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Evaluating the impact of overranging on patient effective dose and organs' dose in chest CT examinations utilizing VirtualDoseCT software

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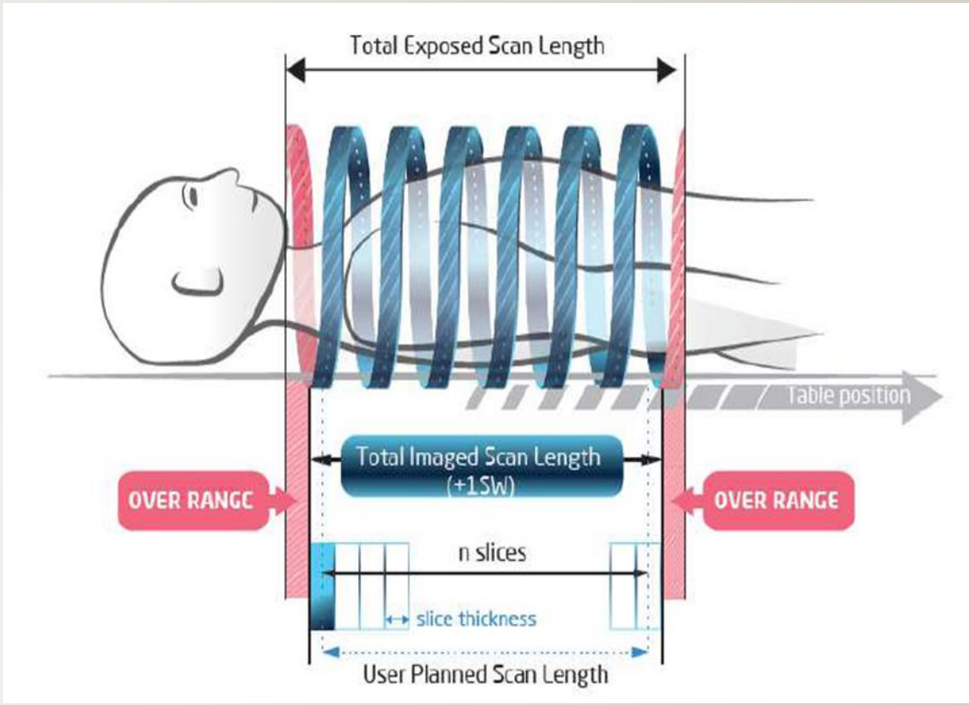
Theoretical Background

Overranging (O/R) is defined as the difference between the imaged and the exposed scan length.

O/R is **inherent to the helical scanning process** because data for the image reconstruction are obtained with interpolation from nearby rotations. At least half an additional rotation required at the start and the end of the field.

Due to O/R, different patients' anatomical areas are unintendedly exposed to the primary X-ray beam, increasing the overall radiation dose. However, no images are generated from the overranging area.



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Aim

The aim of the study is to calculate the increase in the effective dose (ED) and the organs' doses (ODs) for patients undergoing **chest CT** examinations at the **General University Hospital of Patras**.

Materials & Methods (a)

- The **anatomical** and **demographica**l data, along with the **exposure parameters** and the **scanning field length**, have been retrospectively collected from **111 patients** (46 females and 65 males) undergoing **chest CT examinations** during the period **July 2022 – February 2023** at the **General University Hospital of Patras**.

- The examinations have been performed on a **Toshiba Aquilion Prime 80-slice** scanner and fulfilled the required diagnostic image quality. The average scanning filed size was **35.1 cm + 4 cm** additional length due to overranging in the specific chest protocol.

- The data have been collected from **Picture Archiving and Communication System** of the Hospital.

- The **VirtualDoseCT** software has been utilized for the calculation of the ED and the ODs. The software uses an extensive database of lookup tables based on **Monte Carlo simulations** to determine the radiation dose for various scanning parameters and patient phantoms.

- The **95% confidence interval** of **mean ED and OD** values with and without considering the overranging effect were calculated.

