Comparative study of patient doses on seven CT scanners and establishment of local diagnostic reference levels

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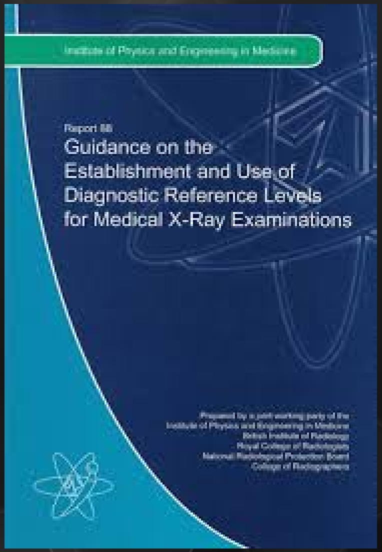
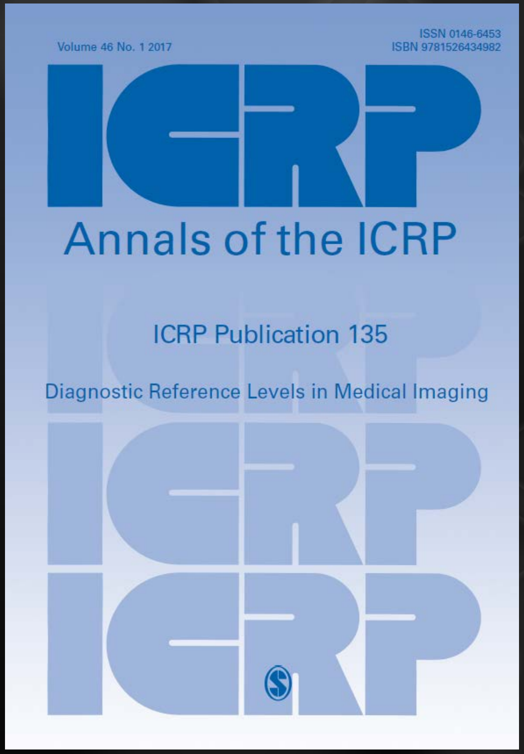
Introduction

- Introduction and periodical review of DRLs is recognized as an instrument for optimisation of radiological practice
- Existing UK guidance is the IPEM Report 88 (2004)
- Approach & Terminology:
  - Estimate **mean room dose**;
  - Local Diagnostic Reference Level (LDRL) defined at Trust/Hospital level;
  - LDRL based on **mean values of the distributions of the mean doses**
  - National Diagnostic Reference Level (NDRL) based on **third-quartile values of the distributions of the mean doses** on a sample of close to standard-sized patients;



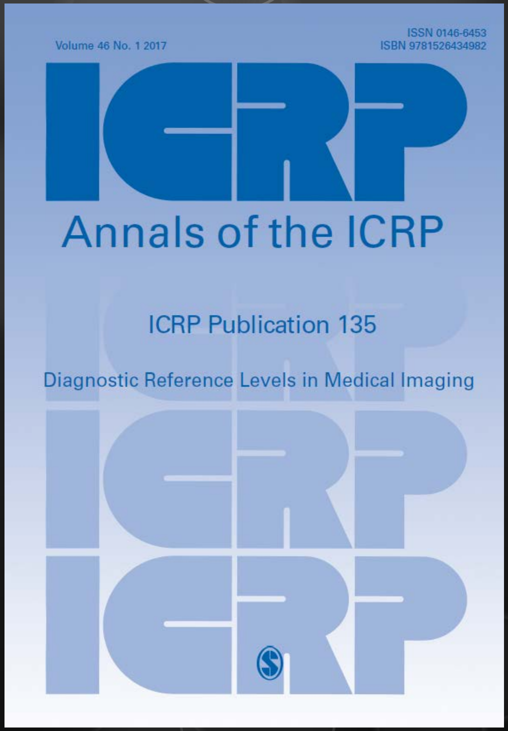
Introduction

- Own experience shows that terms are often confused e.g. the room dose is called LDRL; due to unavailability of the Report even the methodology is not always known
- New international guidance available
- ICRP Publication 135 (2017) Diagnostic Reference Levels in Medical Imaging



Introduction

- Approach & Terminology:
  - Estimate **<u>typical value as median</u>** of the distribution of data from a room or a healthcare facility with small number of rooms
  - LDRL & NDRL based on **<u>third-quartile values of the distributions of the median values</u>**
  - LDRLs may be set for procedures for which no national DRL is available, or where there is a national value but local equipment or techniques have enabled a greater degree of optimisation to be achieved



Introduction

- Recent study revealed that 'medians should be preferred to means, with recalculation of DRLs from older surveys.' Vanaudenhove et al. 2019

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https://doi.org/10.1007/s00330-019-06141-8

COMPUTED TOMOGRAPHY

CT diagnostic reference levels: are they appropriately computed?

Thibault Vanaudenhove[1] · Alain Van Muylem[2] · Nigel Howarth[3] · Pierre Alain Gevenois[4] · Denis Tack[5]

Received: 26 October 2018 / Revised: 18 February 2019 / Accepted: 8 March 2019 / Published online: 8 April 2019

Introduction

- Another recent study revealed that the currently used approach 'makes people think that if you are below the DRL, optimization is in place', and also…
- The higher the value of the typical dose in a room, the more pronounced is the dose reduction in next national survey Roch et al. 2019

European Radiology
https://doi.org/10.1007/s00330-019-06422-2

PHYSICS

Long-term experience and analysis of data on diagnostic reference levels: the good, the bad, and the ugly

Patrice Roch[1] · David Célier[1] · Cécile Dessaud[2] · Cécile Etard[1] · Madan M. Rehani[3]

Received: 26 May 2019 /Revised: 25 July 2019 / Accepted: 12 August 2019

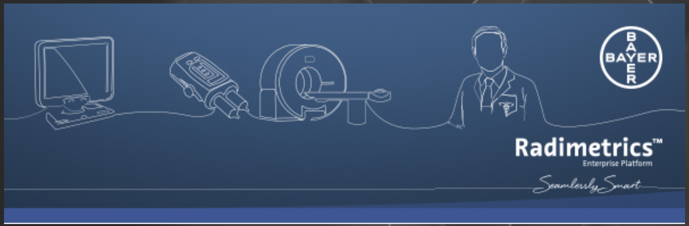
Aim

- To raise discussion on the methodology for DRLs establishment
- To determine typical patient doses from the seven CT scanners in our Trust, to compare the CT protocols most commonly used and to establish LDRLs

Materials & Methods

- The present study initiated as a part of the PHE national patient dose survey in CT
- All 7 CT scanners in our Trust included, still ongoing analysis
- 4 SOMATOM Definition AS+ (Siemens), all with auto kV selection and TCM, one w/o Iterative Recon (IR)
- 2 Ingenuity and 1 Brilliance iCT 256 (Philips), all with TCM and IR

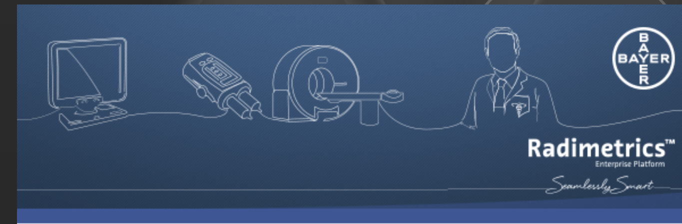
Materials & Methods



- Data retrospectively retrieved from PACS for half an year period (11.2018-04.2019) with Radimetrics (Bayer),
  13 exams (as defined by PHE),
  total of 24,529 patients

