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Comparison of patient effective doses from multiple CT examinations based on different calculation methods: An update

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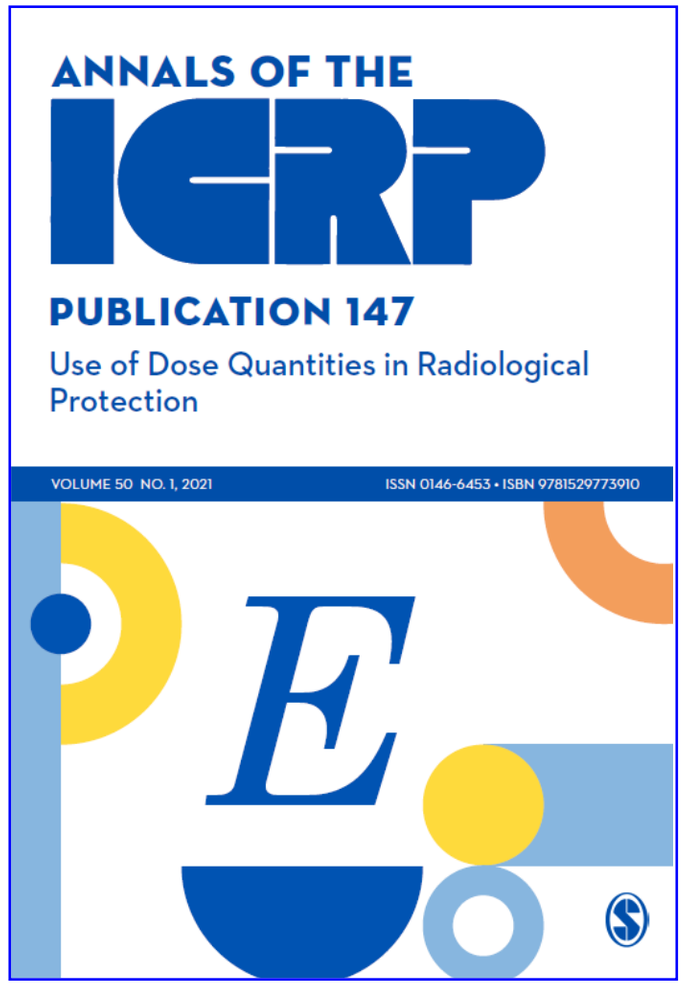
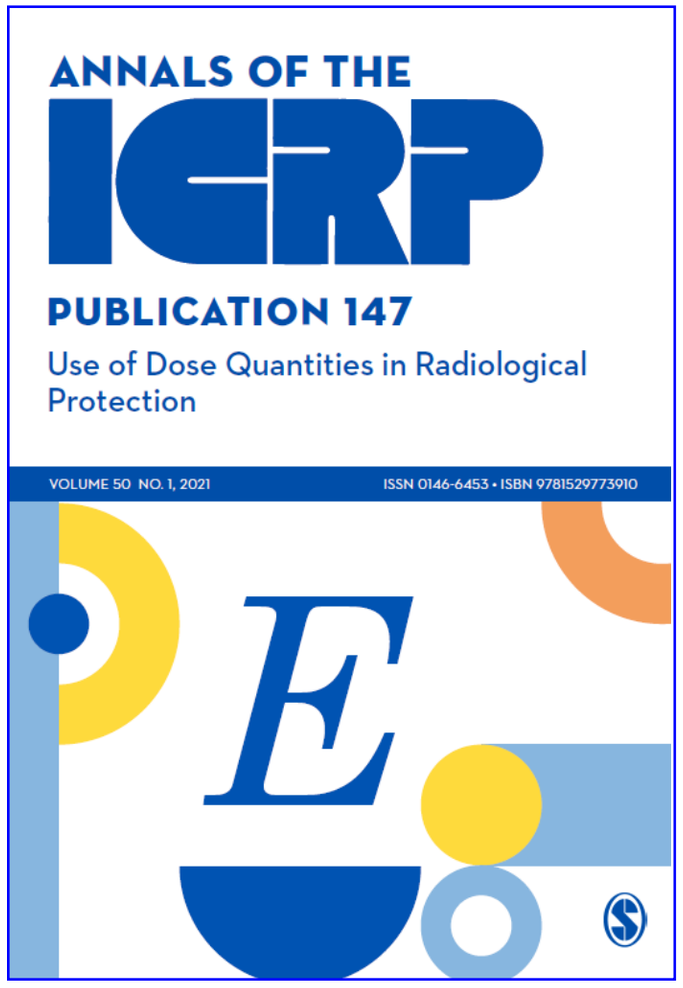
Introduction

- Effective dose *E* – used to estimate & compare radiation risks at low dose levels
- Related to many assumptions, averaged over all ages and both sexes by definition
- Hence, related to many uncertainties and **not recommended for use to individuals**
- However…
  ICRP 147 (2021) - Still needed to be used to individuals in particular cases



Introduction

- Some applications of *E* at medical exposures recommended by ICRP:
  - Optimisation: dose distributions within the body substantially different
  - Biomedical research
  - Reporting of unintended exposures
  - Health screening procedures that involve exposure of many organs/tissues



Introduction

- Recent studies reveal that many patients receive recurrent CT exposures with cumulative *E* (CED) ≥ 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[1] · Emily R. Melick[1] · Raza M.
Tomas G. Neilan[1] · Michael Bettmann[3]

European Radiology
https://doi.org/10.1007/s00330-019-06528-7
COMPUTED TOMOGRAPHY

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

Marco Brambilla[1] · Jenia Vassileva[2] · Agnieszka Kuchcinska[3] · Madan M. Rehani[4]

European Radiology
https://doi.org/10.1007/s00330-019-06523-y
COMPUTED TOMOGRAPHY

Patients undergoing recurrent CT scans: assessing the magnitude

Madan M. Rehani[1] · Kai Yang[1] · Emily R. Melick[1] · John Heil[2] · Dušan Šalát[3] · William F. Sensakovic[4,5] · Bob Liu[1]

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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[a,*], Michael Hauptmann[b]

Probability of receiving a high cumulative radiation dose and primary clinical indication of CT examinations: a 5-year observational cohort study

Cécile R L P N Jeukens ,[1] Hub Boere,[1] Bart A J M Wagemans,[1]
Patty J N
Joachim

European Radiology
https://doi.org/10.1007/s00330-021-07734-y
COMPUTED TOMOGRAPHY

Multicentric study of patients receiving 50 or 100 mSv in a single day through CT imaging—frequency determination and imaging protocols involved

Madan M. Rehani[1,2] · John Heil[3] · Vinit Baliyan[1]

Cite this article as:
Vassileva J, Holmberg O. Radiation protection perspective to recurrent medical imaging: what is known and what more is needed?. *Br J Radiol* 2021; **94**: 20210477.

