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Cardiac dosimetry and radiotherapy-induced cardiotoxicity in patients with thymic malignancies

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1. Background-Aim

- Cardiac morbidity and mortality is always a concern for patients subjected to radiation therapy for tumors in the chest region such as thymic malignancies .

- The objectives of the present study were:

  (a) to determine the radiation dose received by the heart and critical cardiac substructures, and,

  (b) to assess the relevant risk for cardiotoxicity attributable to radiotherapy for malignant diseases originating from the thymus gland.

2. Materials & Methods

- Twelve patients with thymic malignancies underwent a treatment planning CT scan.
- CT-based treatment plans were generated with the 3D-CRT and IMRT techniques using 6 MV photon beams (Infinity, Elekta).
- Five-field arrangements were used for the IMRT plans. The 3D-CRT plans consisted of four to five treatment fields.
- The prescribed tumor dose was 50-54 Gy depending upon patient's disease stage with a fraction dose of 1.8-2 Gy.
- All treatment plans satisfied dose constraints recently published by NCCN [1].

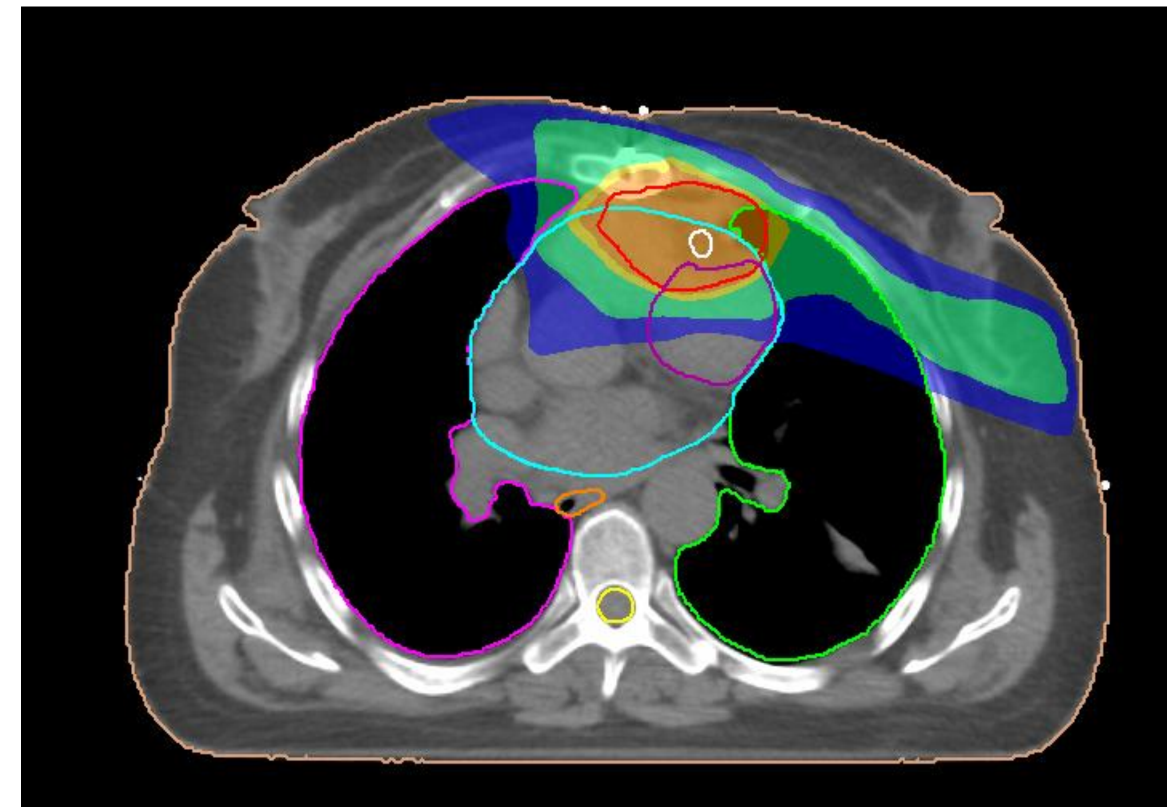

Fig. 1. Dose distribution of an IMRT plan.