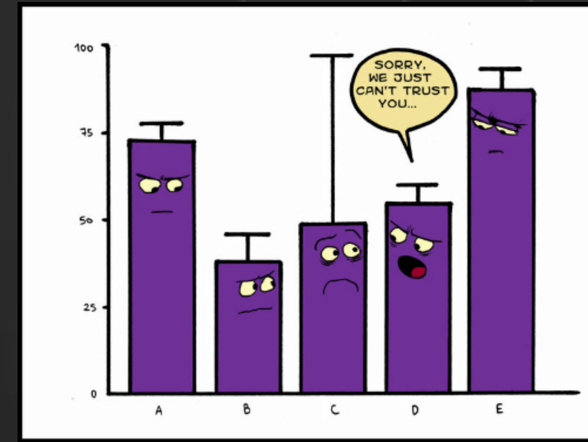
PHE CT protocol	Clinical indication
Head	Acute stroke
Paranasal sinuses	Paranasal sinuses
Cervical spine (C-spine)	Fracture
Neck, chest, abdomen and pelvis	Query Cancer
Chest	Query Lung cancer
Chest – high resolution	Interstitial lung disease
Chest and abdomen	Query Lung cancer
Chest-abdomen-pelvis (CAP)	Query Cancer
CT pulmonary angiography (CTPA)	Pulmonary embolism
Abdomen and pelvis	Abscess
Colonography/Virtual colonoscopy (VC)	Polyps/tumour
Kidney-ureters-bladder (KUB)	Stones/colic
Urogram	Stones/colic or tumour

Materials & Methods



- When detailed data retrieved for all acquisitions with Radimetrics, provided by scanner total DLP was not available
- Data filtered by DICOM tags Examination, Modality, Protocol Name, Equipment: to sort the exam on the particular scanner
- Procedure, Description, Scan Regions: to reject other examinations performed under the same CT protocol
- Additional filtering on Rotation Time, Slice Thickness, Pitch, Acquisition Type (Helical/Axial) and Series Description to select appropriate phases/acquisitions and to reject non typical exams
- PreMonitoring/Monitoring excluded (only ~ 1% contribution)
- Total DLP calculated as sum of DLP from separate acquisitions, when performed

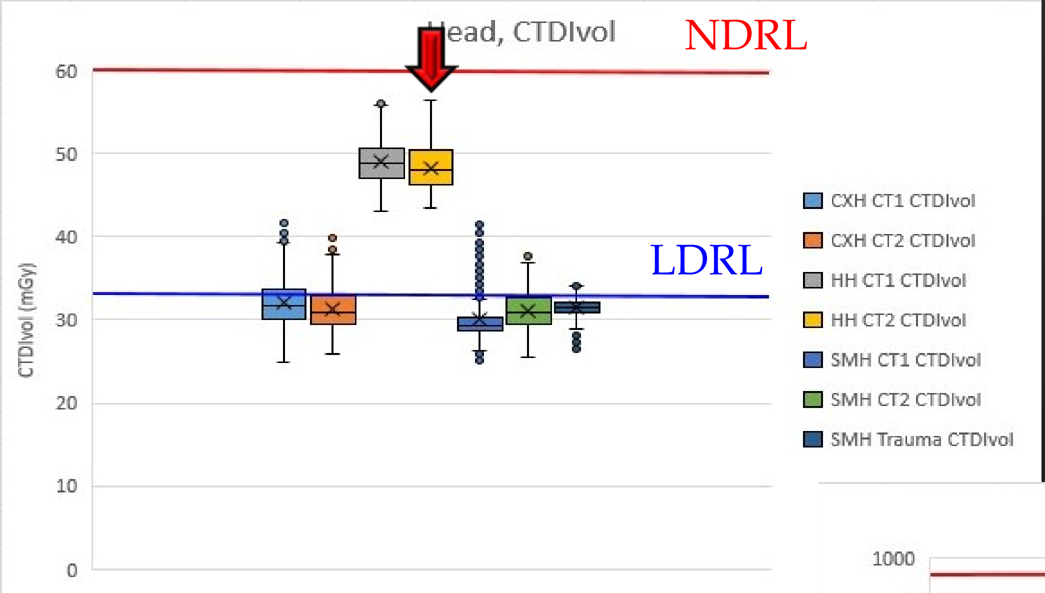
Materials & Methods



He's the reason medians are preferred

- The ICRP approach was adopted
- Mean, median, SD, min, max, 1st&3rd quartiles, 5th&95th percentiles calculated for CTDI$_{vol}$ and DLP
- No data for patient weight available, so all data $<5^{th}$ & $>95^{th}$ percentiles removed (ICRP 135 recommendation)
- Descriptive stat. data recalculated for reduced samples
- Mean value of each reduced sample (CT scanner) compared to UK NDRLs
- Typical dose established based on median, LDRL based on 3rd quart. of medians (data from the CT w/o IR not included)
- Max ratio of medians calculated, if >50%, need of optimisation (ICRP)

