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Research Article

Bowman's Capsule" Isodose Distribution in Orbital Lymphoma: Dosimetric Considerations and Planning Strategies for Radiation Oncologists and Physicists

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Abstract: Radiation therapy is a crucial component in the management of orbital lymphoma, requiring precise planning to maximise tumor control while minimising radiation exposure to critical ocular structures. This report provides a systematic approach to radiotherapy planning, covering key aspects such as dose selection, immobilisation techniques, computed tomography- magnetic resonance imaging fusion for target delineation, organ-at-risk (OAR) sparing, and treatment execution. A special emphasis is placed on achieving the characteristic "Bowman's Capsule" isodose distribution, which ensures optimal dose delivery while effectively sparing the ipsilateral lens and optic structures. Various radiotherapy techniques, including Three-Dimensional Conformal Radiotherapy (3D-CRT), Intensity-Modulated Radiotherapy (IMRT), and Volumetric Modulated Arc Therapy (VMAT), are compared, highlighting their advantages and limitations. The guide also outlines quality assurance protocols, treatment verification strategies, and follow-up recommendations to monitor for treatment-related complications and disease recurrence. By integrating modern radiotherapy techniques and image-guided verification, treatment precision and safety can be enhanced, reducing long-term morbidity. This technical report is designed to aid radiation oncology residents in developing expertise in orbital lymphoma treatment planning, ensuring effective and evidence-based clinical practice.

Keywords: Bowman's Capsule, Isodose Distribution, Orbital Lymphoma, Radiotherapy Planning, Simulation, Treatment Delivery .

INTRODUCTION

Orbital lymphoma is a primary extranodal lymphoma, comprising 1-2% of all non-Hodgkin's lymphomas and 7-8% of extranodal lymphomas.[1] It predominantly affects individuals in their fifth to eighth decade of life.[2] The disease typically presents unilaterally, with bilateral involvement in 10-15% of cases. [2,3] Common sites include the orbit (40%), conjunctiva (35-40%), lacrimal gland (10-15%), and eyelid (10%). [3,4]

Most cases manifest as an insidiously progressive, painless orbital mass, often involving adjacent adnexal structures. Depending on the anatomical location of the lesion, associated symptoms may include ptosis, diplopia, proptosis, and restricted ocular motility. [2,5] The extent of local disease is evaluated using computed tomography (CT) and/or magnetic resonance imaging (MRI) of the orbit. A definitive diagnosis is established through histopathological analysis of an incisional or excisional biopsy, with extranodal marginal zone lymphoma being the most prevalent histological subtype, followed by follicular lymphoma, diffuse large B-cell lymphoma and mantle cell lymphoma. Staging is performed using the Ann Arbor staging system or the Tumour Node Metastasis classification. [4,6]

Radiation therapy plays a pivotal role in localised orbital lymphoma management. This technical report delineates the stepwise radiation planning process from simulation to treatment execution.

Indications for Radiation in Orbital Lymphoma:

- Early-stage (I-IIE) and indolent lymphoma: Radiation therapy alone is the standard treatment.
- Advanced-stage (III-IV) orbital lymphoma: Radiotherapy is employed as consolidation therapy following induction chemotherapy, irrespective of complete or partial response.[7]

Radiation Dose Selection:

According to the International Lymphoma Radiation Oncology Group (ILROG) guidelines [7], the recommended radiotherapy doses are as follows:

- Early-stage/low-grade indolent lymphoma: 24-25 Gy (1.5-2 Gy/fraction)
- High-grade diffuse large B-cell lymphoma: 30-36 Gy (2 Gy/fraction)
- Residual disease post-chemotherapy: 40-45 Gy

More recently, the ILROG 2020 article offers updated consensus guidance on field definitions and dose

constraints [8], while outcome series published between 2021 and 2024, including a phase 2 trial of response-adapted ultra-low-dose Radiotherapy [9] and a 2-year retrospective cohort showing 95% complete response with 4 Gy total dose [10] expand the evidence base for reduced-dose strategies.

