

# Comparison of different methods for calculation of patient effective dose from multiple CT examinations

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# Introduction

- Effective dose ( $E$ ) – created to provide a dose quantity linked to health detriment due to stochastic effects
- Well known that  $E$  is related to many uncertainties and not applicable to individual patients
- Intended for use in RP and assessment of risks in general terms
- However  $E$  is extensively applied to medical exposure and in some cases for individual patients (e.g. when estimating unintended exposure)

Martin 2007,  
Martin 2008

Imperial College Healthcare 

NHS Trust

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# Introduction


- Recent publications reveal many patients receive recurrent CT exposures with cumulative  $E$  (CED)  $\geq 100$  mSv

European Radiology

<https://doi.org/10.1007/s00330-019-06551-8>

COMPUTED TOMOGRAPHY

Patients undergoing recurrent CT exams: assessment of patients with non-malignant diseases, reasons for imaging and imaging appropriateness

Madan M. Rehani<sup>1</sup>  • Emily R. Melick<sup>1</sup> • Raza M. Alvi<sup>1</sup> • Ruhani Doda Khara<sup>1</sup> • Salma Bator Tomas G. Neilan<sup>1</sup> • Michael Bettmann<sup>3</sup>

European Radiology

<https://doi.org/10.1007/s00330-019-06528-7>

COMPUTED TOMOGRAPHY

Multinational data on cumulative radiation exposure of patients from recurrent radiological procedures: call for action

Marco Brambilla<sup>1</sup>  • Jenia Vassileva<sup>2</sup> • Agnieszka Kuchcinska<sup>3</sup> • Madan M. Rehani<sup>4</sup>

European Radiology

<https://doi.org/10.1007/s00330-019-06523-y>

COMPUTED TOMOGRAPHY

Patients undergoing recurrent CT scans: assessing the magnitude of cumulative radiation exposure

Madan M. Rehani<sup>1</sup>  • Kai Yang<sup>1</sup> • Emily R. Melick<sup>1</sup> • John Heil<sup>2</sup> • Dušan Šalát<sup>3</sup> • William

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Technical note

Estimates of the number of patients with high cumulative doses through recurrent CT exams in 35 OECD countries

Madan M. Rehani<sup>a,\*</sup>, Michael Hauptmann<sup>b</sup>

# Introduction

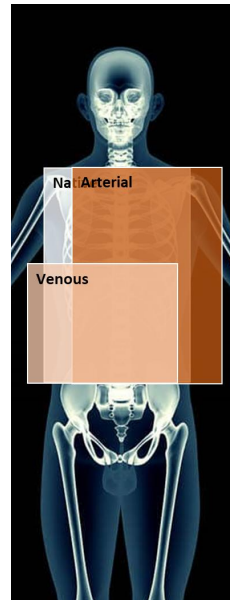
- A group of 8952 patients, with mean of 21 and a max of 109 CT scans during 5-y period, CED from 100 to 1185 mSv Rehani 2019
- UK – the estimated number of patients with CED  $\geq 100$  mSv in 5-y period is 70,499 ;  
35 countries – 2.5 million patients with CED  $\geq 100$  mSv in 5-y period against a population of 1.2 billion Rehani 2020
- Proven cancer risks at these dose levels; a recent review article suggests proven excess cancer risk even below 100 mGy
- Awareness of the impact of different methods Hauptmann 2020  
for calculation of  $E$  needed

# Aim

- To compare different methods for effective dose estimation of patients that have undergone several CT examinations with a CED of 100 mSv and above

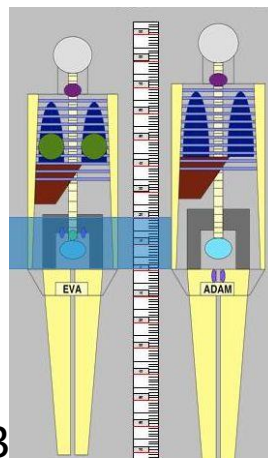
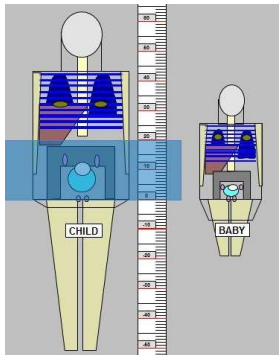
# Materials & methods