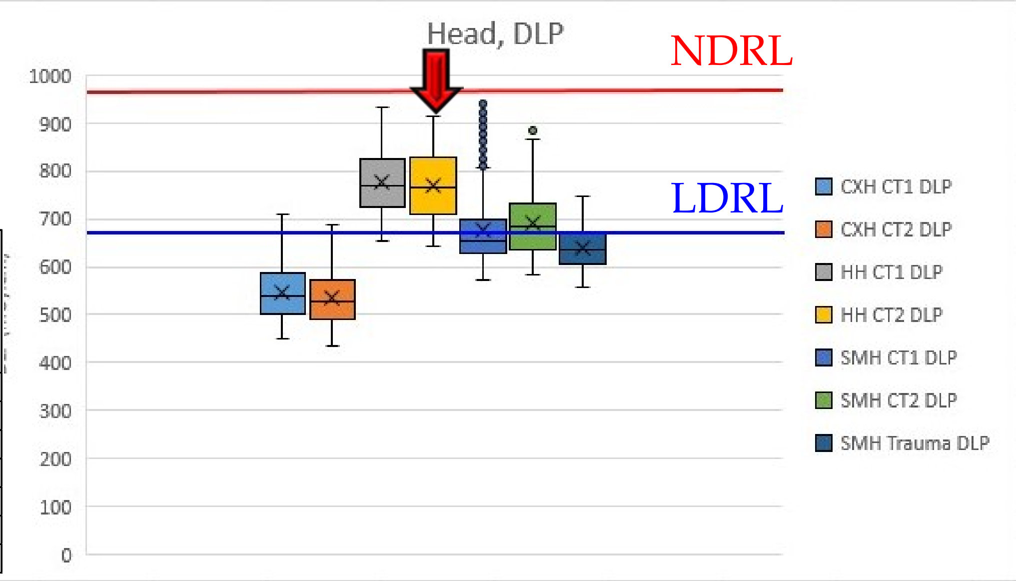
Results



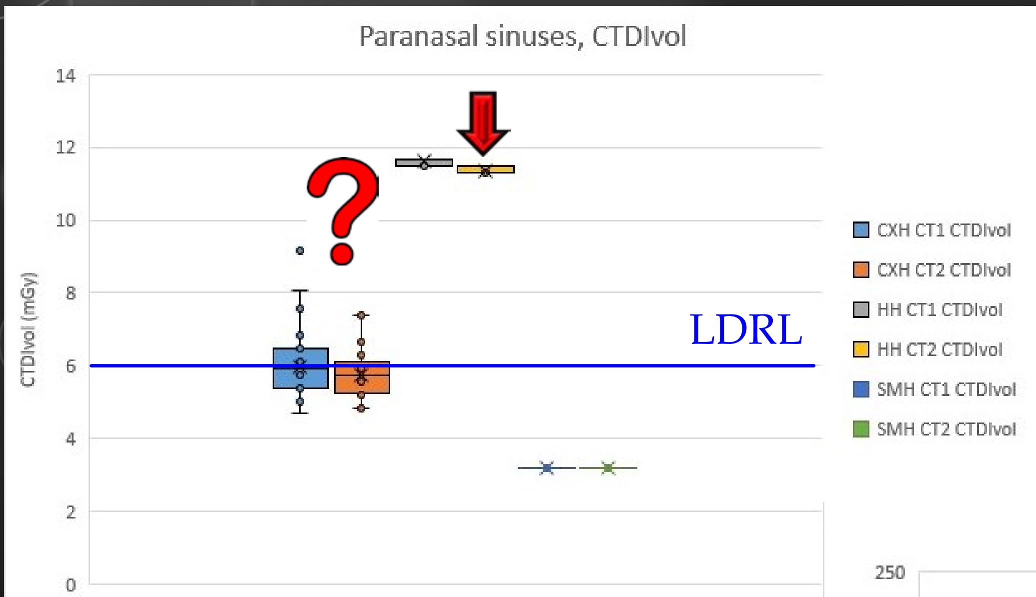
7,446 patients

Max ratio of medians 1.45

System	Tube voltage (kV)	TCM/QRM (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	120	Z/290	SAFIRE 3	38.4	1	1	0.55	N
CXH CT2	120	Z/290	SAFIRE 3	38.4	1	1	0.55	N
HH CT1	120	Z/350	N	12	3	1	0.55	N
HH CT2	120	Z/350	N	12	1	1	0.55	N
SMH CT1	120	Z	iDose 2	40	3	0.4	0.392	N
SMH CT2	120	Z	iDose 2	40	3	0.4	0.392	N
SMH T	120	Z	iDose 2	40	3	0.4	0.39	N