2. Materials & Methods

- DVHs were used to calculate the patient-specific average dose (D_{av}) of the whole heart, left anterior descending artery (LAD) and left ventricle (LV). Critical V_{iGy} values were also found for these structures.
- The obtained dosimetric data were combined with the linear model of Darby et al. [2] to assess the risk for developing major cardiac events (MCE) such as myocardial infarction, coronary revascularization and death.
- The extracted dose data were also employed to assess the probability for radiation-induced chronic heart failure (CHF) on the basis of previously reported methodology [3] .

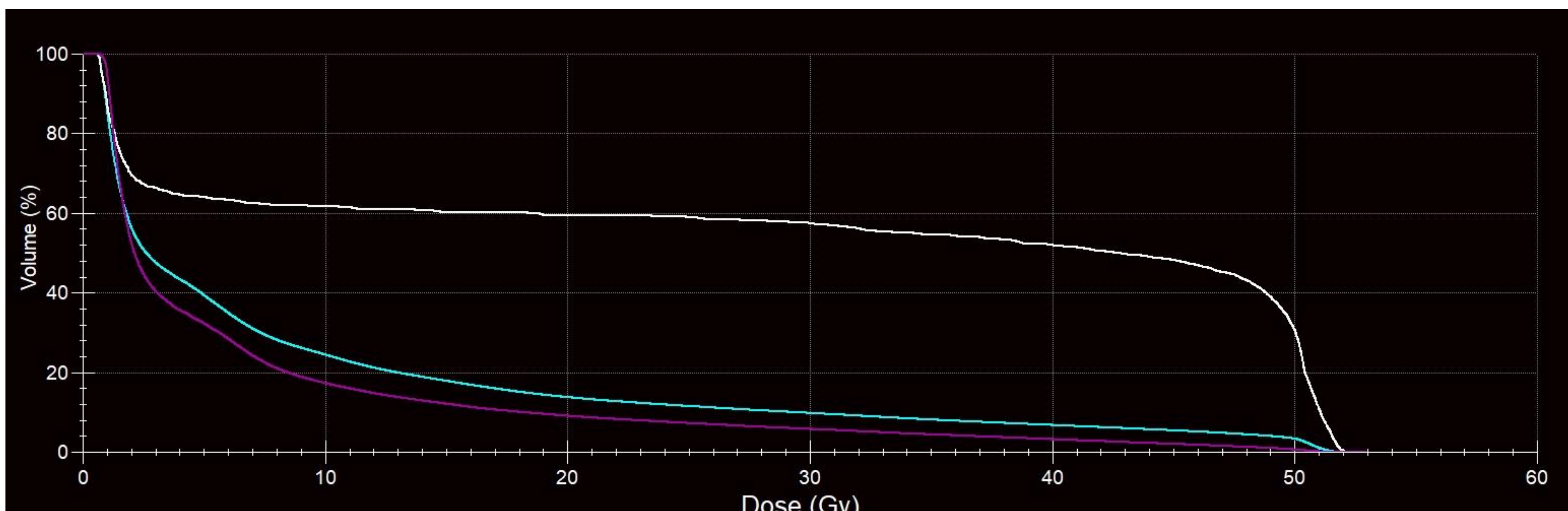

Fig. 2. DVH of the heart, LAD and LV shown in blue, white and magenta colors from an IMRT plan.

2. Materials & Methods

- Differential DVHs of the whole heart were employed to determine the normal tissue complication probability (NTCP) for pericarditis.
- The equivalent uniform dose (EUD)-based model was applied for calculating the NTCP values [4].
- All EUD and NTCP calculations were automatically carried out with the aid of an in-house software tool [5].