REVIEW ARTICLE

Radiation protection perspective to recurrent medical imaging: what is known and what more is needed?

JENIA VASSILEVA, PhD and OLA HOLMBERG, PhD
Radiation Protection of Patients Unit, International Atomic Energy Agency, Vienna, Austria

Introduction

- At CED > 100 mSv, single organs can receive > 200 mGy

  Zwede et al. Organ doses and cancer risk assessment in patients exposed to high doses from recurrent CT exams. Eur J Radiol 2022 (149) 110224.

- **Proven cancer risks at these dose levels**; a recent review article suggests **proven excess cancer risk even below 100 mGy**

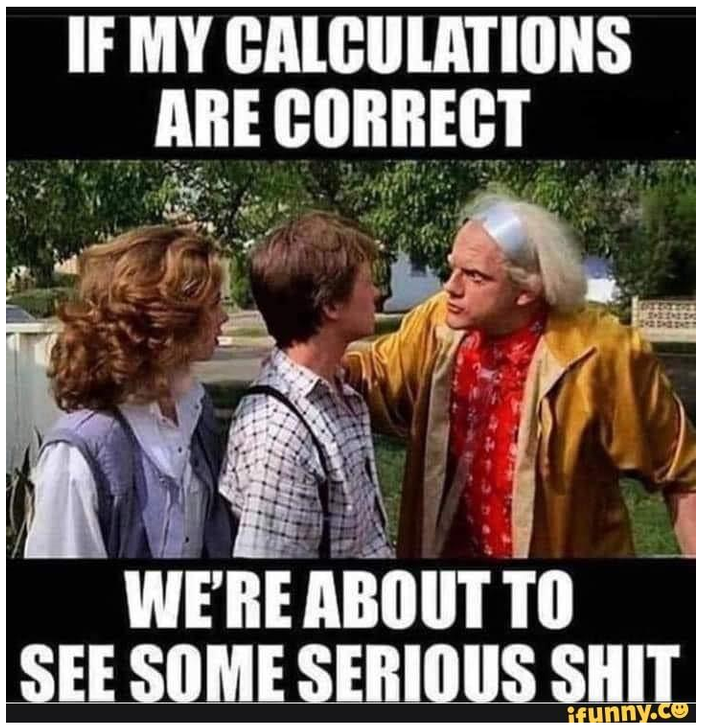
  Hauptmann et al. epidemiological studies of low-dose ionizing radiation and cancer: Summary bias assessment and meta-analysis. J Natl Cancer Inst Monogr 2020 (56): 188-200.

- Awareness of the impact of different methods for calculation of *E* needed

Purpose

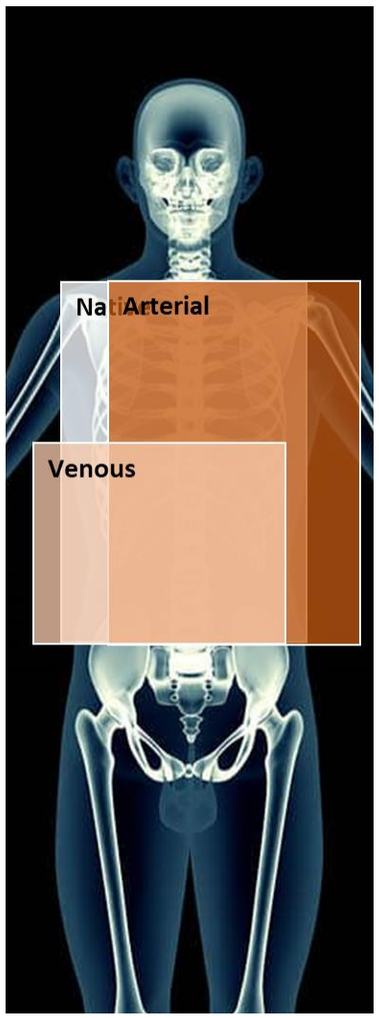
- To **compare *E* estimations based on different calculation methods** for patients with recurrent CT examinations.

- The intention was to select among frequently used and easily accessible methods that would be largely implemented by medical physicists in routine clinical practice.



Materials & Methods

- Two large hospital groups in Bulgaria and UK
  - 8 CT scanners (GE, Siemens, Philips)
  - Patient data retrospectively extracted with dose management software
  - Patients, exposed to CED ≥ 100 mSv identified
  - A total of **40 patients** selected:
    - 10 small, 20 normal, 10 large size (normal size close to median eff. diam.)
  - Scan ranges based on anatomical landmarks checked on PACS for each phase
  - **17 methods** applied to determine *E* received from each phase and each exam (based on ICRP 103 w_T)
  - Phase *E* determined & summed to obtain exam *E*, CED of each patient determined by summing exam *E*



Materials & Methods

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- Three groups of methods used for *E* calculations
  1. Based on the adoption of **published values** for the given type of exam
  2. Calculated from typical departmental DLP or patient specific DLP multiplied by **standard conversion coefficients** for the particular type of exam

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_{103} (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