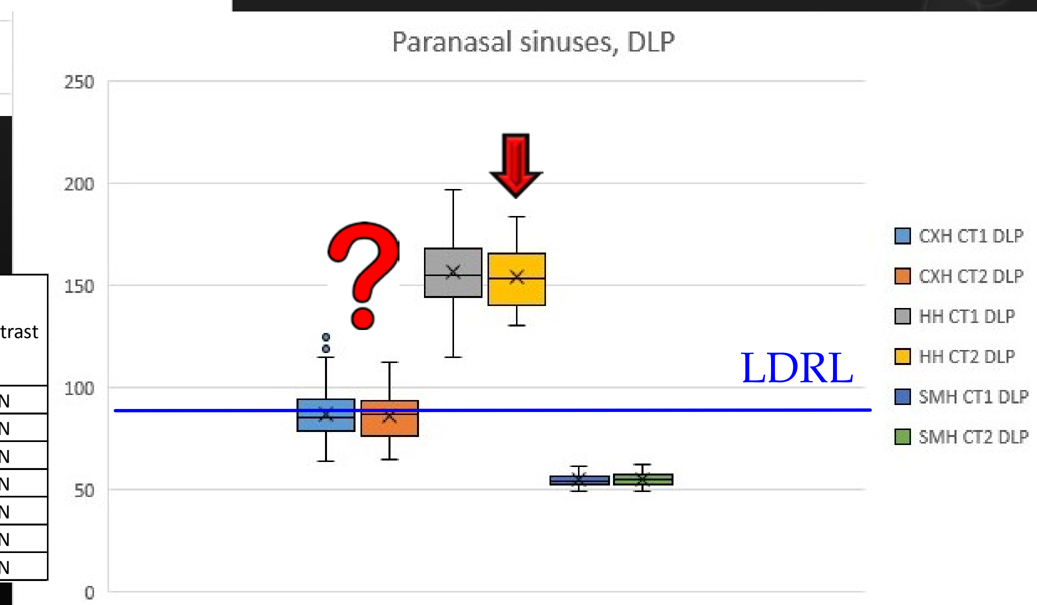


Results



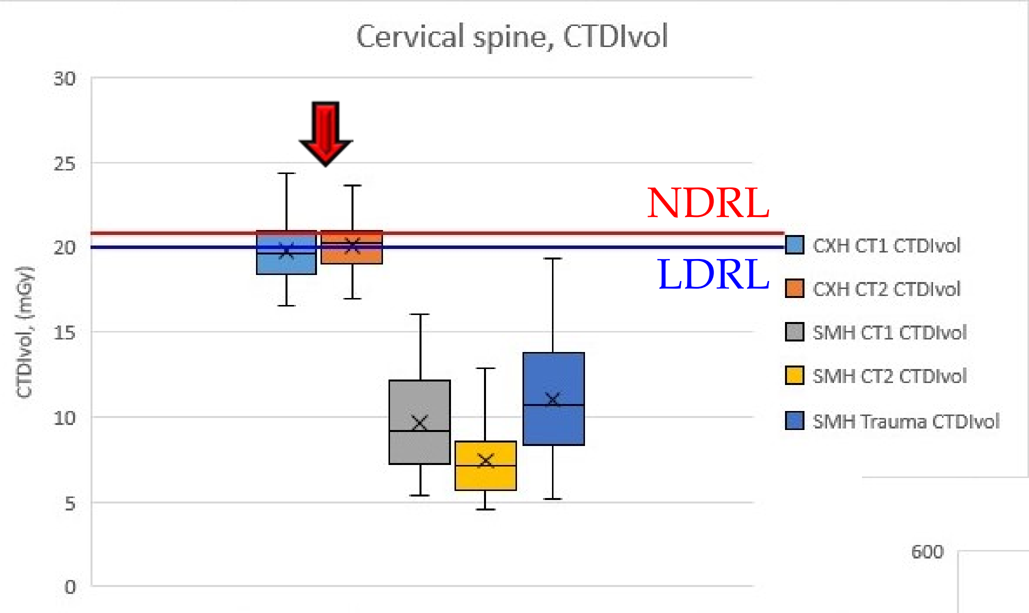
872 patients

Max ratio of medians **2.88**



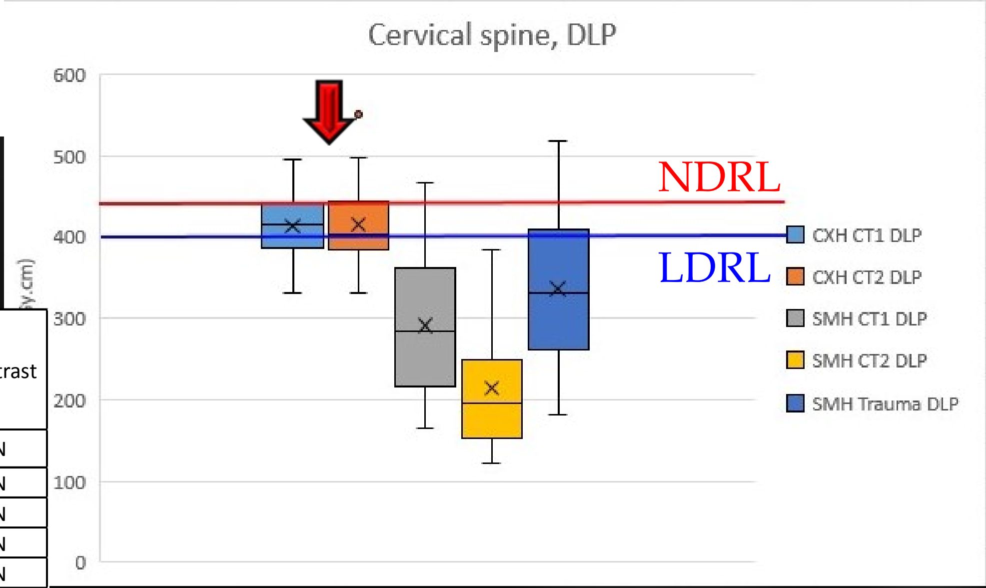
System	Tube voltage (kV)	TCM/QRM or Effective (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	120	Z/50	SAFIRE 3	38.4	1.5	1	0.8	N
CXH CT2	120	Z/50	SAFIRE 3	38.4	1.5	1	0.8	N
HH CT1	120	N/80	N	38.4	1.5	1	0.8	N
HH CT2	120	N/80	N	38.4	1.5	1	0.8	N
SMH CT1	120	N/25	iDose 4	40	1	0.4	0.399	N
SMH CT2	120	N/25	iDose 4	40	1	0.4	0.399	N
SMH T	120	N/25	iDose 4	80	1	0.4	0.383	N

Results



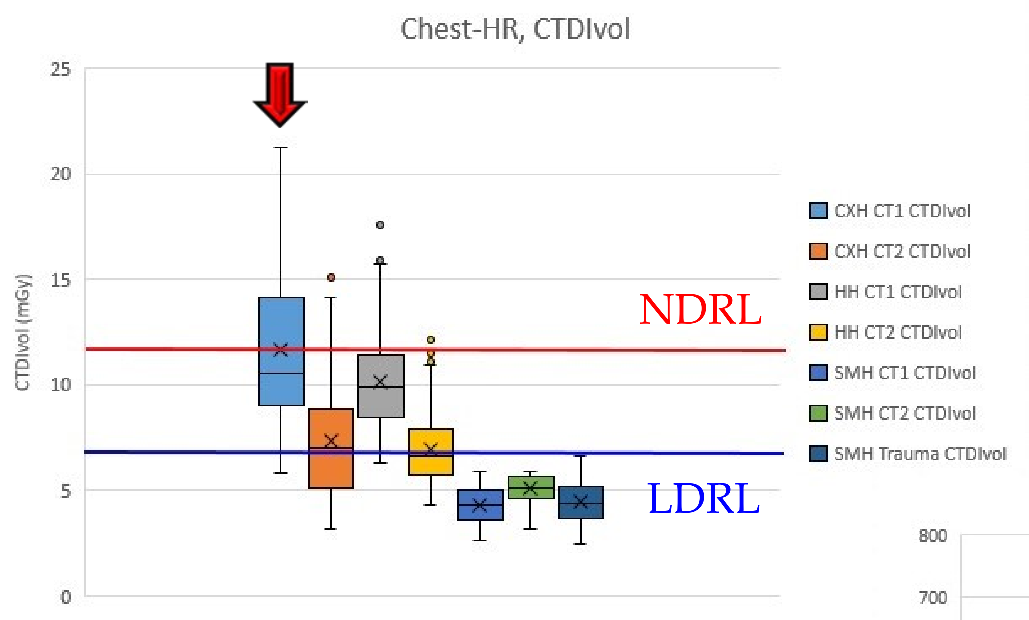
1,067 patients

Max ratio of medians **2.12**



System	Tube voltage (kV)	TCM/QRM (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	120	4D/275	N	38.4	1	1	0.8	N
CXH CT2	120	4D/275	N	38.4	1	1	0.8	N
SMH CT1	120	Z	iDose 4	40	1	Varying	Varying	N
SMH CT2	120	Z	iDose 4	40	1	Varying	Varying	N
SMH T	120	Z	iDose 4	80	1	Varying	Varying	N

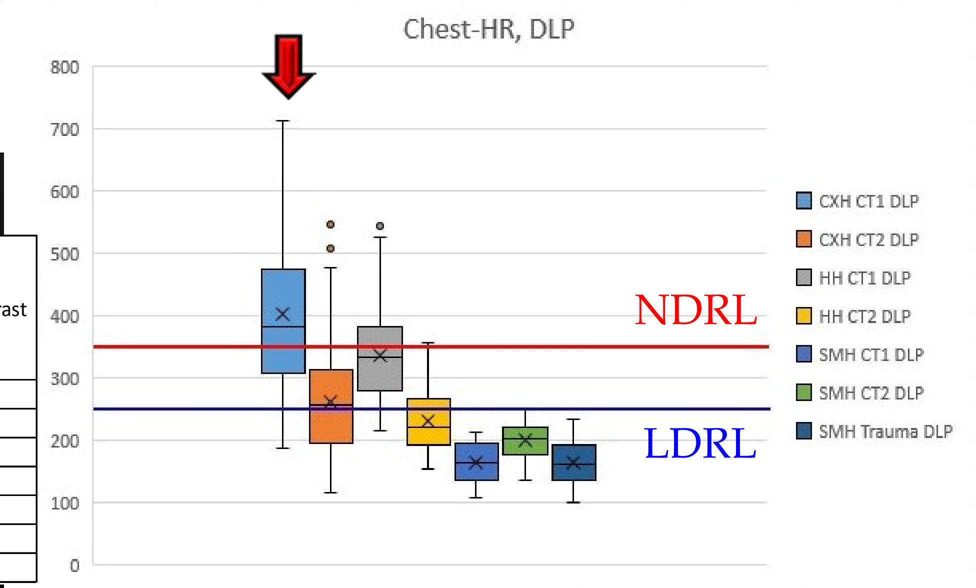
Results



1,338 patients

Max ratio of medians **2.39**

System	Tube voltage (kV)	TCM/QRM (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	120	4D/130	SAFIRE 3	38.4	1.5	0.5	1.2	N
CXH CT2	Auto	4D/80	SAFIRE 3	38.4	1.5	0.3	0.6	N
HH CT1	Auto	4D/130	N	38.4	1.5	0.5	1.2	N
HH CT2	Auto	4D/90	SAFIRE 3	38.4	1.5	0.5	1.2	N
SMH CT1	120	3D	iDose 4	40	1	0.5	1.015	N
SMH CT2	120	3D	iDose 4	40	1	0.4	1.015	N
SMH T	120	3D	iDose 4	40	1	0.4	0.984	N