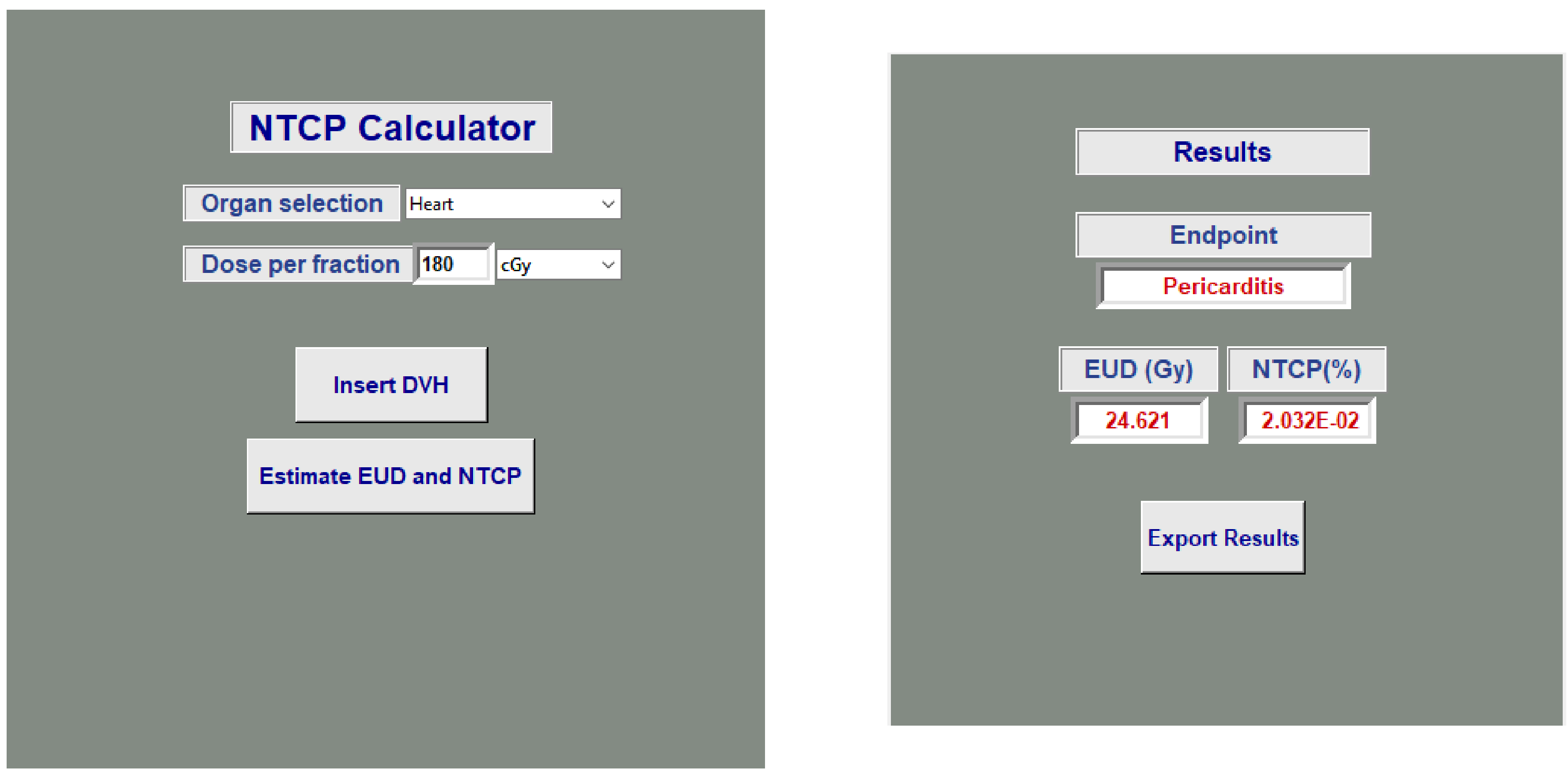

Fig. 3. Software tool for the automatic EUD and NTCP calculations.