Radiotherapy Planning Details:

1. CT Simulation:

1A. Patient Positioning:

The patient is positioned supine with the neck in a neutral position to ensure reproducibility during treatment. Head immobilization is achieved using either a three-clamp thermoplastic mask or a stereotactic mask with eye apertures to prevent the bolus effect [Figure 1 A, B].

1B. Ocular Immobilisation:

Ocular immobilisation is a critical component of radiotherapy planning for orbital lymphoma, ensuring treatment accuracy and minimising motion. Various techniques can be utilised:

- Retro-bulbar or peri-bulbar block: This invasive approach provides effective immobilisation but is cumbersome for patients due to the requirement for daily administration throughout the radiation course.
- Eyelid fixation using adhesive tapes [Figure 1C]: A simple, non-invasive technique that restricts ocular movement.
- Binocular vision guidance using a paper frill [Figure 1D]: The patient is instructed to maintain fixation through a central aperture, a convenient and patient-friendly approach for daily immobilisation.

1C. CT Simulation Image Acquisition:

During CT simulation for treatment planning, fiducial markers are positioned on the thermoplastic mask, ensuring accurate alignment with room laser systems.

- Intravenous contrast is administered at 1 mg/kg body weight to enhance anatomical visualisation.
- CT imaging parameters: Scanning extends from the vertex to the neck, utilising a 1 mm slice thickness as outlined in Table 1.
- MRI for brain and orbit: An additional MRI scan is performed in the same immobilization setup, following the MRI imaging protocol described in Table 1.

Both CT and MRI datasets are transferred to the radiotherapy treatment planning system in the radiation oncology department for target volume and organ-at-risk (OAR) delineation.

MATERIALS AND METHODS

2. Target Delineation:

The acquired MRI sequences are fused with planning CT images using an auto-fusion technique, facilitated by contouring anatomical landmarks such as the lens, basilar artery, and sinuses for precise alignment. This fusion enhances the delineation of both the target volume and organs at risk (OARs).

- The Gross Tumor Volume (GTV) is delineated based on all visible tumor regions on the planning CT scan [Figure 2A-C]. The fused MRI images are reviewed to assess the exact disease extent.
- The Clinical Target Volume (CTV) encompasses the GTV along with the entire orbit, superior orbital fissure, inferior orbital fissure, optic foramen, foramen rotundum, and ipsilateral cavernous sinus [Figure 3A-E]. The final CTV delineation is presented in Figure 3F.
- The Planning Target Volume (PTV) is defined according to institutional protocols. At the author's institution, where a stereotactic thermoplastic mask is utilized for immobilization, a 3 mm margin is added to the CTV to generate the PTV [Figure 3G].

3. Critical OARs Delineation:

The critical OARs requiring meticulous contouring include: bilateral eyes, anterior chambers (both sides), lenses, optic nerves, optic chiasm, brainstem and cochlea. The cochlea is contoured using bone window settings, whereas the remaining OARs - including the eyes, anterior chambers, lenses, brainstem, optic chiasm, and optic apparatus - are delineated with the assistance of fused MRI images for optimal accuracy.

4. Radiation Planning Techniques:

The commonly employed techniques for radiation planning include Three-Dimensional Conformal Radiotherapy (3D-CRT), Intensity-Modulated Radiotherapy (IMRT), and Volumetric Modulated Arc Therapy (VMAT), as illustrated in Figure 4A-C.

5. Plan Evaluation Parameters:

The clinical objectives for target volume coverage are as follows:

- 100% of the GTV should receive 100% of the prescribed dose (PD).
- 99% of the CTV should receive at least 98% of the PD.
- 98% of the PTV should receive a minimum of 95% of the PD.

Additionally, radiation doses to critical OARs - including the eyes, anterior chambers, lenses, brainstem, optic chiasm, and optic apparatus - must be maintained within acceptable tolerance limits to minimize toxicity.

A comparative study of 3DCRT, IMRT and VMAT plans is depicted in Table 2 and it clearly showcases that the target coverage and OARs dose constraints are best achieved with VMAT plans. Also the VMAT technique provides an optimal "Bowman's Capsule" - like isodose distribution, effectively sparing the ipsilateral lens [Figure 4D]. A comparative analysis of these three techniques is presented in Table 3.