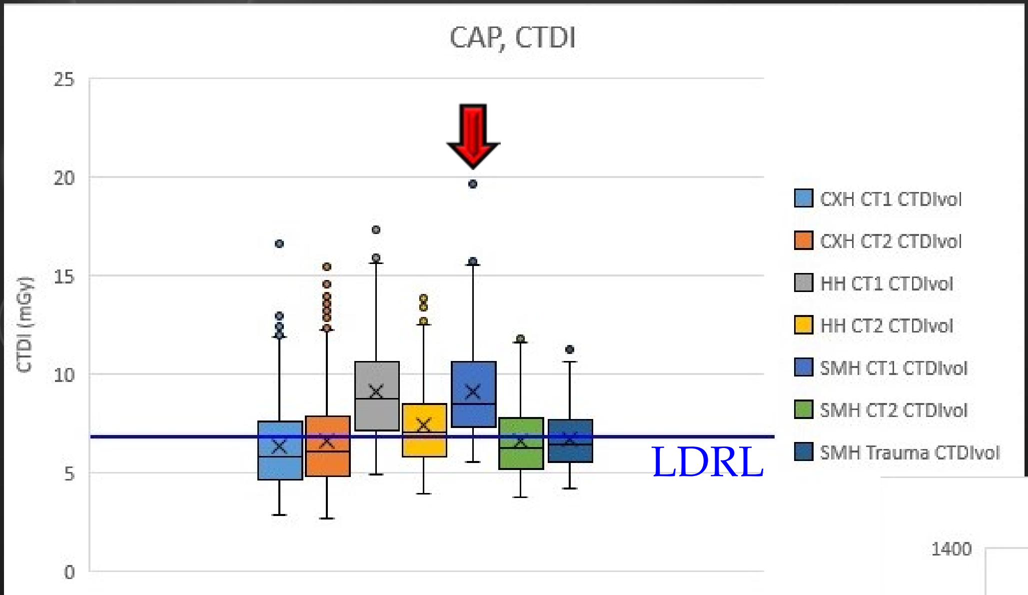


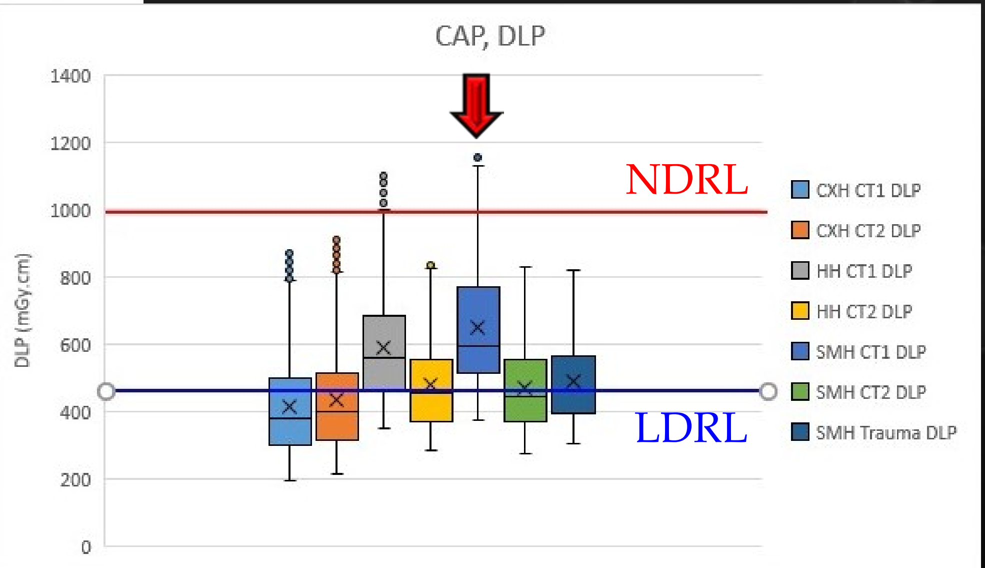
Results

3,637 patients

Max ratio of medians **1.58**

Similar trends for Chest&Abd, same protocol used

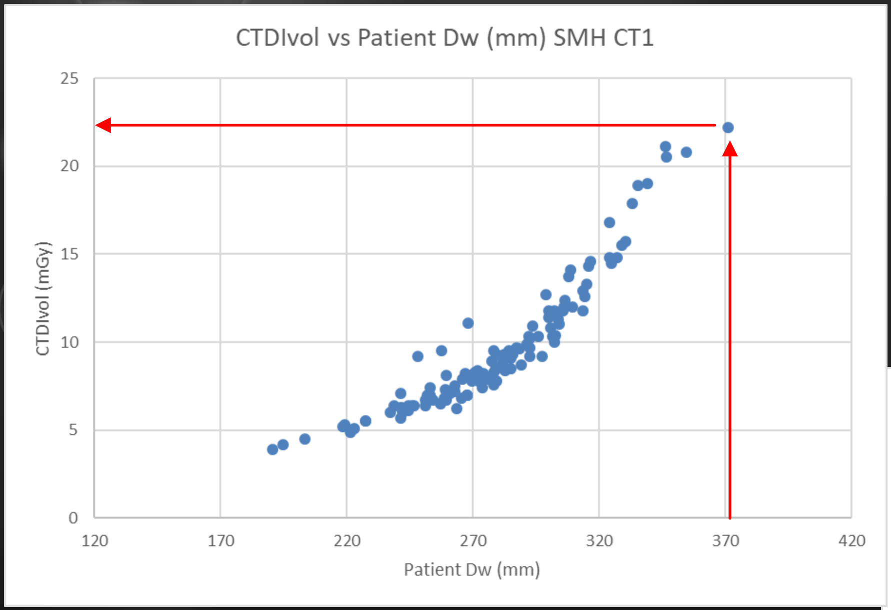




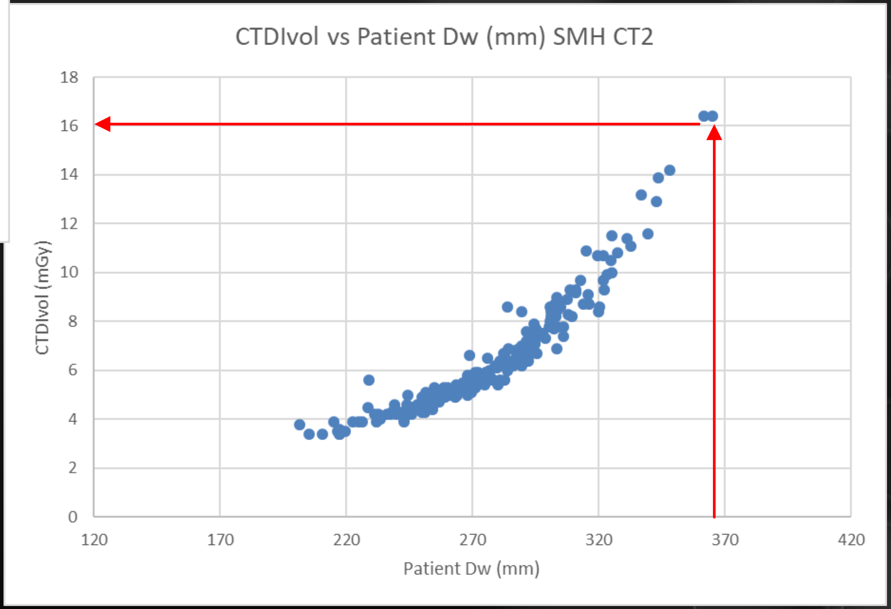
System	Tube voltage (kV)	TCM/QRM (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	Auto	4D/150	SAFIRE 3	38.4	1.5	0.5	0.6	IV
CXH CT2	Auto	4D/150	SAFIRE 3	38.4	1.5	0.5	0.6	IV
HH CT1	Auto	4D/210	N	38.4	1.5	0.5	0.6	IV
HH CT2	Auto	4D/170	SAFIRE 3	38.4	1.5	0.5	0.6	IV
SMH CT1	120	3D	iDose 4	40	2	0.5	0.798	IV
SMH CT2	120	3D	iDose 4	40	2	0.5	0.798	IV
SMH T	120	3D	iDose 4	80	2	0.4	0.804	IV

