

Impact of Different Radiotherapy Planning Techniques on OAR Sparing in Thymoma.

Rajdip Mitra , Avik Kundu , Anjan Bera , Doli Mridha .

Abstract

Background

Thymomas, located in the anterior mediastinum, often require adjuvant radiotherapy after surgery or as the primary treatment. Because they are close to critical organs-at-risk (OARs) such as the lungs, heart, esophagus, thyroid, and spinal cord, reducing damage to normal tissues is essential.

Objective

The objective of this study was to evaluate and compare the dosimetric outcomes of three radiotherapy planning techniques—3D Conformal Radiotherapy (3DCRT), Intensity-Modulated Radiotherapy (IMRT), and Volumetric Modulated Arc Therapy (VMAT)—focusing on target coverage and OAR sparing.

Material and Methods

Eleven (11) patients with pathologically confirmed thymoma were planned using all three techniques. Planning Target Volume (PTV) coverage and doses to OARs were analysed and compared.

Results

IMRT and VMAT significantly improved PTV conformity and homogeneity compared to 3DCRT. OAR doses (lung V20, heart mean dose, spinal cord Dmax) have no significant differences. Only the mean oesophagus dose was less for IMRT and VMAT.

Conclusion

IMRT and VMAT techniques are superior to 3DCRT in terms of conformity and homogeneity. However, there is no statistically significant OAR dose sparing for these three techniques. The treatment time for VMAT is significantly less compared to IMRT because the total MU for VMAT is much lower. Therefore, to improve patient comfort during radiation, reduce intrafractional lung motion, and ensure a faster workflow, VMAT is considered superior to IMRT.

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Original Article

Author Affiliations

Rajdip Mitra , Avik Kundu , Medical Physicist cum RSO ; **Anjan Bera , Associate** Professor; **Doli Mridha** ;Senior Resident: Department of Radiotherapy, NRS Medical College and Hospital, Kolkata, West Bengal, India

Correspondence

Dr. Anjan Bera, Associate Professor, Department of Radiotherapy, NRS Medical College and Hospital, Kolkata-14, West Bengal, India.
Phone no- 8336855482
Email id- anjanbera78@gmail.com

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EMBASE, SCOPUS, IndMED , ESBCO, Google Scholar besides other national and international databases.

Introduction

Thymomas are rare tumours of the mediastinum that develop from the epithelial cells of the thymus. About 0.15 cases per one lakh of the Indian population are diagnosed with thymoma.

[1] Surgery remains the primary treatment, with complete thymectomy, i.e. complete en bloc surgical resection bis the preferred procedure. [2] The extent of resection, meaning the complete removal of the tumour mass, and the disease stage are two key prognostic factors for invasive thymoma that influence survival and local disease control. [1,2] The results from SEER data suggest that in patients with Masaoka stage II, & III, there is a possible overall survival (OS) benefit of the addition of postoperative radiotherapy (PORT). [3,4,5] The PORT had no advantage for patients with surgically resected localized disease (Masaoka stage I). Given the anatomical proximity of the thymus to vital thoracic organs, radiotherapy planning must focus on sparing OARs to minimize the risk of late toxicities. Similarly, analysis of the ITMIG database of 1263 cases who had received PORT after complete resection of stage II or III thymoma, found a seven percent improvement in ten years' Overall survival (79 % to 86%, p=0.002).[4,6]

In today's environment, using a CT-based treatment planning system is crucial to deliver a tumoricidal dose to the tumour accurately while sparing the organ at risk. Advances in radiotherapy planning, like IMRT and VMAT, enable highly conformal dose distributions. This study aims to compare these advanced techniques with traditional 3DCRT to evaluate their effects on PTV coverage and OAR dose exposure.

Materials and Methods

Patient selection

A total of 11 patients with histologically confirmed postoperative

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Keywords

Thymoma, 3DCRT, IMRT, and VMAT

cases of Masaoka stage II and III thymoma, treated with PORT in our department between 2023 and 2024, were selected. Patients' age ranges from 20-57 years, and the male-to-female ratio was 1:1.2. All patients underwent CT simulation (Somatom Definition AS Open RT) in the head-first supine position (HFS) with 3 mm slice thickness. These CT images were transferred to TPS for contouring and planning.