- Optima 660 (GE) CT scanner
- Patient data retrospectively extracted with DoseWatch
- Firstly, patients exposed to  $CED \geq 100$  mSv identified
- Then, 10 patients with effective diameter close to the median value (265 mm) of the whole sample selected
- Scan ranges based on anatomical landmarks checked on PACS for each phase
- 12 different methods for calculation of  $E$  applied
- $E$  from different phases summed to obtain exam  $E$
- All methods considered based on ICRP 103  $w_T$



# Materials & methods

1.  $E_{tot}$  – total exam DLP as provided by DMS x  $k$
2.  $E_k$  – phase DLP x  $k$
3.  $E_{Shrimpton}$  – typical published  $E$  values for the exams considered
4.  $E_{typ}$  – typical department DLP (median) x  $k$
5.  $E_{typ}$  CT Expo typical CTDI
6.  $E_{typ}$  CT Expo typical DLP



Zankl 1991, 1993

160 cm, 60 kg 170 cm, 70 kg

**Calculate**

1. Age Group: Child, Gender: male, female

3. Scanner Model: Siemens, Spout

4. Select mode: Body mode for head/neck region, Spiral mode

5. Scan Parameters: U=130, I=30, t=0.8, Q<sub>eff</sub>=40, Q=40, N \* h<sub>ref</sub>=8.0, TF=16.0, h<sub>ref</sub>=5.0, p=2, Ser=1

6. Results

CTDI <sub>w</sub> [mG]	CTDI <sub>vol</sub> [mGy/cm]	DLP <sub>w</sub> [mGy*cm]	E' [mSv]	D <sub>area</sub> [mSv]
7.6	3.8	78	1.2	n.a.

Effective dose E refers to ICRP 103

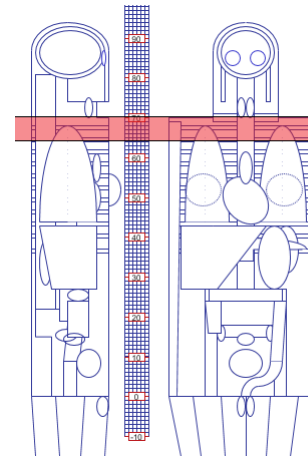
Tissue or Organ	H <sub>eff</sub> per Series [mSv]	Tissue or Organ	H <sub>eff</sub> per Series [mSv]
Brain	0.0	Upp. large int.	2.7
Salivary glands	0.0	Thymus	0.0
Thyroid	0.0	Spleen	0.5
Breasts	0.1	Pancreas	0.7
Oesophagus	0.0	Adrenals	0.4
Lungs	0.1	Kidneys	2.0
Liver	0.4	Small intestine	3.7
Stomach	0.7	Uterus	3.8
Low Large int.	0.7	Prostate	0.0
Testicles	0.0	Gall bladder	0.7
Ovaries	3.7	Heart	0.0
Bladder	4.0	ET tissue	0.0
Bone marrow	0.7	Oral mucosa	0.0
Bone surfaces	2.3	Lymph nodes	1.3
Skin	1.2	Muscle	1.3
		Eye lenses	0.0

Please note: All organ doses H<sub>eff</sub> are based on conversion coefficients for standard patients (ADAM, EVA, CHILD, BABY) and serve for information purposes only (in particular for organs outside the scan range!).