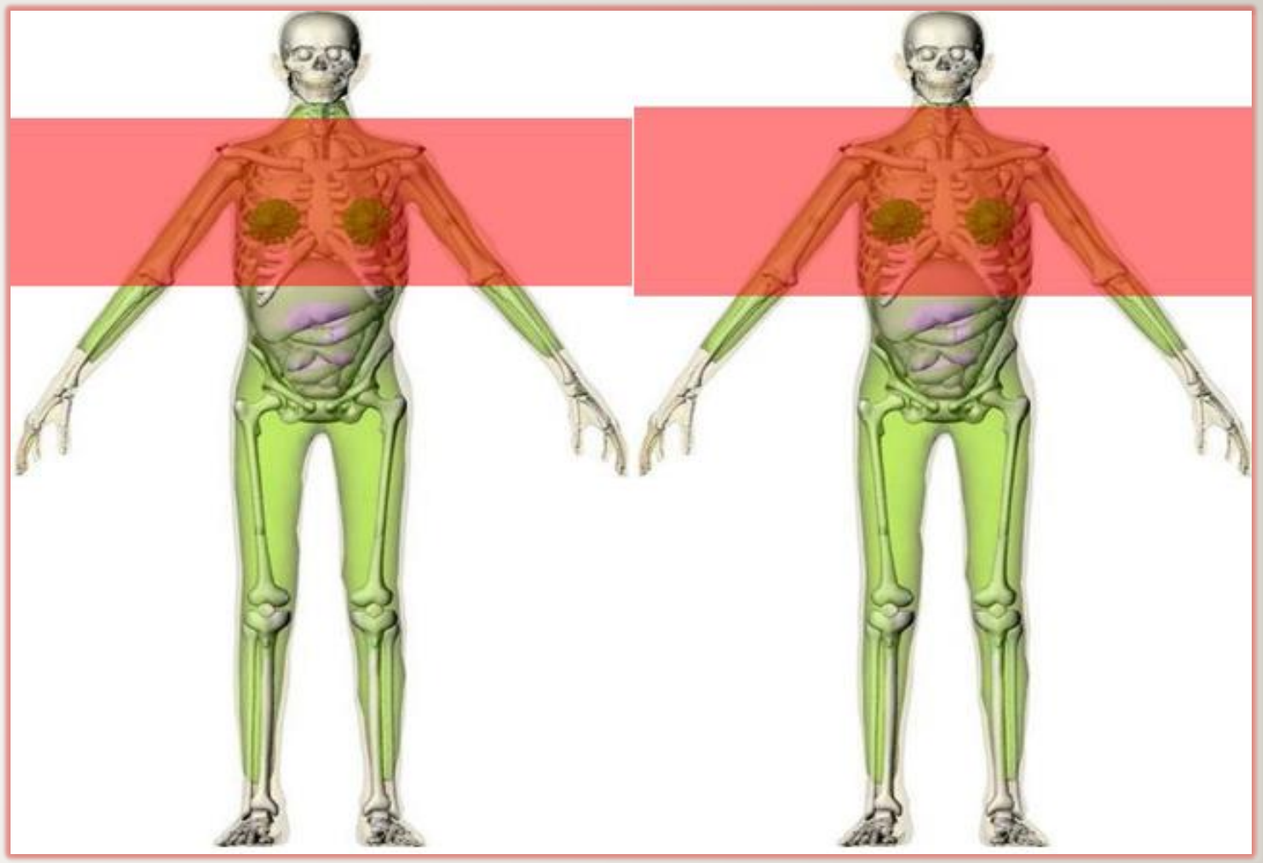
Materials & Methods (b)

VirtualDoseCT dose calculation process

1) Anatomical Data → Phantom selection
2) Scanner and protocol data
3) Selection of the scanning region
4) Dose calculation twice: with and without the O/R effect