3. Results

Cardiac dosimetry

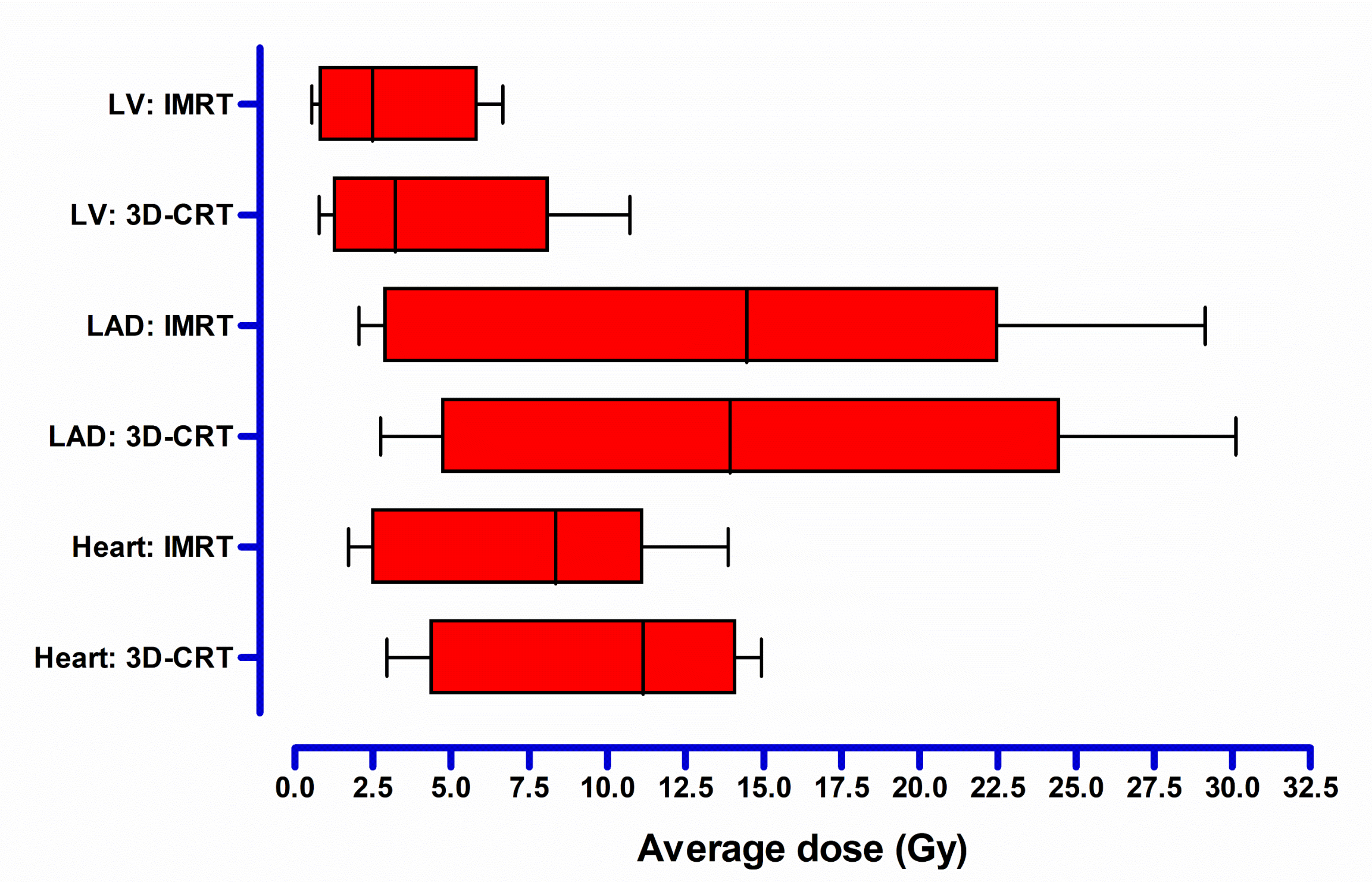

Fig. 4. Box and whisker plots presenting the D_{av} of the heart, LAD and LV from 3D-CRT and IMRT plans. The median is shown with a solid line within each box .

- The mean value of the D_{av} of the whole heart, LV and LAD from IMRT plans was 7.5±4.4 Gy, 3.0±2.3 Gy and 14.3±9.9 Gy, respectively.
- The corresponding values from 3D-CRT plans were equal to 9.5±4.7 Gy, 4.3±3.4 Gy and 15.7±10.2 Gy.