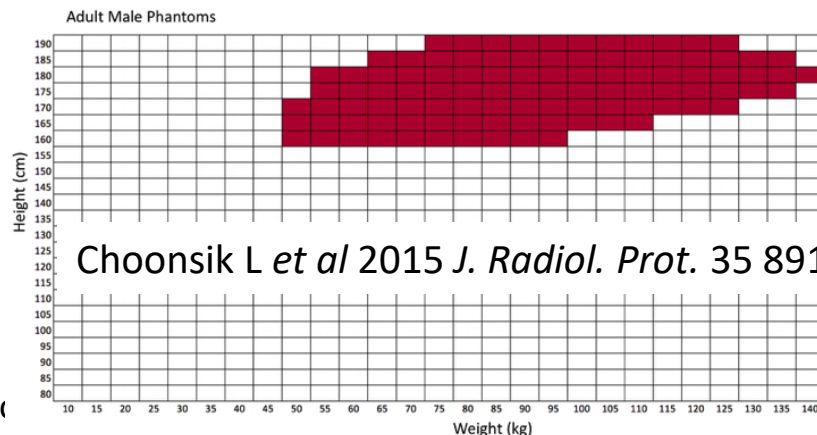
In

# Materials & methods

7. E CT Expo phase CTDI
8. E CT Expo phase DLP
9. E ImPACT phase CTDI
10. E ImPACT phase DLP
11. E NCI phase CTDI
12. E NCI phase DLP



ImPACT CT Patient Dosimetry Calculator																																																																																																																			
Version 1.0.4 22/05/2011																																																																																																																			
<b>Scanner Model:</b>																																																																																																																			
Manufacturer: Siemens	Acquisition Parameters:																																																																																																																		
Scanner: Siemens Definition AS	Tube current: 500 mA																																																																																																																		
kV: 125	Rotation time: 1 s																																																																																																																		
Scan Region: Head	Spiral pitch: 1																																																																																																																		
Data Set: MCTSET17	mAs / Rotation: 500 mAs																																																																																																																		
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End Position: 70.5 cm	CTDI (air): Look up 22.4 mGy/100mAs																																																																																																																		
	CTDI (soft tissue): 24.0 mGy/100mAs																																																																																																																		
	CTDI <sub>w</sub> : Look up 15.4 mGy/100mAs																																																																																																																		
Organ weighting scheme: ICRP 103																																																																																																																			
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DLP: 463 mGy.cm																																																																																																																			
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National Cancer Institute dosimetry system for CT Version 2.1

Age Group:  0-year  1-year  5-year  10-year  15-year  Adult

Gender:  Male  Female

Reference Body Size: Height (cm) 051, Weight (kg) 004

Scanner information: Manufacturer GE, Model 880L 9000 Series

Filters:  Head filter  Body filter

Parameters: nCTDI<sub>w</sub> (mGy/100 mAs) 6.2, Tube potential (kVp) 120, Current x time (mAs) 100, Pitch 1, Total collimation (mm) 10, CTDI<sub>w</sub> (mGy) 6.2, DLP (mGy-cm) 62, Effective diameter (cm) 9.9, SSDE (mGy) 7.9

Scan Coverage: Scan Start (cm) 1, Scan End (cm) 10, Scan Length (cm) 10, Predefined protocol Head

Organ	Organ dose (mGy)
Brain	1.49
Pituitary gland	5.86
Lens	6.69
Eye balls	6.41
Salivary glands	2.58
Oral cavity	2.42
Spiral cord	0.27
Thyroid	1.03
Esophagus	0.54
Trachea	0.5
Thymus	0.37
Lung	0.21
Breast	0.12
Heart wall	0.2
Stomach wall	0.07
Liver	0.09
Gall bladder	0.06
Adrenals	0.07
Spleen	0.1
Pancreas	0.06
Kidney	0.05
Small intestine	0.03
Colon	0.04
Rectosigmoid	0.02
Urinary bladder	0.02
Prostate	0.01
Uterus	0
Ovaries	0.01
Skin	1.4
Muscle	1.26
Active marrow	1.89
Shallow marrow	3.01
Effective dose(mSv)	0.52



# Materials & methods

- Typical published  $E$  values and conversion coefficients  $k$  based on: Shrimpton *et al.* Updated estimates of typical effective doses for common CT examinations in the UK following the 2011 national review. *Br J Radiol* 2016; 89: 20150346.