Materials & Methods

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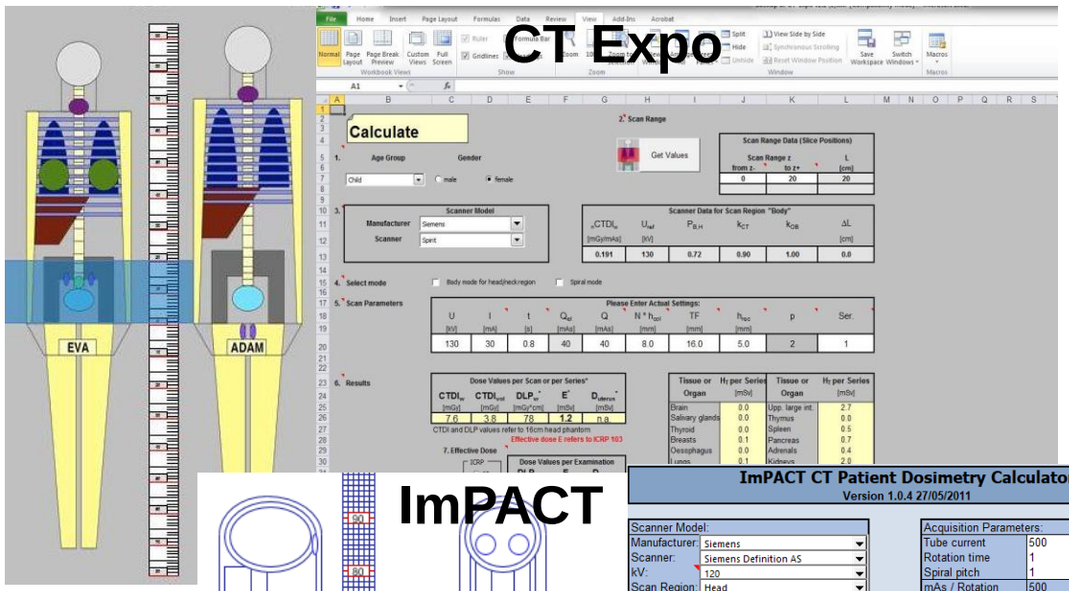
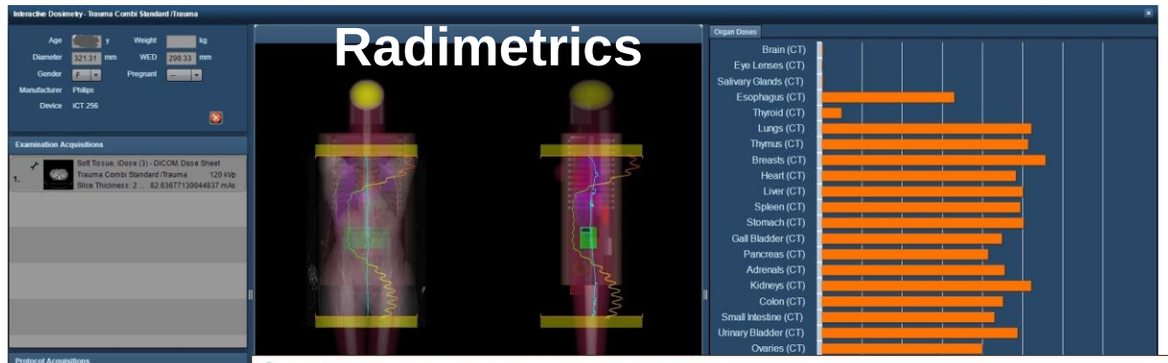
- Three groups of methods used for *E* calculations

  3. Based on typical dose indices or patient-specific calculations with **4 software packages**

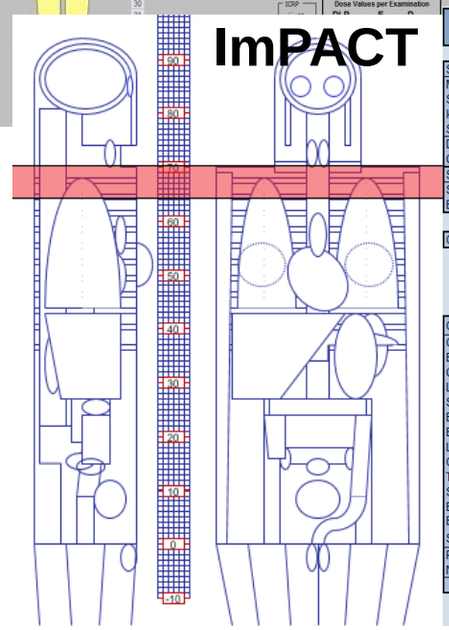


CT Expo

Radimetrics



ImPACT



ImPACT CT Patient Dosimetry Calculator
Version 1.0.4 27/05/2011

Scanner Model:	
Manufacturer:	Siemens
Scanner:	Siemens Definition AS
kV:	120
Scan Region:	Head
Data Set	MCSET17 Update Data Set
Current Data	MCSET17
Scan range	
Start Position	64.5 cm
End Position	70.5 cm

Get From Phantom Diagram

Organ weighting scheme: ICRP 103

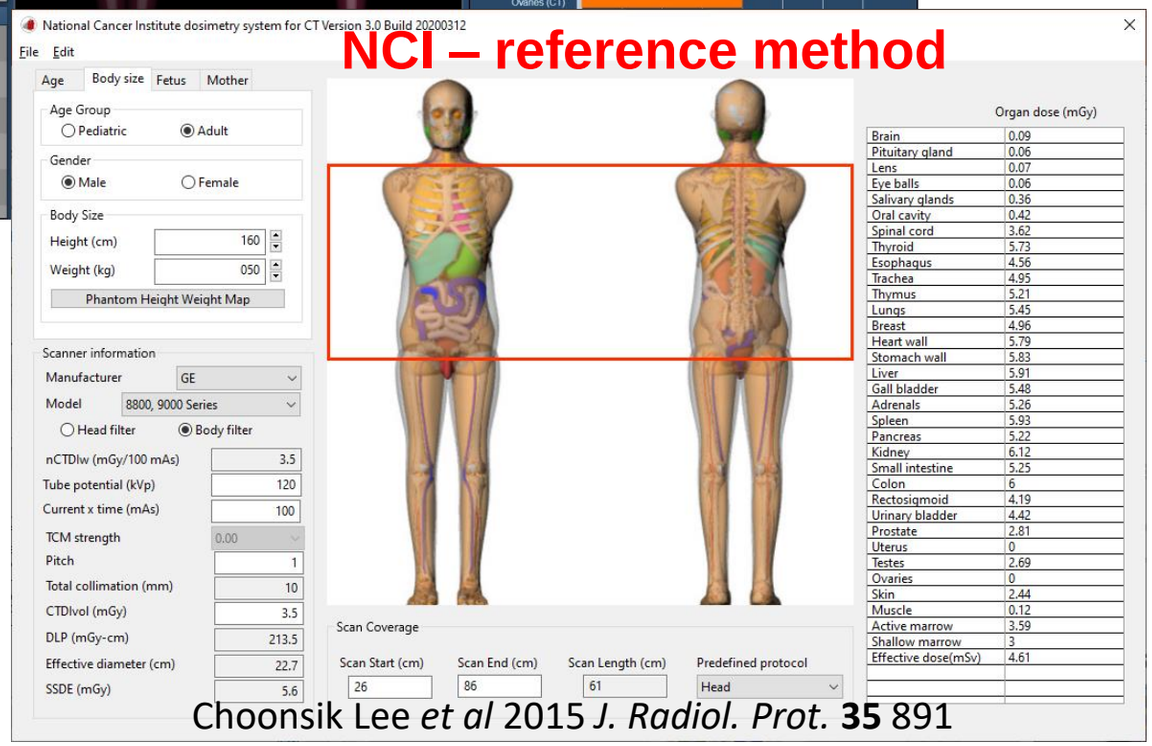
Acquisition Parameters:		
Tube current	500	mA
Rotation time	1	s
Spiral pitch	1	
mAs / Rotation	500	mAs
Effective mAs	500	mAs
Collimation	19.2 (32 x 0	mm
Rel. CTDI	Look up 1.32	at selected collimatio
CTDI (air)	Look up 22.4	mGy/100mAs
CTDI (soft tissue)	24.0	mGy/100mAs
$_nCTDI_w$	Look up 15.4	mGy/100mAs