Contouring

Target Volumes: GTV, CTV, and PTV were delineated based on both Preoperative and postoperative imaging, as well as RTOG guidelines. A 0.5 cm margin was added to the CTV to create the PTV. Lungs (right and left), heart, esophagus, and spinal cord were contoured for each case as OAR. The total dose delivered ranges from 54 to 60 Gy in 30 fractions (#) over six weeks, with the dose per fraction ranging from 1.8 to 2 Gy. According to Quantec, the heart dose constraint V25 is listed as 10%. However, since thymoma lies anterior to the heart and pericardium, it is often challenging, if not nearly impossible, to achieve this dose constraint. Therefore, we use a different institutional dose constraint protocol that is consistent with published literature, which is $V25 \leq 25\%$.

Treatment Planning

Three radiotherapy plans were generated for each patient: 3DCRT, IMRT, and VMAT. In the 3DCRT plan, three coplanar beams with gantry angles of 0° (anterior), and two anterior oblique beams- RAO between (300°-330°) and LAO between 30°-60°-were used. An enhanced dynamic wedge with a wedge angle of 45° was applied to the RLO and LLO beams. The MLC was fitted to the PTV structure using a 0.5 cm block margin and optimized collimator jaws. For oblique beams, the spinal cord was blocked by the MLC. Similarly, seven beam angles were used for the IMRT technique: gantry angles of 30°, 75°, 120°, 180°, 240°, 285° and 330°. For the VMAT plan, two full arcs with dose modulation optimization were employed- one from 179° to 181° counter-clockwise and the other from 181° to 179° clockwise, with a collimator angle of 30°. The normal tissue objective parameters and dose constraints (upper objective, lower objective, and the mean value with the same priority during optimization) were the same for both VMAT and IMRT. For optimal movement of MLC during dose delivery, the Varian leaf motion calculator (version 15.5.12) was used. All the Plans are done with 6MV photon with Eclipse (Varian_Siemens) version-15.1 planning system, with calculation grid size-0.25cm, photon volume dose calculation model-AAA (Anisotropic Analytic Algorithm), and VMAT calculation model-PO (Photon Optimizer) algorithm was used with inhomogeneity correction, and all plans are normalized at -Target Mean. A total dose of 54 Gy/30 # over five and a half weeks was prescribed for the above-mentioned treatment plan.

Dosimetric Comparison:

The Key metrics evaluated included the following: PTV Coverage and OAR sparing. To evaluate PTV coverage, the D95%, Dmean, Conformity Index (CI), and

Homogeneity Index (HI) were used. The HI is defined as $(D2\% - D98\%) / D50\%$ and the RTOG Conformity Index is defined as $CIRTOG = VRI / TV$. Similarly, to evaluate OAR Sparing, V5, V20, Mean Lung Dose (MLD) for lung, V25, Mean Heart Dose (MHD) for the heart, Dmean for the esophagus, and Maximum Dose (Dmax) for the spinal Cord were recorded. The dose received by 2% of the PTV represents the near-maximum dose(D2%), the Dose received by 98% of the