Examination	E/DLP (mSv/mGy cm)	E <sub>103</sub> (mSv)
Chest	0.027	14
CTPA	0.027	9.7
Abdomen	0.024	16
Abdomen&Pelvis	0.02	13
Chest&Abdomen	0.0255	15
Pelvis	0.02	13
Chest-Abd-Pelvis	0.021	19
KUB	0.018	6.4
Head	0.002	1.8
Cervical Spine	0.0057	3

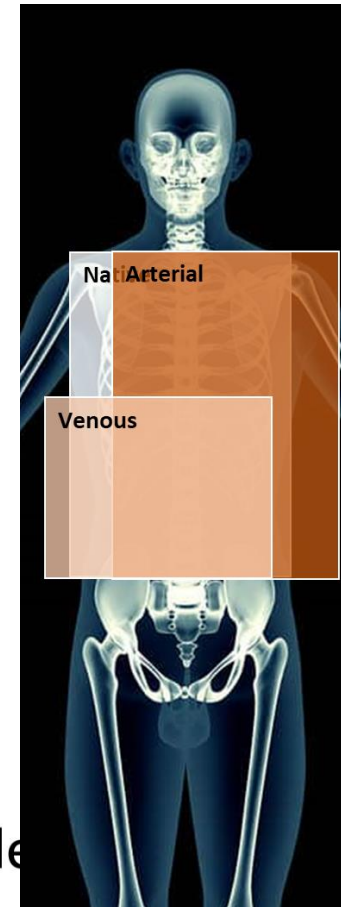
# Results

- 5 males & 5 females

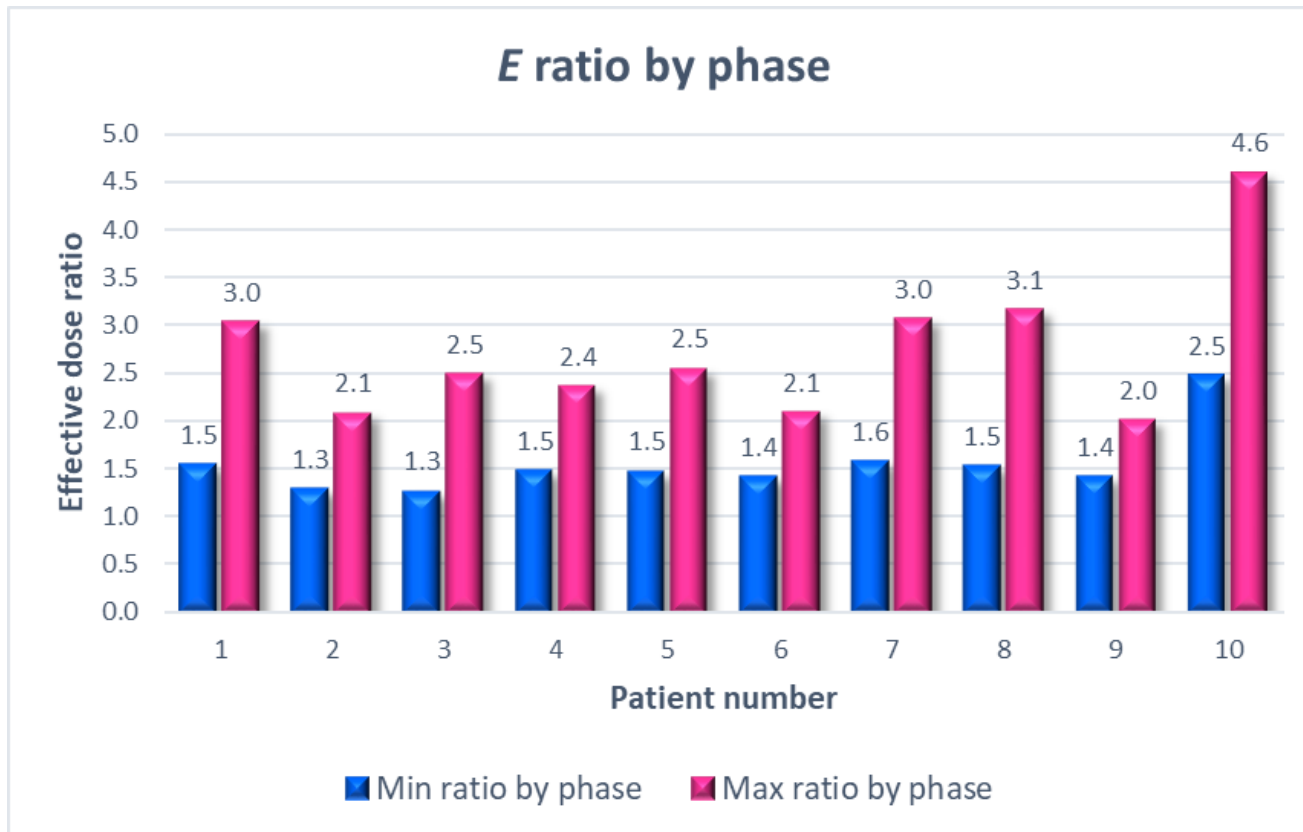
<b>Sex</b>	<b>Mean (range) weight (kg)</b>	<b>Mean (range) height (cm)</b>	<b>Mean (range) eff. diameter (mm)</b>
Males	80 (70-113)	174 (160-193)	277 (246-315)
Females	68 (59-75)	163 (153-166)	269 (233-341)

