options, and is linked to the circumstances such as the type of health case, the need to have info on health, the patient's criticality and the our will to act in the appropriate way.


Thanks for your attention

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