Chest protocol parameters

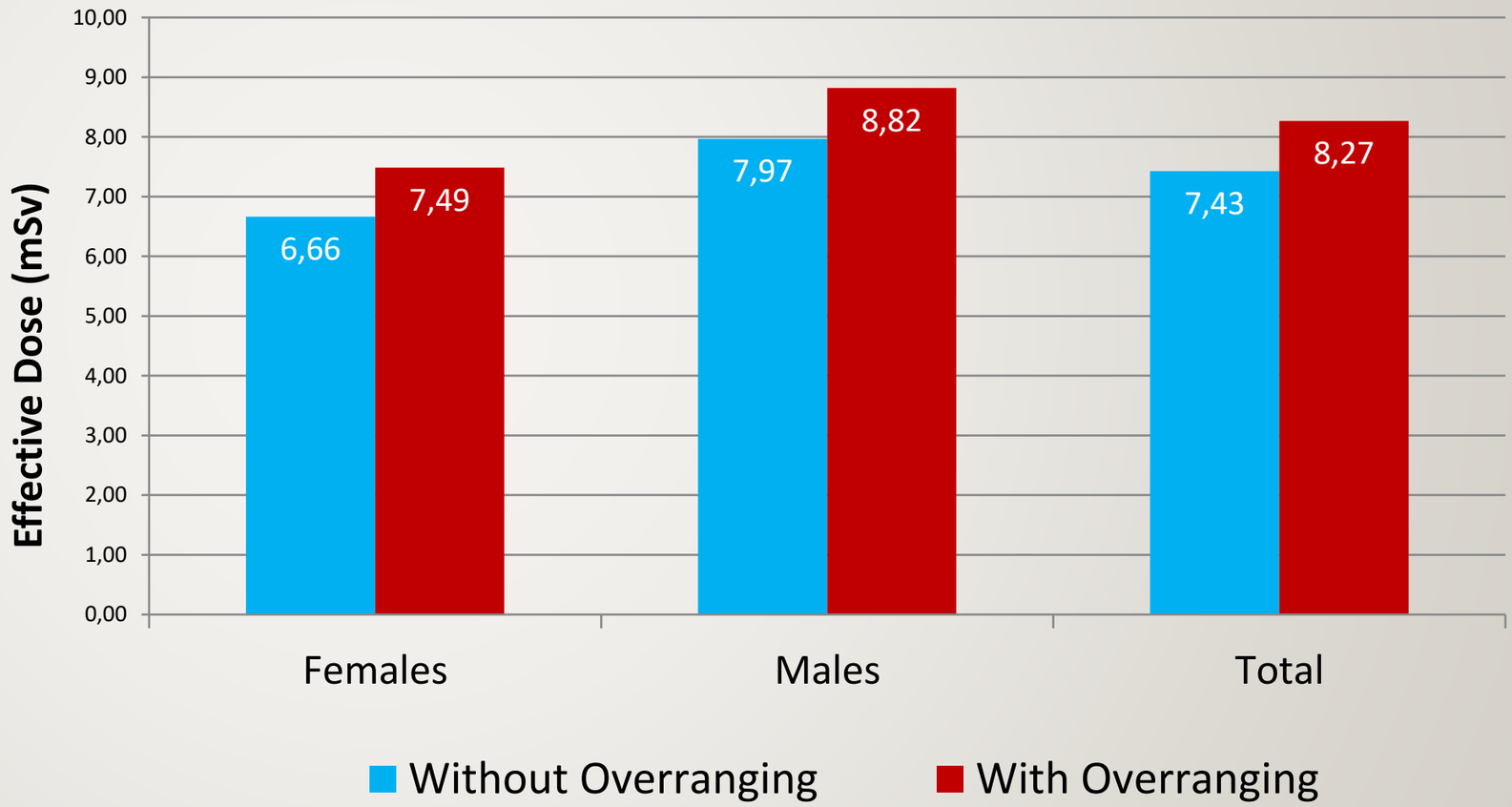
- Tube voltage: 120 kVp
- Beam collimation (N x T): (80 x 0.5) = 40 mm
- Pitch: 0.813
- O/R length: 4 cm
- Tube current (range): 75-223 mAs
- Rotation time: 0.5 s
- Automatic tube current modulation (ATCM): yes
- Nominal slice thickness: 1 mm
- Reconstruction slice thickness: 3.0 mm
- Reconstruction algorithm: iterative (AIDR)



The scanning field size without (left) and with (right) the overranging effect in the VirtualDoseCT interface, for a normal weight female

Results (a): Effective Dose

- The total sample receives **11.5% increased mean ED** due to O/R (7.43 vs. 8.27 mSv).
- **Additional 0.84 mSv** due to O/R, approximately equal to **8-10 chest radiographs.**
- The increase in ED is **greater for female (12.4%)** than for male patients (10.8%).
- The **increase in ED is significant** for the **total sample, females and males** (paired t-test $p<0.0001$).
- **Female patients receive less ED** due to their lower average BMI value.



Results (b): ODs and Organs classification

- The **percentage increase in the mean ODs** for the total sample ranges from **3.8%** for **breast** up to **63.7%** for **colon**.

- The percentage increase in the mean ODs is **significant for all organs for the entire sample, females and males** (paired t-test $p<0.0001$).