$CTDI_w$	77.2	mGy
$CTDI_{vol}$	77.2	mGy
DLP	463	mGy.cm

Organ	w_T	H_T (mGy)	$w_T.H_T$
Gonads	0.08	0.0009	0.000072
Bone Marrow	0.12	2.9	0.34
Colon	0.12	0.0081	0.00097
Lung	0.12	3.7	0.44
Stomach	0.12	0.092	0.011
Bladder	0.04	0.000015	5.9E-07
Breast	0.12	0.56	0.067
Liver	0.04	0.17	0.0068
Oesophagus (Thymus)	0.04	2.9	0.11
Thyroid	0.04	15	0.59
Skin	0.01	3.2	0.032
Bone Surface	0.01	6.1	0.061
Brain	0.01	0.45	0.0045
Salivary Glands (Brain)	0.01	0.45	0.0045
Remainder	0.12	2	0.24
Not Applicable	0	0	0
Total Effective Dose (mSv)			1.9

Remainder Organs	H_T (mGy)
Adrenals	0.18
Small Intestine	0.0071
Kidney	0.051
Pancreas	0.15
Spleen	0.16
Thymus	2.9
Uterus / Prostate (Bladder)	0.00046
Muscle	3
Gall Bladder	0.049
Heart	0.84
ET region (Thyroid)	15
Lymph nodes (Muscle)	3
Oral mucosa (Brain)	0.45
Other organs of interest	H_T (mGy)
Eye lenses	0.56
Testes	0
Ovaries	0.0018
Uterus	0.0009
Prostate	0.000015