# Results

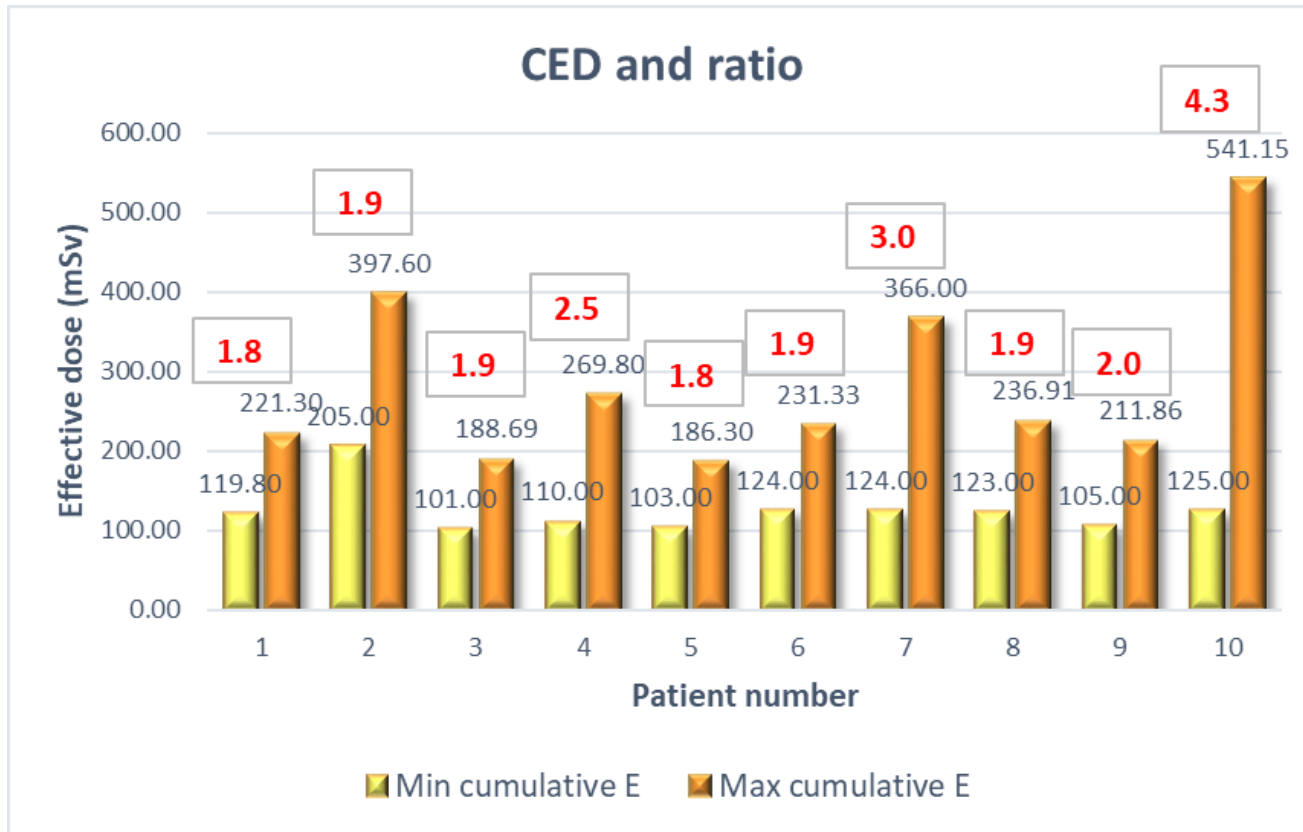
- Oncology patients, mostly receiving 2 or 3 phase CAP exams
- The % difference between  $E$  determined based on CTDI or DLP approach used in the software packages varied between -1.7 % and 3.5 %