3. Results

Risk for cardiotoxicity

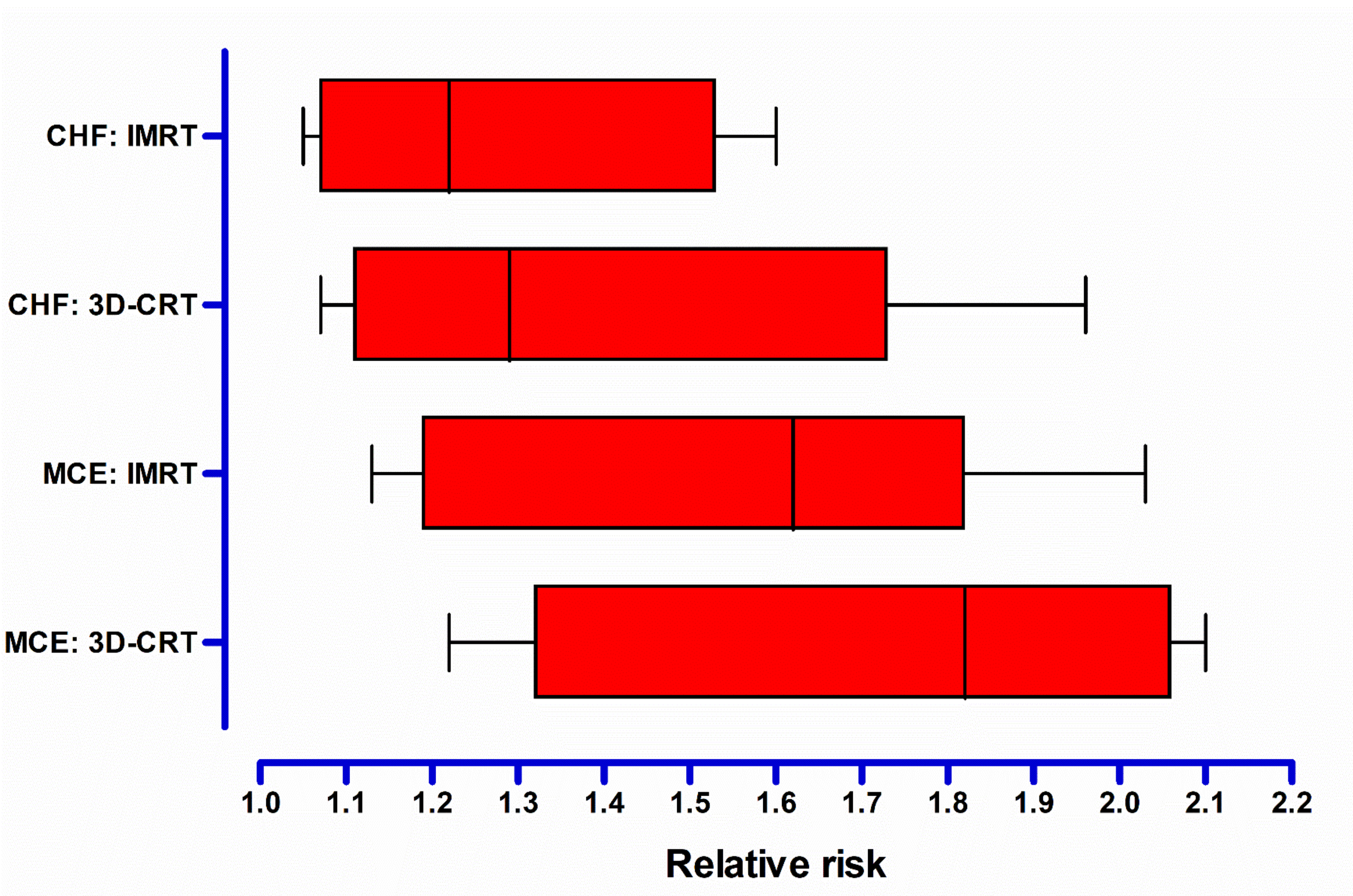

Fig. 5. Box and whisker plots presenting the risk for MCE and CHF from 3D-CRT and IMRT plans. The median is shown with a solid line within each box .

- The mean relative risk for CHF and MCE estimated by the IMRT plans was 1.5±0.3 and 1.3±0.2, respectively.
- The corresponding relative risks from 3D-CRT plans were 1.7±0.4 and 1.4±0.3.