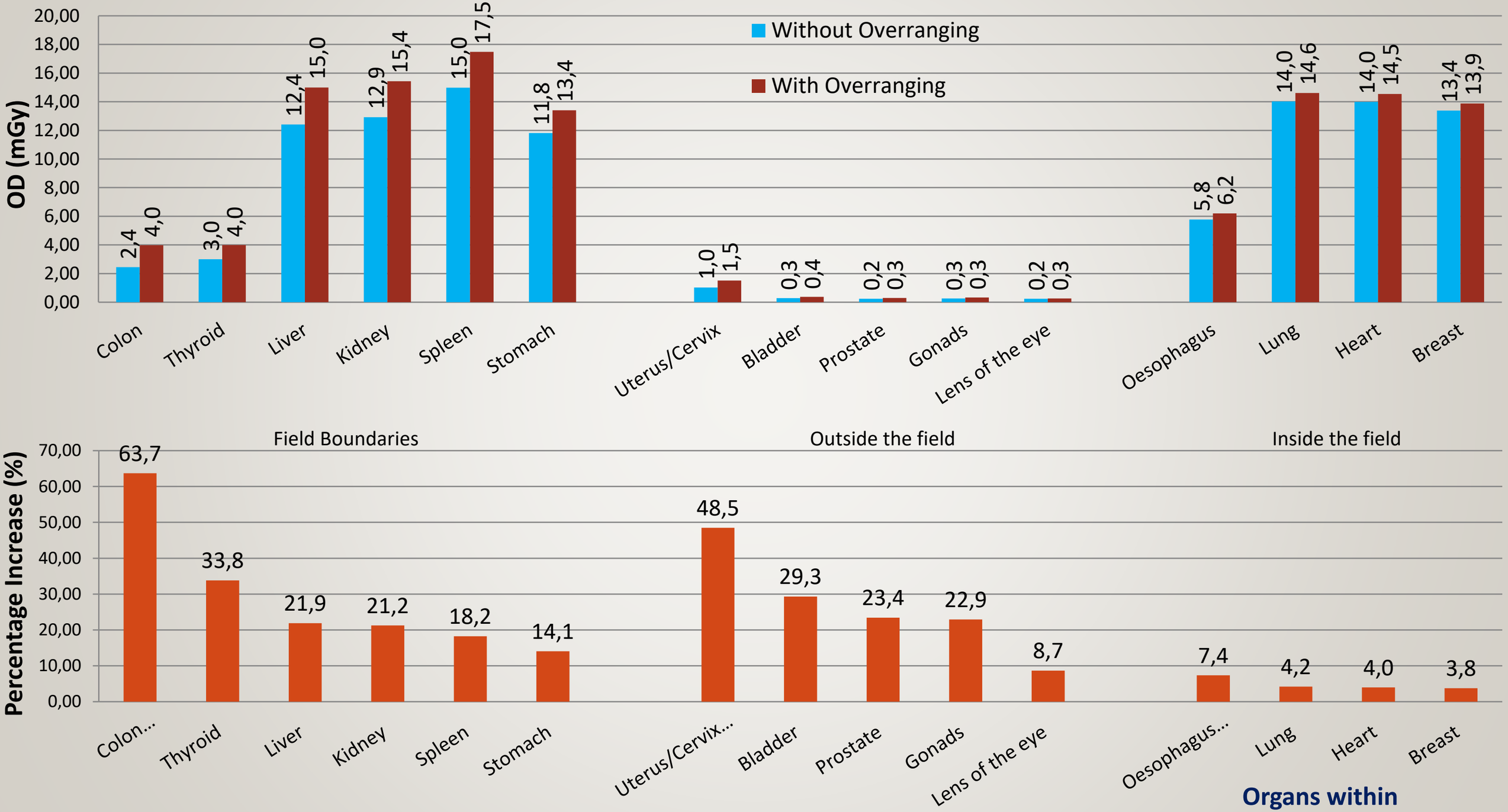
- Wide variation in the mean ODs received **according to the position of the organs** relatively to the scanning field:

  - **Organs within the irradiated field:** **Received higher amount** of radiation dose**. Small percentage increase in ODs** only from scattering radiation due to O/R.

  - **Organs lying at the field boundaries:** **Notably increased ODs** as larger volume of the organ is subjected to primary radiation when the field size increases due to O/R.

  - **Organs outside of the irradiated field:** **Small amount of ODs** from scattering radiation received but **high percentage increase** in ODs.