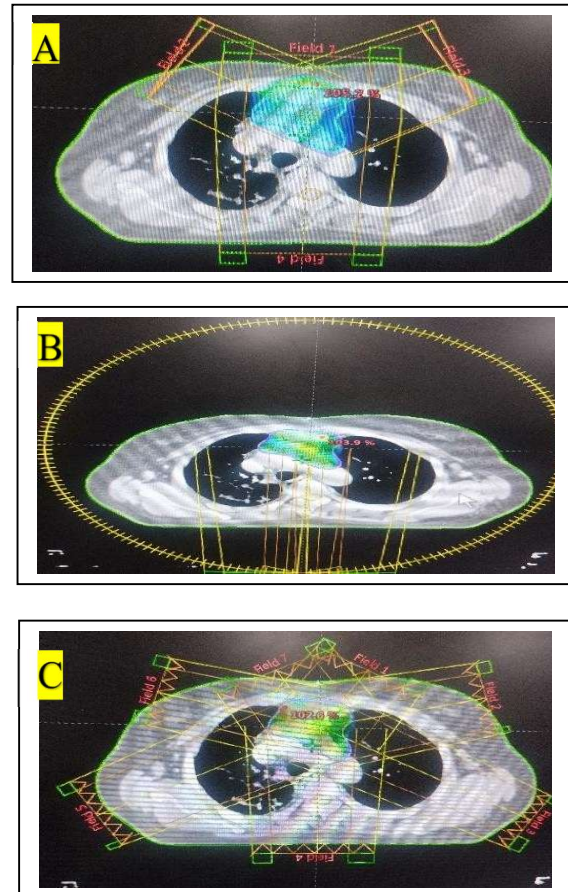


Figure illustrates the three different Radiotherapy Techniques (A) 3DCRT (B) VMAT AND (C)IMRT

PTV represents a near-minimum dose(D98%), and the Median dose to the PTV represents D50%. The volume of tissue receiving the Reference Isodose (e.g., 95% of the prescribed dose) is VRI. HI value defines the dose uniformity in PTV and CI defines the degree of dose conformity to the PTV. In an ideal scenario, the value of $HI=0$, and $CI=1$. The Paddick Conformity Index (CIPaddick) is defined as $(TVRI)^2 / (TV * VRI)$, and TVRI is defined as the Target volume or Volume of PTV covered by the Reference Isodose(e.g., 95% of the prescribed dose). In the Ideal scenario, $CIPaddick=1$, but in clinical practice, its value ranges from 0.7 to 1.

Statistical Analysis

Due to the different PTV volumes for different patients, the fluctuation of OAR doses is greater, and the data are not normally distributed and the number of patients we have taken for calculation is eleven ($n=11$), so we have

to choose a non-parametric test (Friedman test). P-value was compared across the three techniques (3DCRT, IMR, and VMAT) for the same

Results: 11 patients using the Friedman test (a non-parametric test), an alternative to repeated measures ANOVA

PTV Dosimetric Comparison: (illustrated in Table 3). The Friedman test reports the chi-square value and p-value. The p-value ≤ 0.05 signifies the result predicts statistically significant, i.e., we reject the null hypothesis (There is no significant difference of 3DCRT, IMRT, and VMAT). The doses to all OAR are comparable across three different techniques, i.e., 3DCRT, IMRT, and VMAT. No statistically significant differences were observed except for the mean OAR dose of the esophagus ($p < 0.05$), as illustrated in Figure (A)-(H). Considering

Table -1: PTV Dosimetric Comparison					
Technique	PTVD95%	CIRTOG	CIPaddick	HI	Total MU
3DCRT	93.88±0.919	1.376±0.181	0.601±0.083	0.159±0.023	242.8±15.2
IMRT	96.24±2.312	1.065±0.076	0.830±0.033	0.089±0.033	860±93.2
VMAT	95.08±1.17	1.014±0.063	0.831±0.026	0.097±0.027	437±88.23

Table -2: OAR Dose Comparison				
Volume	Parameter	3DCRT	IMRT	VMAT
Lung (Left)	V20Gy(%)	20.1±5.9	20.38±5.7	18.52±5.5
	V5Gy(%)	57.16±10.2	55.82±8.62	55.64±8.57
	MLD(Gy)	12.05±2.5	11.434±2.2	11.366±2.2
Lung (Right)	V20Gy(%)	16.42±9.1	15.46±6.7	18.04±5.5
	V5Gy(%)	59.96±16.3	58.94±15.7	57.18±13
	MLD(Gy)	11.16±2.8	10.35±2.4	11.73±1.9
Heart	V25(%)	15.64±9.6	10.34±6.92	10.32±8.01
	MHD(Gy)	9.8±5.5	7.63±3.83	7.4±1.41
Spinal Cord	Dmax	26.78±5.97	25.15±2.42	24.66±0.80
Oesophagus	Mean dose (Gy)	19.31±3.4	12.27±0.86	12.17±0.20
Thyroid	Mean dose (Gy)	3.31±1.09	2.88±0.87	3.03±0.73