Results

CAP

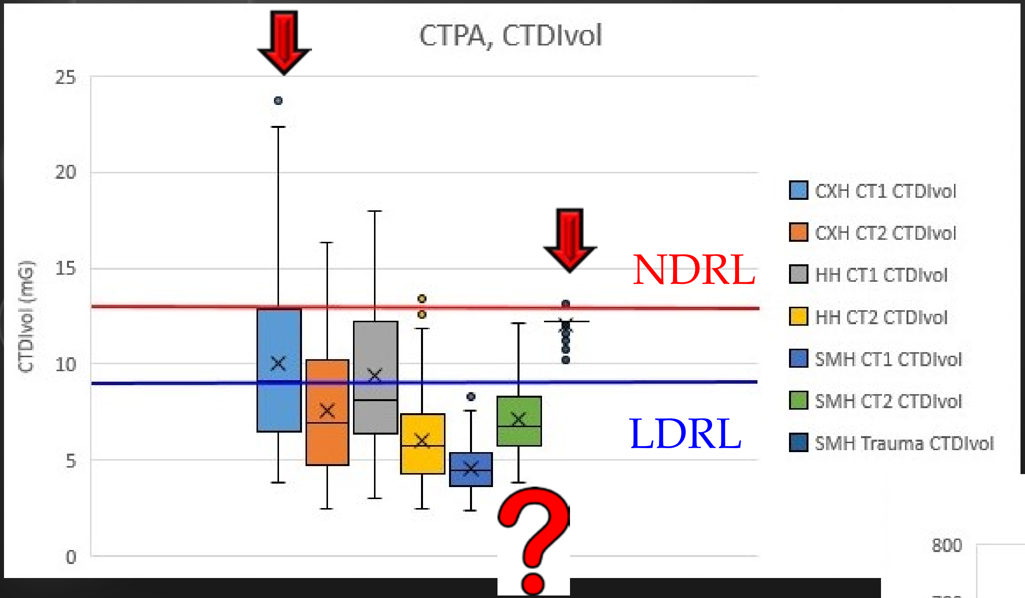


CTDIvol vs Patient Dw (mm) SMH CT1
CTDIvol (mGy)
0
5
10
15
20
25
120
170
220
270
320
370
420
Patient Dw (mm)



CTDIvol vs Patient Dw (mm) SMH CT2
CTDIvol (mGy)
0
2
4
6
8
10
12
14
16
18
120
170
220
270
320
370
420
Patient Dw (mm)