# Results

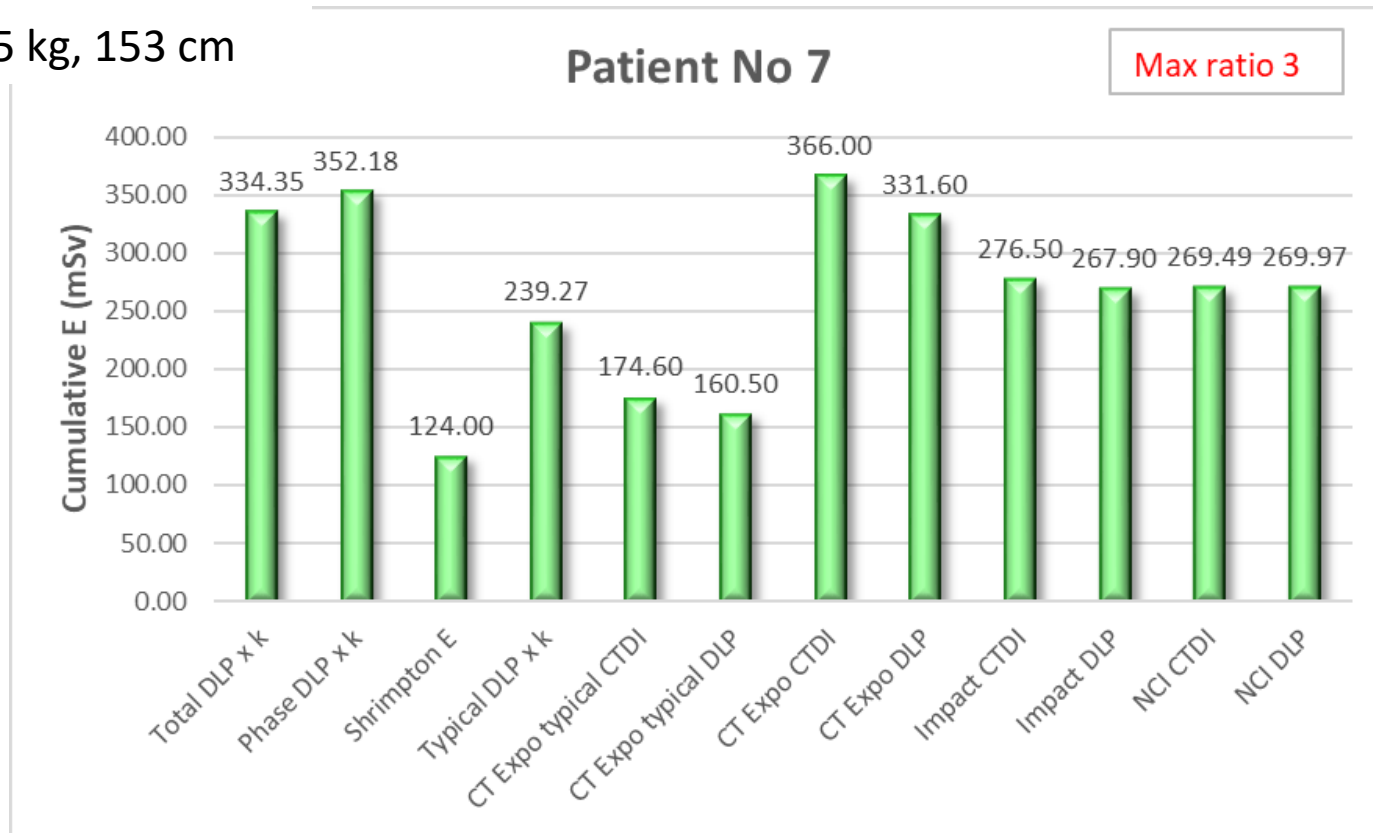


# Results



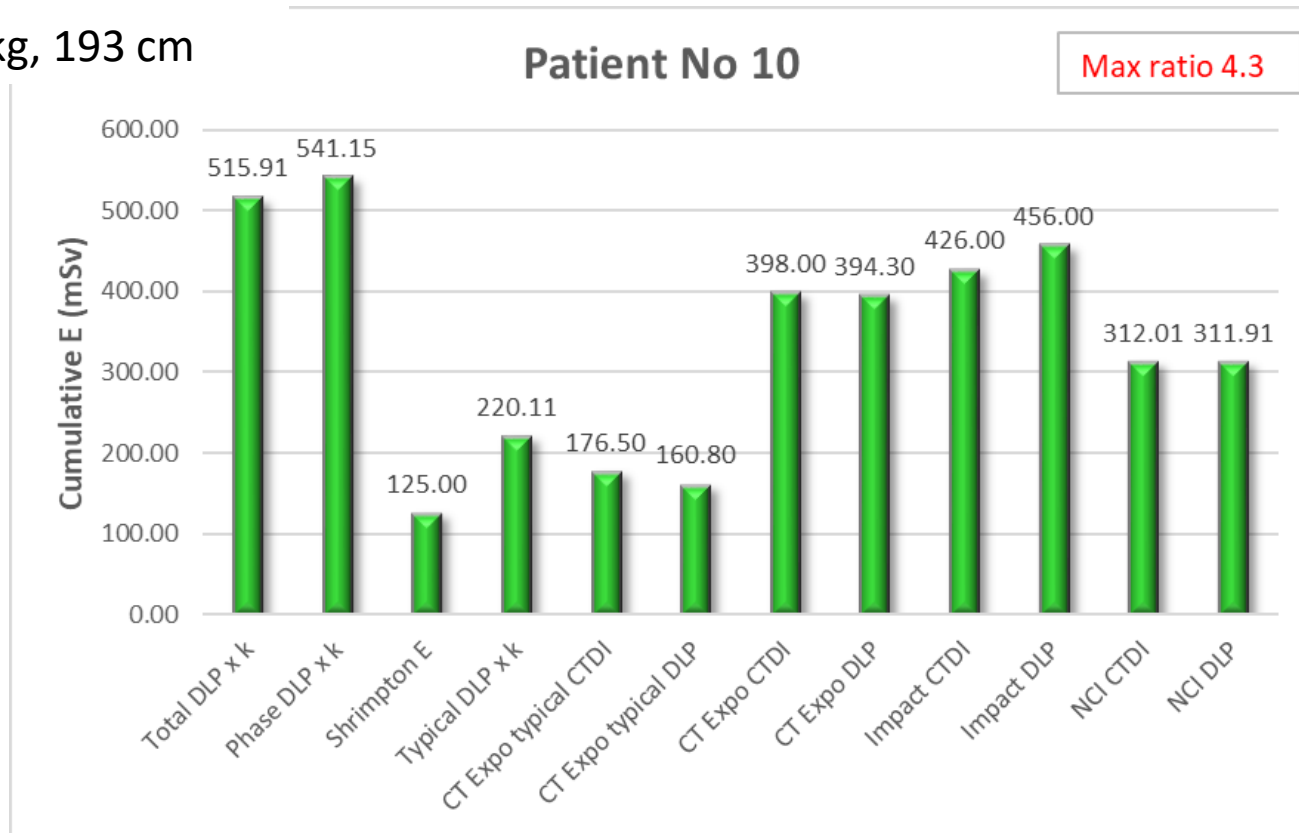
# Results

Female, 75 kg, 153 cm



# Results

Male, 113 kg, 193 cm



# Conclusions

- Although effective dose estimation is not recommended for individual patients, this is sometimes needed in clinical practice
- It is highly dependent on the method used
- CED estimations can differ up to 4-5 times or maybe more
- The large uncertainties related to these estimations should always be taken into account



Thank you for your attention!