Statistical Analysis Summary:

CI, HI, Dose constraints to the OAR (left lung, right lung, heart, esophagus, and thyroid) and the total MU

PTV coverage, D95%, no statistically significant differences were observed between the three techniques as illustrated in Figure 7. But CI and HI were much

better for IMRT and VMAT compared to 3DCRT. The VMAT and IMRT showed comparable target coverage with comparable CI and HI. The Only total MU of VMAT was much lower than the IMRT, which leads to better treatment efficacy.

Discussion:

As the thymoma is a rare malignancy, the knowledge regarding the treatment of thymoma is based on evidence gathered from small case series and retrospective analysis. [7]

Although surgical excision of

Of the tumour is the mainstay of treatment,

radiotherapy is commonly used as an adjuvant setting or sole modality in case of inoperability.[1]The anterior mediastinal location of thymomas places multiple

intrathoracic OARs at risk during radiotherapy[4].

The normal tissue toxicity (NTT) depends on the volume of the organ irradiated during the course of

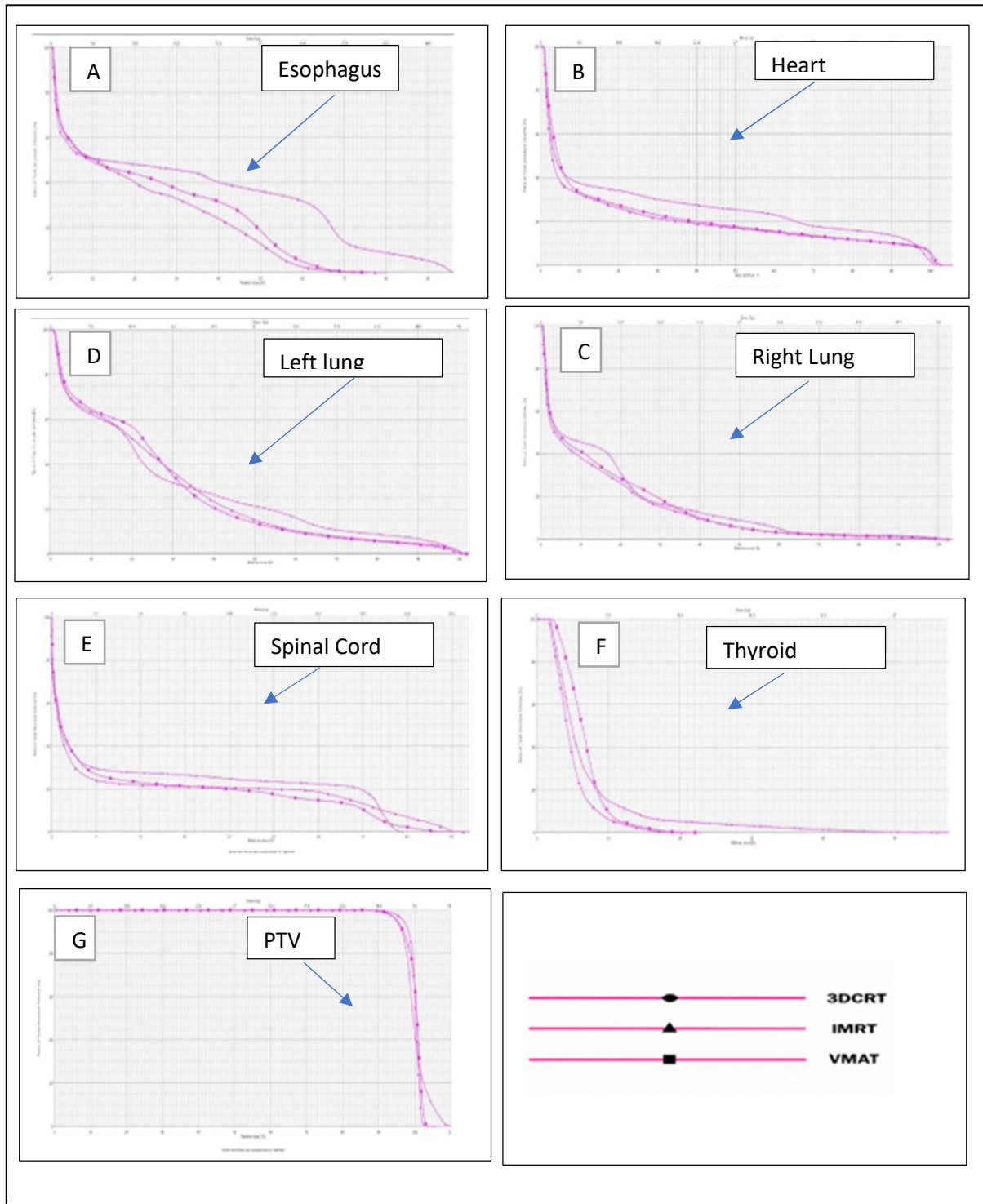
radiotherapy, and includes acute esophagitis, acute pneumonitis, and pericarditis. [5]This study aims to compare these