NCI – reference method

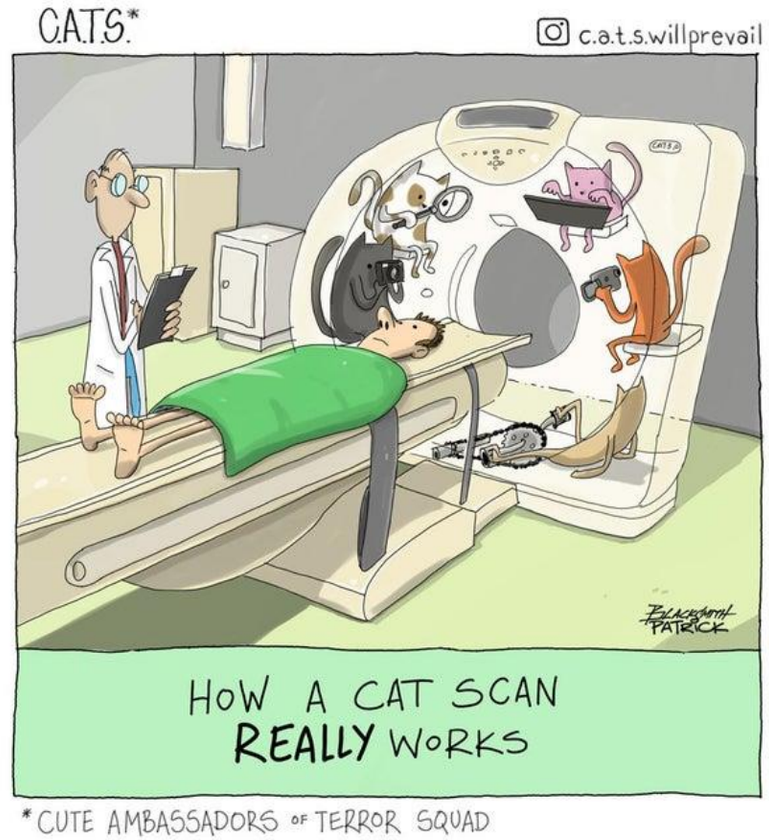


Choonsik Lee *et al* 2015 *J. Radiol. Prot.* **35** 891

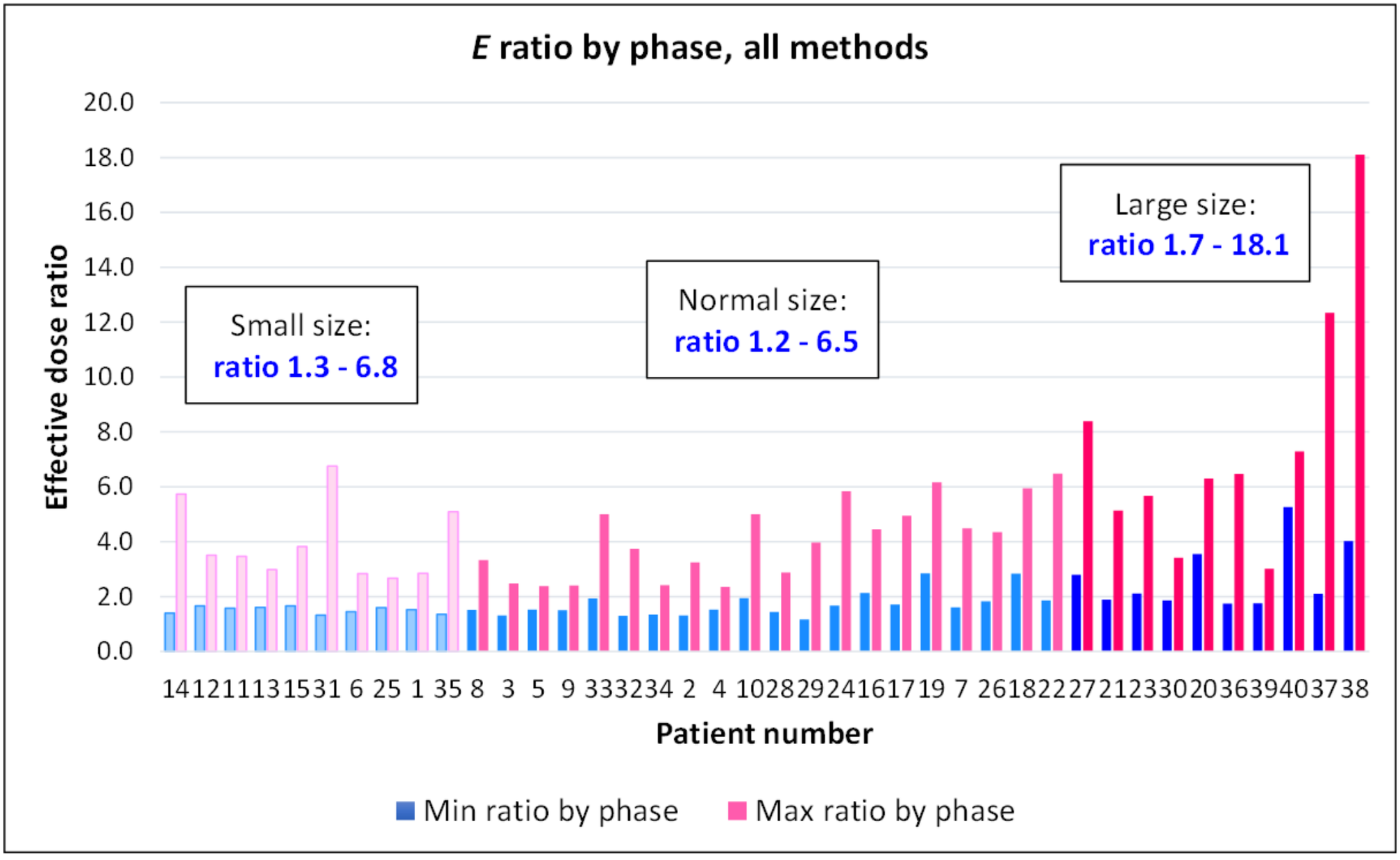
Results

- Patient demographics – 18 males, 22 females
- Each patient - between 3 and 20 exams, consisting of 1 to 4 phases each
- A total of 345 exams and 665 phases considered

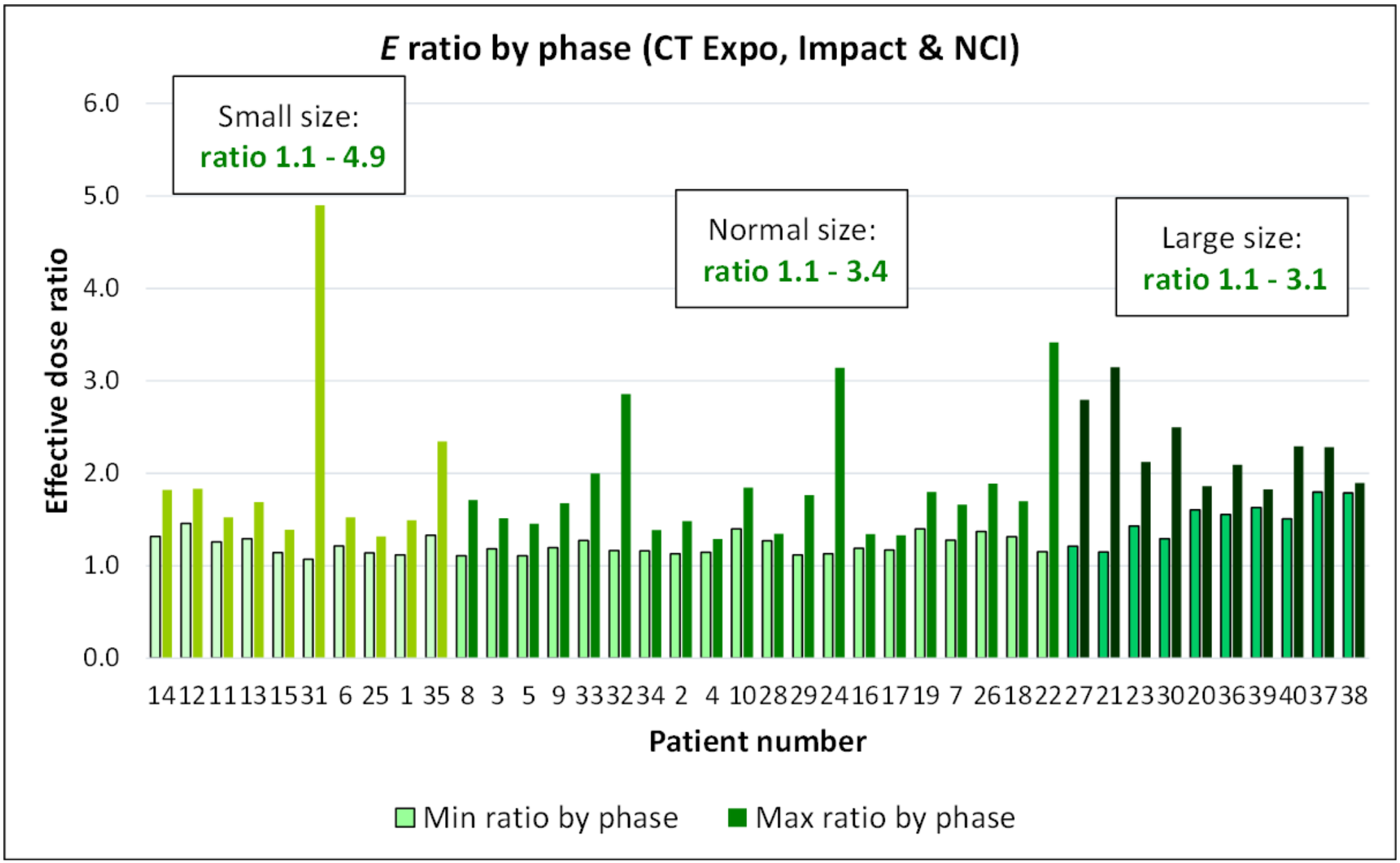
Patient size/Number of patients/Trust	Weight (kg) Mean (range)	Height (cm) Mean (range)	Effective diameter (mm) Mean (range)
Small/10/All	60 (45, 70)	167 (143, 182)	241 (201, 254)
Normal/20/All	74 (45, 113)	168 (153, 193)	288 (256, 322)
Large/10/All	111 (90, 125)	170 (165, 175)	375 (328, 431)