3. Results

EUD - NTCP calculations

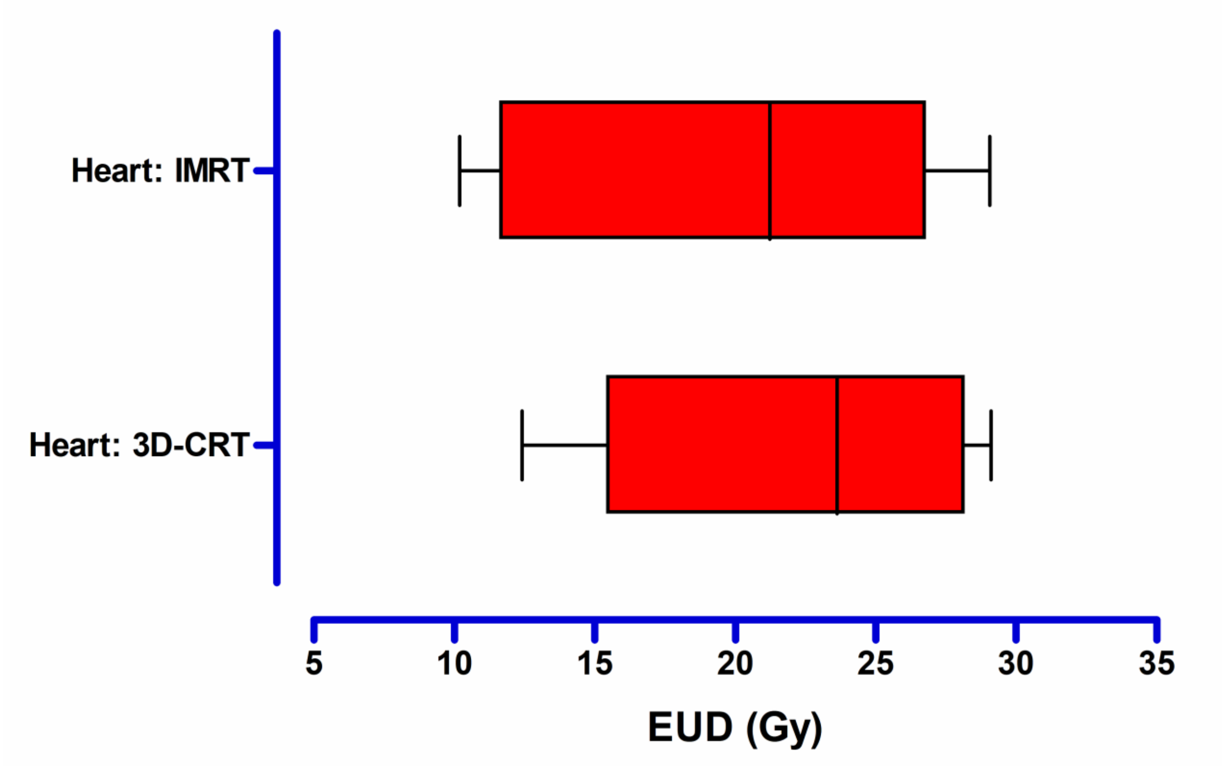

Fig. 6. Box and whisker plots presenting the EUD derived from 3D-CRT and IMRT plans.
The median is shown with a solid line within each box .

- The EUD-based model resulted in a mean NTCP for pericarditis from IMRT plans of 0.03±0.04 %.
- The corresponding NTCP derived from 3D-CRT plans was 0.05±0.06 %.

4. Conclusions

- The risk for the development of pericarditis is rather low irrespective of the radiotherapy technique applied for the management of thymic malignancies.

- Both IMRT ad 3D-CRT for thymic tumors may lead to an elevated risk for MCE and CHF. This increased risk for the appearance of adverse cardiac effects needs to be taken into account in treatment planning and in the follow-up procedures of cancer survivors.

5. References

1. National Comprehensive Cancer Network. NCCN Clinical Practice Guidelines in Oncology: Thymomas and Thymic Carcinomas, version 1. 2024.

2. SC Darby, et al. Risk of ischemic heart disease in women after radiotherapy for breast cancer. N Engl J Med 2013; 368: 987–98.

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