advanced techniques with traditional 3DCRT to evaluate their effects on PTV coverage and OAR dose exposure. Postoperative radiotherapy to the tumour bed in the thymic epithelial malignancy is usually delivered by using either 3DCRT or IMRT technique, and the clinical

Table3: Statistical Analysis Summary

Parameter	X ² value		Df(=K-1)	P value
Target Volume (PTV)				
D95%	3.6		2	0.1653
CI-RTOG	9.1			0.01057
CI-Paddick	8.4			0.015
HI	8.4			0.015
Organ at Risk (OAR)				
Spinal cord	1.2			0.54881
Heart Mean dose	4.8			0.09072
Heart V25(%)	5.2			0.07427
Left LungV20Gy(%)	1.6			0.44933
Left LungV5Gy(%)	0.4			0.81873
Left LungMLD(Gy)	0.4			0.81873
Right LungV20Gy(%)	0.4			0.81873
Right LungV5Gy(%)	1.2			0.54881
Right LungMLD(Gy)	2.8			0.2466
Esophagus(Mean dose)	8.4			0.015
Thyroid(Mean dose)	0.7			0.70469
Total MU	10			0.00674

target volume includes the whole thymic space, the tumour, its extensions, and the anterior, superior, and middle mediastinum. [8] Although the optimal PORT dose, fractionation is still to be defined, a total dose of 45-50 Gy after R0 resection, 50-54 Gy after R1 resection, with a boost to areas of likely residual disease, is recommended. [8] The conventional fractionation with a daily dose of 1.8 -2 Gy per fraction over 4- 6 weeks is recommended.



Figures illustrate dose volume histograms (DVH) for Organ at Risk (OAR) and Planning Target Volume (PTV) – [fig-A to F] in 3DCRT, IMRT and VMAT Techniques

A comparative study between IMRT vs VMAT for adjuvant radiotherapy treatment in postoperative thymoma, He DC, et al., showed that VMAT (fan-shaped) dosimetrically protects the lung and breast (in females) better than IMRT. The fan-shaped field performed better than the average and full arc field in PORT thymoma.

In another study by Haefner MF et al., comparing particle therapy vs photon therapy showed that charged particle therapy is superior to photon in reducing dose to lungs, heart, esophagus, spinal cord, and breast while providing optimal target coverage. [9] In our study, IMRT and VMAT provide superior PTV coverage and better sparing of the lungs, heart,

esophagus, and spinal cord compared with 3DCRT. VMAT, in particular, shows advantages in delivery efficiency, reduced treatment time, and marginally improved dosimetry. However, both advanced techniques should be considered depending on institutional resources and clinician preference.

Limitations:

Apart from retrospective design and small sample size, the limitations of our study is the inclusion of only adjuvant RT (PORT) cases, and the definitive RT or salvage RT cases were not included.