Results


E ratio by phase, all methods
Effective dose ratio
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Small size:
ratio 1.3 - 6.8
Normal size:
ratio 1.2 - 6.5
Large size:
ratio 1.7 - 18.1
14 12 11 11 13 15 3 1 6 25 1 35 8 3 5 9 33 32 34 2 4 10 28 29 24 16 17 19 7 26 18 22 27 21 23 30 20 36 39 40 37 38
Patient number
Min ratio by phase
Max ratio by phase

Results


E ratio by phase (CT Expo, Impact & NCI)
Small size:
ratio 1.1 - 4.9
Normal size:
ratio 1.1 - 3.4
Large size:
ratio 1.1 - 3.1
Effective dose ratio
6.0
5.0
4.0
3.0
2.0
1.0
0.0
14 12 11 13 15 31 6 25 1 35 8 3 5 9 33 32 34 2 4 10 28 29 24 16 17 19 7 26 18 22 27 21 23 30 20 36 39 40 37 38
Patient number
Min ratio by phase
Max ratio by phase

Results

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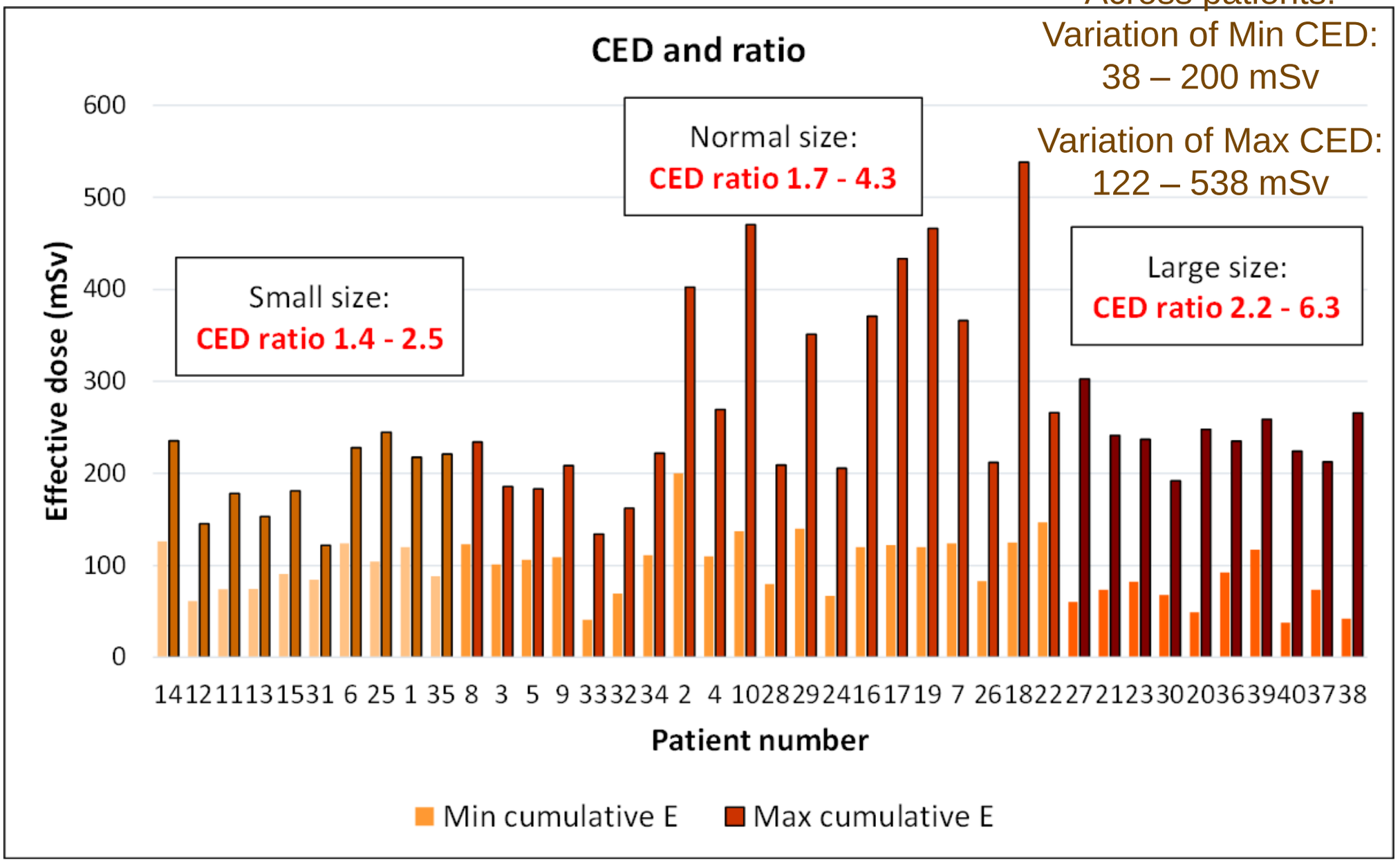