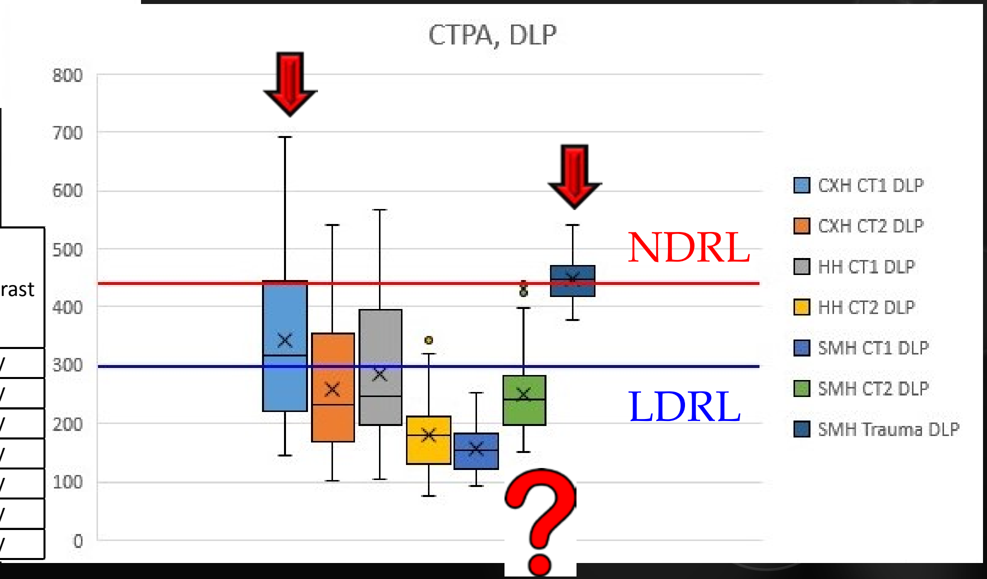
Results



1,138 patients

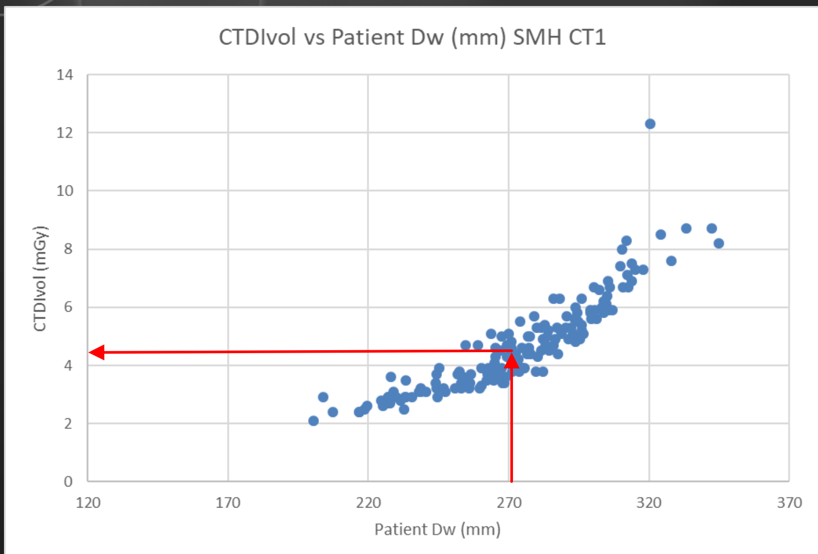
Max ratio of medians **2.90**

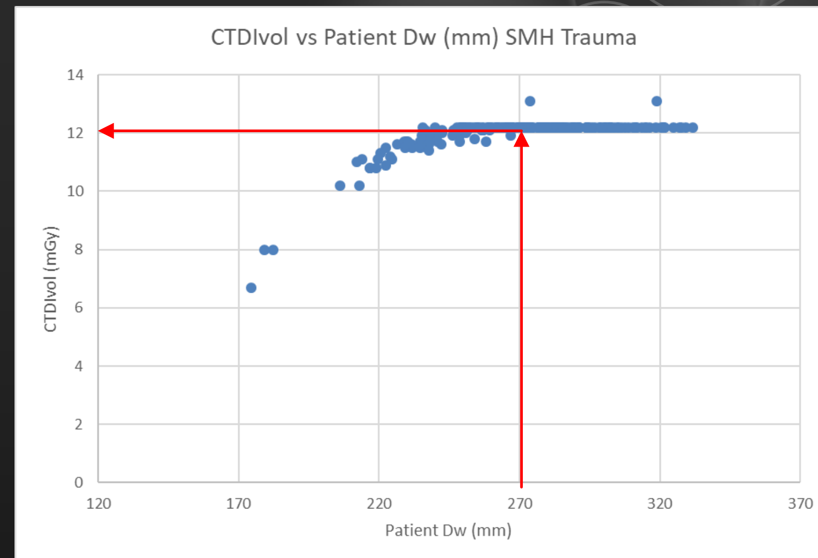
System	Tube voltage (kV)	TCM/QRM (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	Auto	4D/110	SAFIRE 3	38.4	1	0.5	1.2	IV
CXH CT2	Auto	4D/80	SAFIRE 3	38.4	1	0.5	1.2	IV
HH CT1	Auto	4D/140	N	38.4	1	0.5	1.2	IV
HH CT2	Auto	4D/100	SAFIRE 3	38.4	1	0.5	1.2	IV
SMH CT1	100	3D	iDose 4	40	2	0.5	0.798	IV
SMH CT2	100	3D	iDose 4	40	2	0.5	0.798	IV
SMH T	100	3D	iDose 4	80	1	0.33	0.763	IV