Results (c): ODs and percentage increase due to O/R

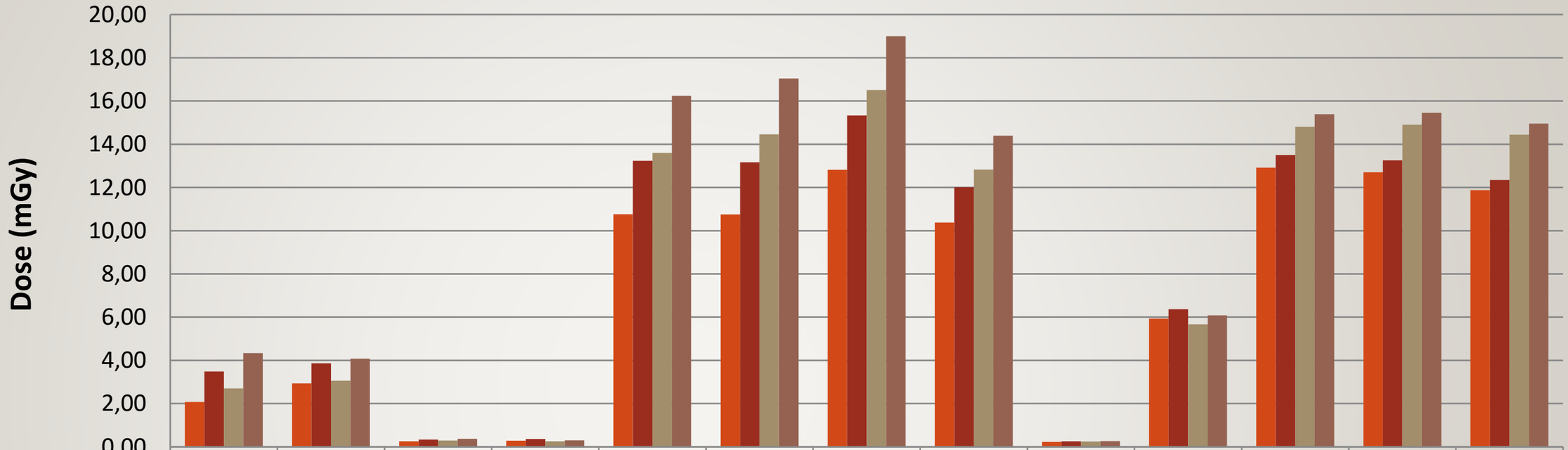


Organs at the field boundaries

Organs outside the irradiated field

Organs within irradiated field

Results (d): ODs – Males vs. Females



	Colon	Thyroid	Bladder	Gonads	Liver	Kidney	Spleen	Stomach	Lens of the eye	Oesophagus	Lung	Heart	Breast
Females Without Overranging	2,08	2,93	0,26	0,28	10,75	10,75	12,82	10,38	0,23	5,93	12,91	12,70	11,87
Females With Overranging	3,48	3,86	0,33	0,36	13,24	13,17	15,33	12,01	0,25	6,37	13,50	13,25	12,35
Males Without Overranging	2,71	3,06	0,29	0,25	13,59	14,46	16,51	12,83	0,25	5,67	14,81	14,90	14,44
Males With Overranging	4,34	4,08	0,37	0,30	16,24	17,04	19,00	14,39	0,27	6,08	15,39	15,45	14,96

- The ODs, with and without O/R **are higher for males than females for all organs**, **except** the **gonads** and the **oesophagus**.

- This difference is **significant for all ODs** with and without O/R between males and females (independent t-test, $p<0.05$) **except** from the **eye lenses** and the **thyroid** (independent t-test, $p>0.05$).

Conclusions

- Overranging in chest CT **significantly increases the patients' ED** and especially **ODs** for the organs located **at the radiation field boundaries**.

- It is necessary to **inform the technologist and medical staff** about the impact of O/R, as it usually **goes unnoticed**.

- **Careful planning** of the irradiation range is critical for **radiosensitive organs** at the **field boundaries considering the additional exposure** beyond the selected field.

- **Protocol optimization is needed** to minimize the additional O/R length by **reducing the pitch or the detector collimation** width while always maintaining the diagnostic image quality.

- Because new CT scanners have wider coverage per rotation, it is useful to **adopt innovations** (e.g., adaptive collimators) to **eliminate** the **O/R impact**.

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