Across patients:
Variation of Min CED:
38 – 200 mSv

Variation of Max CED:
122 – 538 mSv

Results – methods based on published or typical doses, compared to NCI

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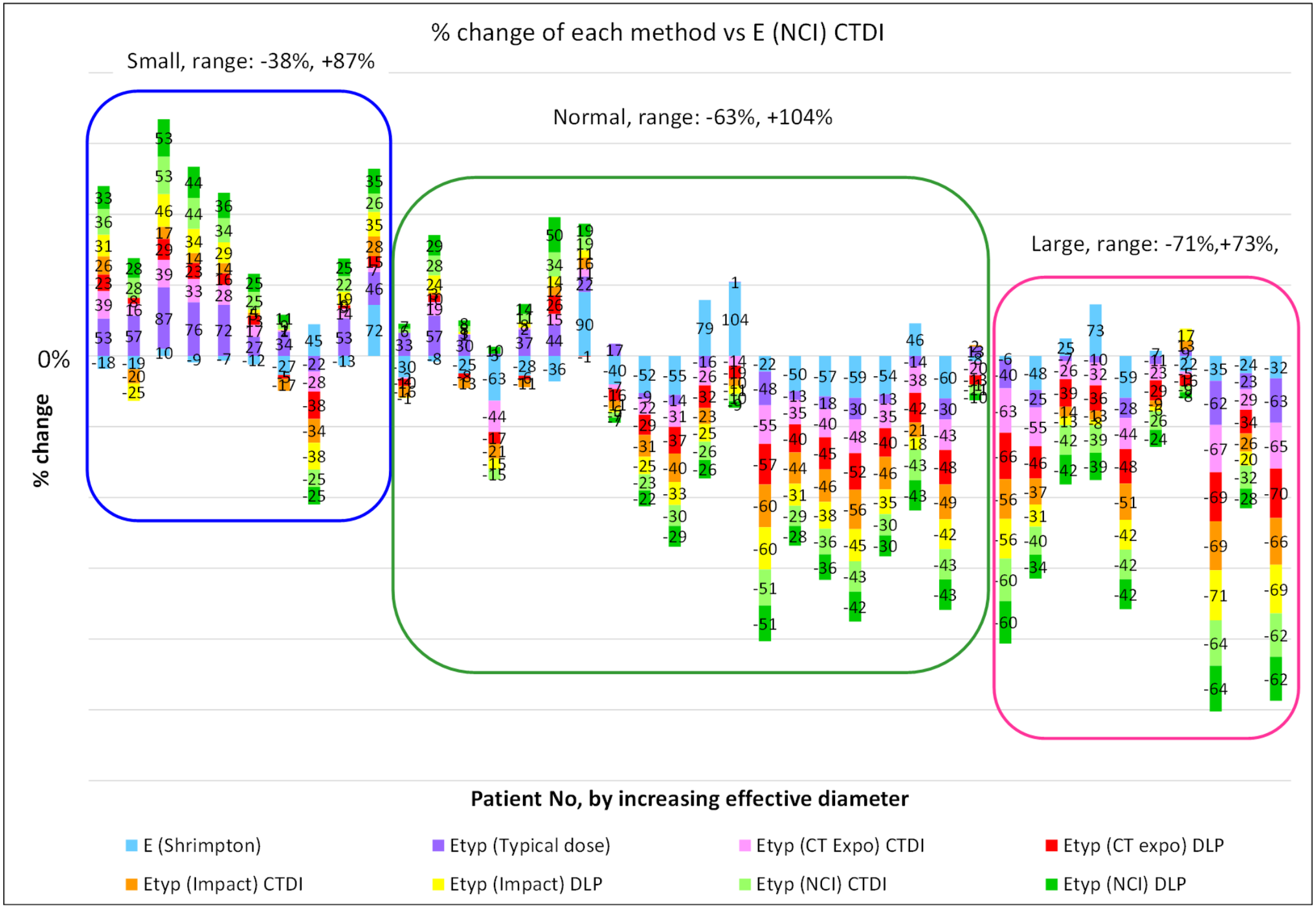