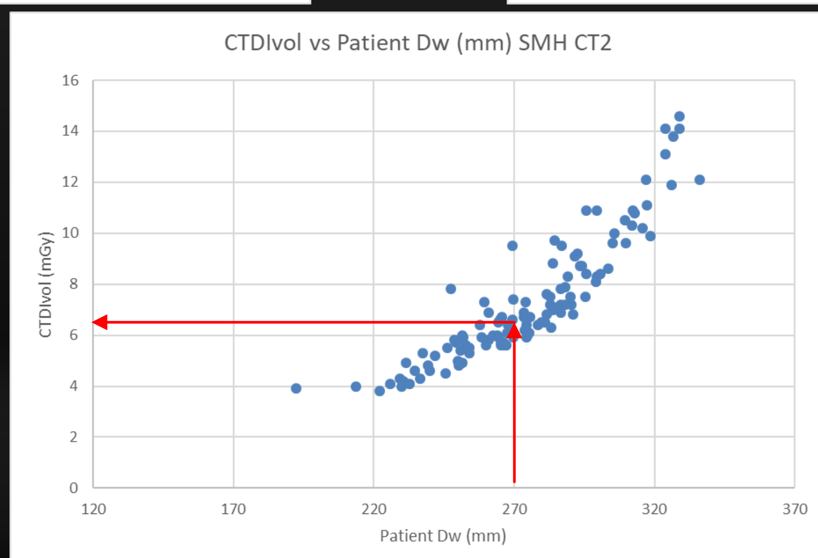


Results

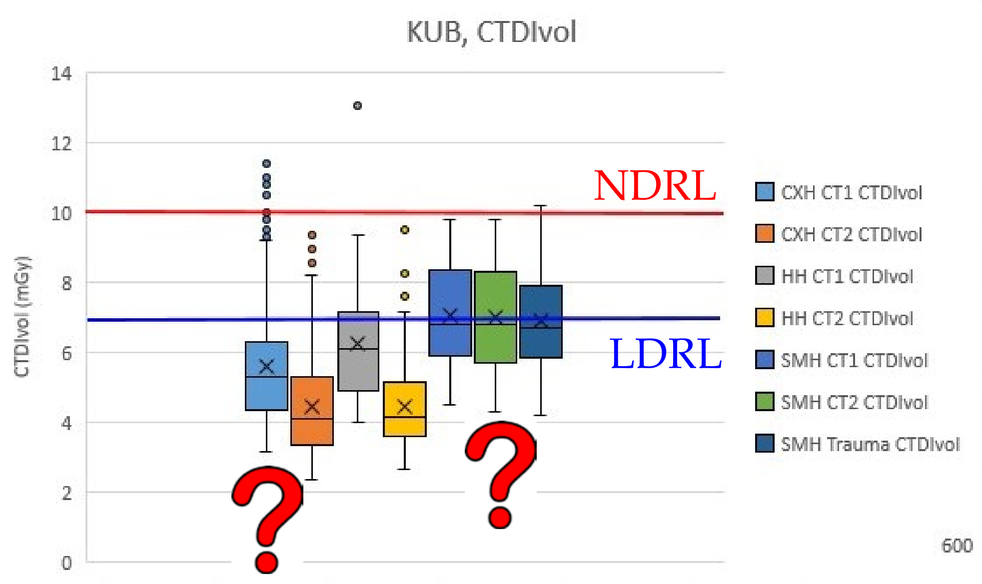
CTPA





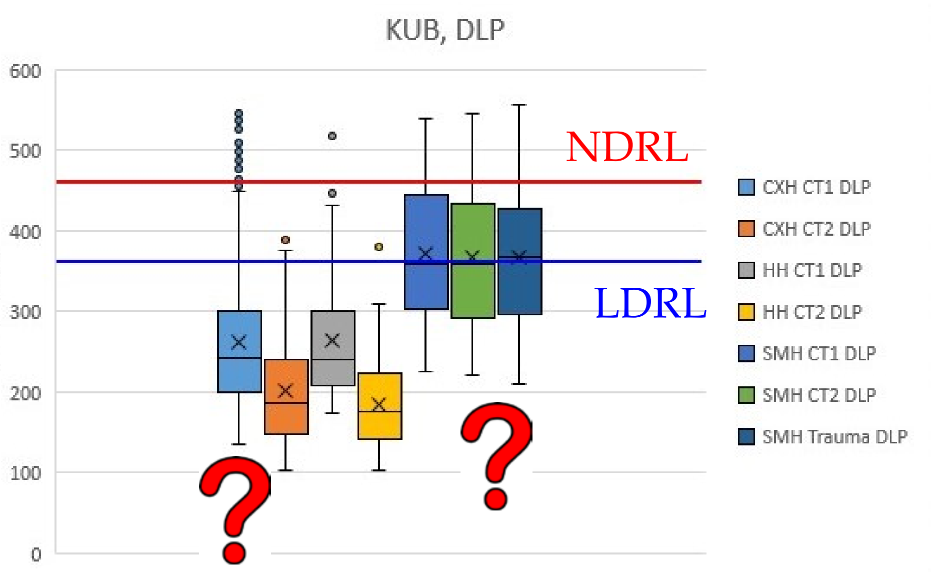


Results



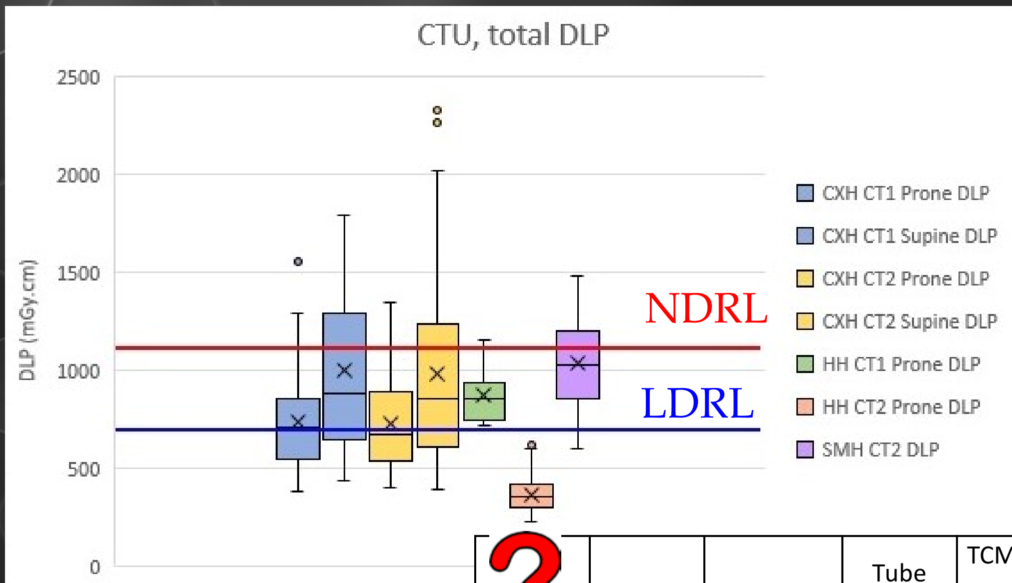
1,263 patients

Max ratio of medians **2.08**



System	Tube voltage (kV)	TCM/QRM (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	Auto	4D/100	SAFIRE 3	38.8	1.5	0.5	0.6	N
CXH CT2	Auto	4D/100	SAFIRE 3	38.8	1.5	0.5	0.6	N
HH CT1	Auto	4D/100	N	38.8	2	0.5	0.6	N
HH CT2	Auto	4D/80	SAFIRE 3	38.8	2	0.5	0.6	N
SMH CT1	120	3D	iDose 4	40	2	0.4	Varying	N
SMH CT2	120	3D	iDose 4	40	2	0.4	Varying	N
SMH T	120	3D	iDose 4	80	2	0.5	0.804	N

Results



602 patients

Max ratio of medians **2.86**

n	Protocol	Acquisition	Tube voltage (kV)	TCM/QRM or Effective (mAs)	IR	Beam collimation (mm)	Primary image slice thickness (mm)	Rotation time (s)	Pitch	Contrast
CXH CT1	Prone	PreContrast	Auto	4D/160	SAFIRE 3	38.4	1.5	0.5	0.6	N
		CTU	Auto	4D/150	SAFIRE 3	38.4	1.5	0.5	0.6	IV
CXH CT1	Supine	PreContrast	Auto	4D/150	SAFIRE 3	38.4	1.5	0.5	0.6	N
		CTU	Auto	4D/150	SAFIRE 3	38.4	1.5	0.5	0.6	IV
CXH CT2	Prone	PreContrast	Auto	4D/160	SAFIRE 3	38.4	1.5	0.5	0.6	N
		CTU	Auto	4D/160	SAFIRE 3	38.4	1.5	0.5	0.6	IV
CXH CT2	Supine	PreContrast	Auto	4D/160	SAFIRE 3	38.4	1.5	0.5	0.6	N
		CTU	Auto	4D/160	SAFIRE 3	38.4	1.5	0.5	0.6	IV
HH CT1	Prone	PreContrast	120	N/160	N	38.4	2	0.5	0.6	N
		CTU	Auto	4D/230	N	38.4	2	0.5	0.6	IV
HH CT2	Prone	PreContrast	Auto	4D/80	SAFIRE 3	38.4	2	0.5	0.6	N
		CTU	Auto	4D/80	SAFIRE 3	38.4	2	0.5	0.6	IV
SMH CT2	Prone	PreContrast	120	ACS	iDose 5	40	2	0.5	0.89	N
		CTU	120	3D	iDose 5	40	2	0.5	0.89	IV

S. Avramova-Cholakova

Discussion

- The concept of achievable dose (AD) is introduced by NRPB (1999) and further developed by NCRP (2012)
- AD recommended for use by ICRP 135: AD set at the room median & compared to national median
- If AD is below national median, **ensuring that image quality is adequate!**
- The concept is tested by Kanal et al. 2017

U.S. Diagnostic Reference Levels and Achievable Doses for 10 Adult CT Examinations[1]

Kalpana M. Kanal, PhD
Priscilla F. Butler, MS
Debapriya Sengupta, MBBS, MPH
Mythreyi Bhargavan-Chatfield, PhD
Laura P. Coombs, PhD
Richard L. Morin, PhD

Purpose: To develop diagnostic reference levels (DRLs) and achievable doses (ADs) for the 10 most common adult computed tomographic (CT) examinations in the United States as a function of patient size by using the CT Dose Index Registry.

Discussion

- A full analysis of data covering 10^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles could be explored for optimization of a complete range (Roch et al. 2019)

European Radiology
https://doi.org/10.1007/s00330-019-06422-2

PHYSICS

Long-term experience and analysis of data on diagnostic reference levels: the good, the bad, and the ugly

Patrice Roch[1] · David Célier[1] · Cécile Dessaud[2] · Cécile Etard[1] · Madan M. Rehani[3]

Received: 26 May 2019 / Revised: 25 July 2019 / Accepted: 12 August 2019

Discussion

Acceptable Quality Dose (AQD) proposed by M. Rehani 2015

Too much resources?

BJR

Received: 11 May 2014 | Revised: 18 November 2014 | Accepted: 25 November 2014

doi: 10.1259/bjr.20140344

Cite this article as:
Rehani MM. Limitations of diagnostic reference level (DRL) and introduction of acceptable quality dose (AQD). Br J Radiol 2015;88:20140344.

COMMENTARY

Limitations of diagnostic reference level (DRL) and introduction of acceptable quality dose (AQD)

M M REHANI, PhD

Harvard Medical School and Massachusetts General Hospital, Boston, MA, USA

ACCEPTABLE QUALITY DOSE

This article introduces a new quantity "AQD" as given below:

- Each facility determines averaged dose values (±standard deviation) for individual examination that has images of clinically acceptable quality by well-informed imaging specialists that are classified in weight groups of 10 kg body weight for adults, *e.g.* 41–50, 51–60, 61–70, 71–80 kg and so on. A similar approach can apply to children preferably with lower weight slots of 5 kg.
- One can determine AQDs for local, regional (sub-national) and national situations.
- This AQD will serve the purpose of "standard dose" for that examination and can be compared with the AQD of another room in the same hospital or for intercomparisons between hospitals within or outside a country. It can be used to detect those situations where optimization is needed.
- AQD can be used prospectively in adjusting parameters of patients whose estimated DLP value is likely exceeding AQD ± standard deviation.
- Also, one can identify those patients in whom image quality was not diagnostic or higher than was necessary, investigate and use the outcome as lessons learnt. This shifts focus of the investigation from dose in DRL to image quality in AQD.

Conclusions

- Differences in CT protocols settings although same settings were expected between same models
- Significant patient dose differences in certain cases with median ratio up to 2.9 for Sinuses, CTPA & CTU
- Comparison of local median with national median (AD concept) to be done
- Optimisation of the protocols
  - First step: Same protocols on same models
  - Further analysis and optimisation between models

- Any comments, suggestions, recommendations are very welcome!