Conclusions

In this dosimetric analysis of thymoma radiotherapy, all organs-at-risk (OARs) demonstrated comparable dose distributions across 3DCRT, IMRT, and VMAT techniques, except for the oesophagus dose, where a mean dose variation was observed. However, no statistically significant differences in OAR dose were

found between VMAT IMRT. While VMAT and IMRT provided similar dosimetric outcomes, i.e., PTV coverage with CI and HI, VMAT significantly reduced treatment delivery time compared to IMRT. This suggests that VMAT may be the more efficient modality for thymoma treatment, offering comparable dose conformity and OAR sparing with improved clinical workflow efficiency.

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Conflict of interest- There are no conflicts of interest.

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References

- Rathod S, Munshi A, Paul S, Ganesh B, Prabhaskar K, Agarwal JP.** Thymoma: first large Indian experience. *Indian J Cancer.* 2014 Apr-Jun;51(2):109-12. doi: 10.4103/0019-509X.138144. PMID: 25104189. PMC5257334.
- Zhu G, He S, Fu X, Jiang G, Liu T.** Radiotherapy and prognostic factors for thymoma: a retrospective study of 175 patients. *Int J Radiat Oncol Biol Phys.* 2004 Nov 15;60(4):1113-9. doi: 10.1016/j.ijrobp.2004.05.013. PMID: 15519782.
- Forquer JA, Rong N, Fakiris AJ, Loehrer PJ Sr, Johnstone PA.** Postoperative radiotherapy after surgical resection of thymoma: differing roles in localized and regional disease. *Int J Radiat Oncol Biol Phys.* 2010 Feb 1;76(2):440-5. doi: 10.1016/j.ijrobp.2009.02.016. Epub 2009 May 8. PMID: 19427738.
- Shirvani SM, Gomez DR, Fuller CD, and Thomas CR Jr.** Mediastinum and Trachea. In: Halperin EC, Wazer DE, Perez CA, and Brady LW, editors. *Principles and Practice of Radiation Oncology.* Philadelphia, PA: Lippincott Williams & Wilkins; 2019. p. 3666-3779.
- Bogart JA.** Thoracic neoplasms. In: Tepper JE, Foote RL, Michalaski JM, editors. *Gunderson & Tepper's clinical radiation oncology.* Philadelphia, PA: Elsevier; 2021. P. 817-824.
- Rimner A, Yao X, Huang J, Antonicelli A, Ahmad U, Korst RJ, et al.** Postoperative Radiation Therapy Is Associated with Longer Overall Survival in Completely Resected Stage II and III Thymoma-An Analysis of the International Thymic Malignancies Interest Group Retrospective Database. *J Thorac Oncol.* 2016 Oct;11(10):1785-92. doi: 10.1016/j.jtho.2016.06.011. Epub 2016 Jun 23. PMID: 27346413; PMCID: PMC5257334.
- Kumar N, Kumar R, Bera A, Ghoshal S, Kapoor R, Radotra BD, Sharma SC.** Thymoma: clinical experience from a tertiary care institute from North India. *J Cancer Res Ther.* 2013 Apr-Jun;9(2):235-9. doi: 10.4103/0973-1482.113364. PMID: 23771365.
- Girard N, Ruffini E, Marx A, Faivre-Finn C, Peters S; ESMO Guidelines Committee.** Thymic epithelial tumours: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann Oncol.* 2015 Sep;26 Suppl5:v40-55. doi: 10.1093/annonc/mdv277. PMID: 26314779.
- He DC, Zhu ZJ, Zhang XY, Zhang Y, Hong J, Shi TT, et. al.** Dosimetric analysis of postoperative radiotherapy for thymoma. *Cancer Radiother.* 2022 Jun;26(4):537-541. doi: 10.1016/j.canrad.2021.07.037. Epub 2021 Oct 30. PMID: 34728117.
- Haefner MF, Verma V, Bougattf N, Mielke T, Tonndorf-Martini E, König L, et. al.** Dosimetric comparison of advanced radiotherapy approaches using photon techniques and particle therapy in the postoperative management of thymoma. *Acta Oncol.* 2018 Dec;57(12):1713-1720. doi: 10.1080/0284186X.2018.1502467. Epub 2018 Sep 28. PMID: 30264630.