Results – methods based on individual patient data, compared to NCI

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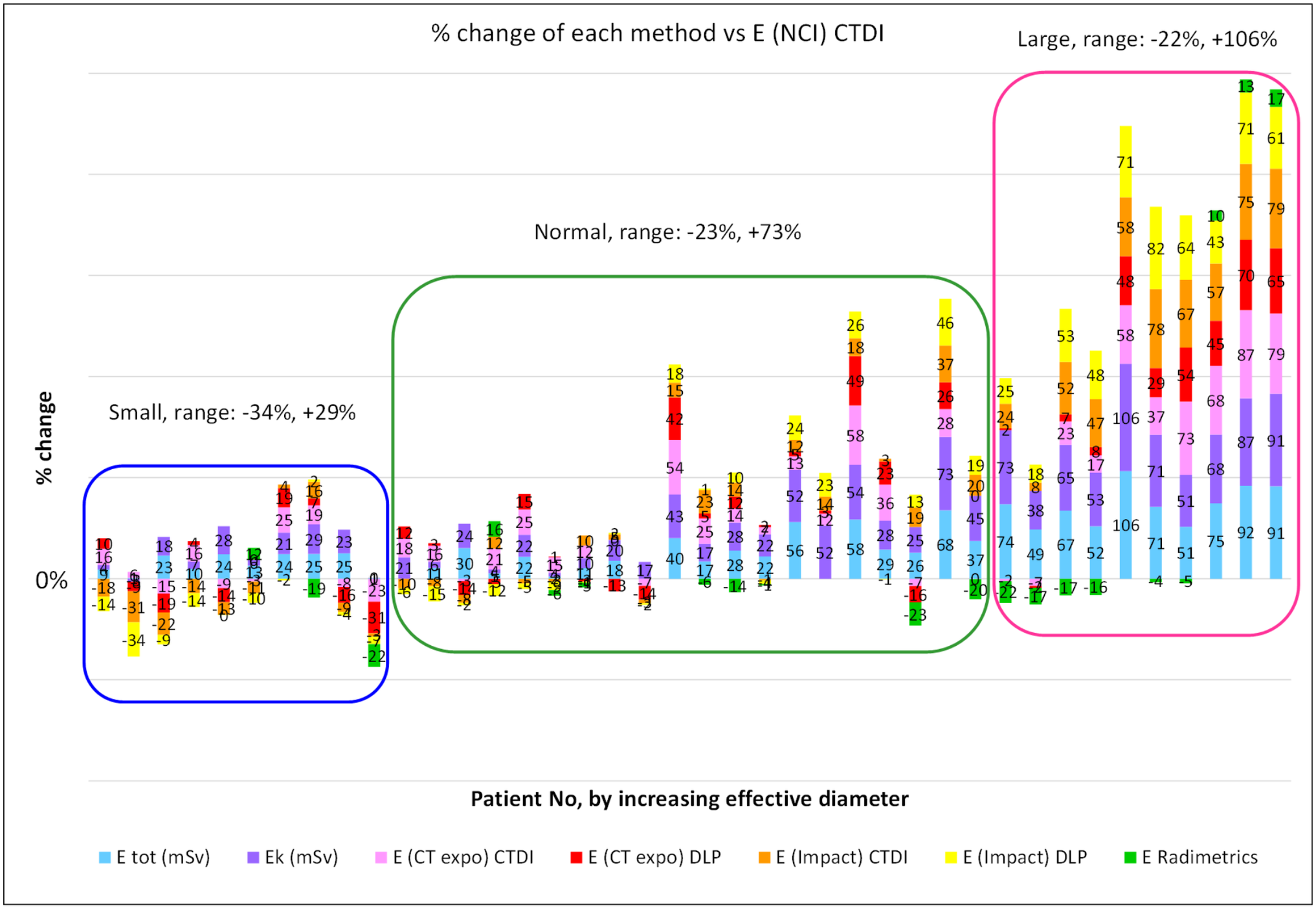
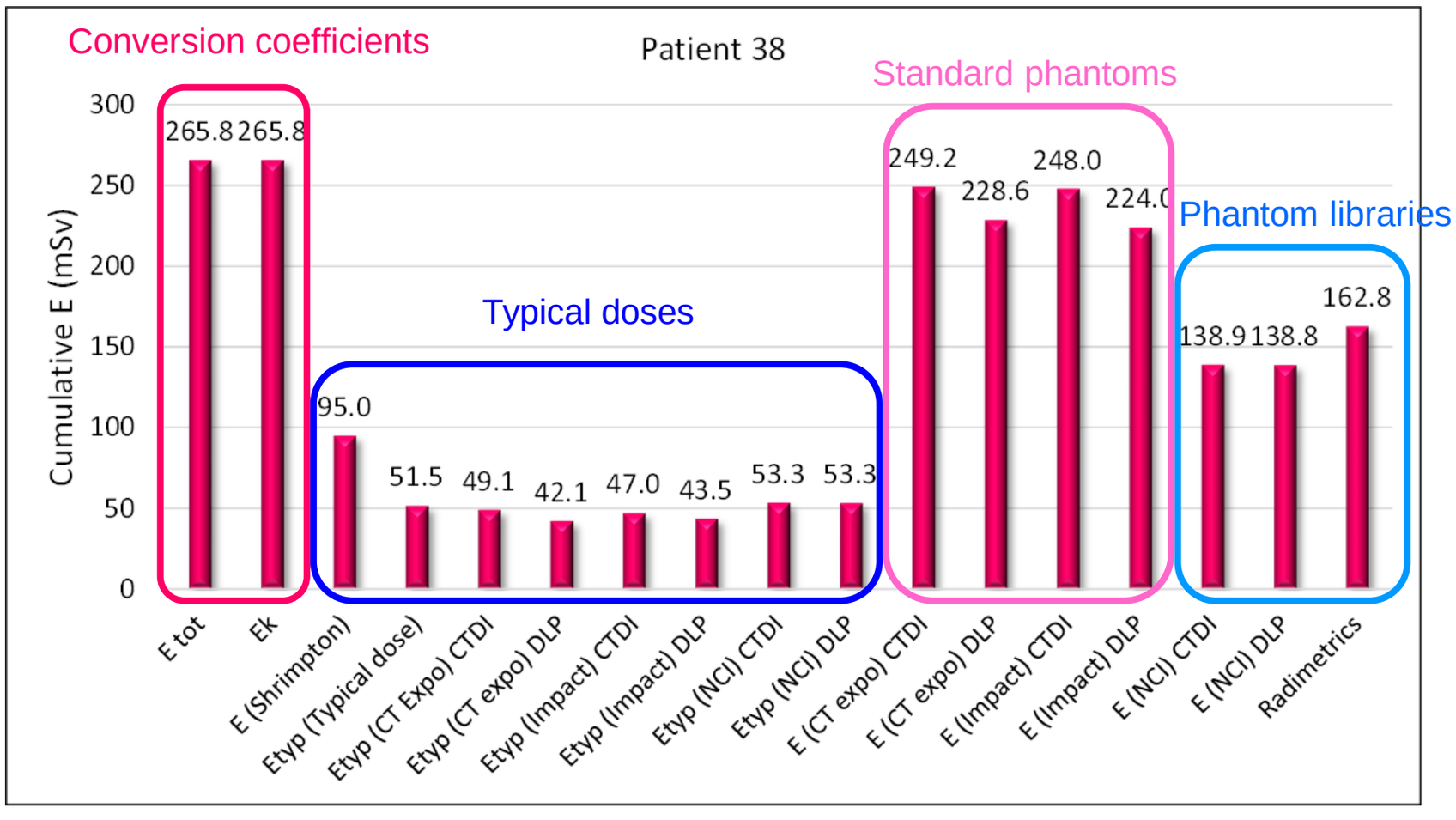
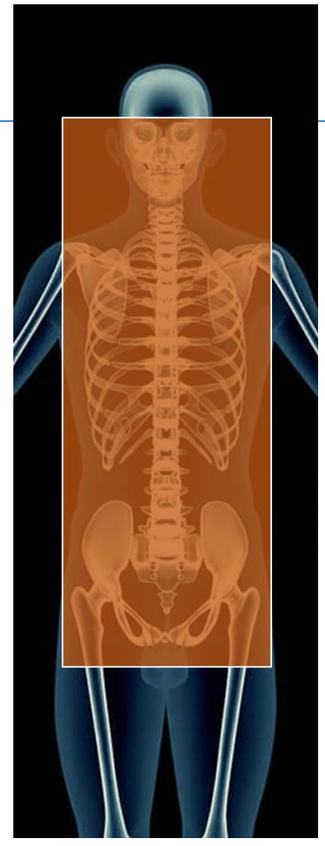


Results

Female 165 cm, 125 kg, large size

Max CED ratio 6.3
Max ratio by phase 18.1





- 4th exam Description CAP (published dose for CAP)
- Real exam NCAP (higher DLP value from scanner)
- Chest phase of protocol for Neck & Chest used – typical doses calculated with data for this protocol & phase
- Additional factor – large size

Conclusions

- Although effective dose is recommended for population estimations, it is sometimes needed for individual patients in clinical practice
- Its value is highly dependent on the method applied
- *E* estimations from individual phases of the exam can differ up to 18 times across different methods
- CEDs were found to differ up to 6.3 times depending on the method

Conclusions

- The methods based on published or typical values were found to generally provide an overestimation of *E* for small size patients (up to 87%) while…
- …large size patients had underestimated doses down to –71%
- The methods based on particular patient data were overestimating *E* for most normal to large size patients (up to 106%), compared to NCI
- The related large uncertainties in *E* estimations should always be taken into account

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Comparison of patient effective doses from multiple CT examinations based on different calculation methods

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Thank you!

Avramova-Cholakova S., Dyakov I., Yordanov H., O'Sullivan J. Comparison of patient effective doses from multiple CT examinations based on different calculation methods. Physica Medica 99 (2022) 73-84.