6. Quality Assurance (QA) and Dry Run:

Quality assurance (QA) protocols include fundamental checks such as mechanical isocenter verification, which is conducted using the Winston-Lutz test, and point dose verification, ensuring a positional tolerance of 1 mm.[11] A dry run is performed prior to treatment initiation and involves:

- Setup reproduction to confirm accurate patient positioning.
- Isocenter verification to ensure precise radiation delivery.
- Clinical verification of each treatment field, assessing beam clearance, multi-leaf collimator (MLC) interlock issues, and potential Monitor Unit (MU) discrepancies.

Upon successful completion of the dry run, immobilisation devices are marked for treatment reproducibility.

7. Treatment Delivery:

On the day of treatment, the patient is positioned identically to the CT simulation setup, using the same immobilisation mask. Cone-beam CT (CBCT) is performed with the patient on the treatment couch to verify alignment. Any required CT-based corrections are applied before initiating radiation delivery.

Patients should be monitored weekly during the treatment course to assess for acute toxicities, including dry eye, blepharitis, keratitis, and conjunctivitis, which should be managed conservatively.[12]

RESULTS

After treatment completion, regular follow-up is essential to monitor for treatment-related complications, recurrence, and secondary malignancies. The recommended follow-up schedule is:

- Every 3 months for the first 2 years
- Every 6 months for the next 3 years
- Annually thereafter for lifelong surveillance

During each follow-up visit, the evaluation includes:

- Comprehensive history-taking and physical examination
- Radiological imaging as indicated

Long-term surveillance focuses on the early detection of late complications such as xerophthalmia, keratitis, corneal ulceration, cataracts, and neovascular glaucoma [12], as well as identifying tumour recurrence or secondary malignancies.

Future directions include multicentric prospective validation of VMAT “Bowman’s Capsule” isodose plans, integration of advanced eye-tracking IGRT technologies to further reduce intra-fraction motion, and systematic assessment of long-term visual outcomes to fully establish the clinical value of this approach.

Key Considerations for Radiation Planning in Orbital Lymphoma:

- Select an appropriate ocular immobilisation technique based on institutional resources and patient comfort.
- Ensure treatment is delivered with the eyes open to maintain accuracy in dose distribution.
- Utilise a stereotactic thermoplastic mask, if available, to enhance head immobilisation and minimize PTV margins.
- Opt for a radiation plan that provides optimal target coverage while ensuring dose conformity.
- Prioritise the sparing of contralateral optic structures to reduce radiation-induced toxicity.
- If the ipsilateral eyeball is uninvolved, choose a plan that minimises radiation exposure to the ipsilateral lens and anterior chamber.
- Optimise dose deposition within the vitreous humour to achieve the characteristic "Bowman’s Capsule" -like isodose distribution.
- Consider planning with a flattening filter-free beam, if available, to reduce overall treatment time.
- Employ non-coplanar beam arrangements to achieve the desired dose distribution and enhance normal tissue sparing.
- Perform daily CBCT imaging for setup verification to ensure precise treatment delivery.

Table 1: Computed tomography and magnetic resonance imaging imaging protocols utilised for radiotherapy simulation in orbital lymphoma.

CT* protocol for radiotherapy simulation	
Patient position	Supine
	Done using 3 clamp thermoplastic mask
Intravenous contrast	1 mg/kg
CT scan	Taken from the vertex to the neck
Slice thickness	1-mm
MRI protocol for radiotherapy simulation	

3D FSPGR† sequence	Look for normal anatomy
T1/T2/FLAIR‡ sequence	Helps in target volume delineation
FIESTA§ sequence	Helps in visualisation of cochlea, brainstem and cranial nerves
Matrix	512 x 512
Slice thickness	1 mm
Gap	No
Tilt	No
Neck position	Neutral
Field of view	Should include body contour, nose, eye, and skull

*CT: Computed Tomography,
†3D FSPGR: 3 Dimentional Fast Spoiled Gradient Echo,
‡ FLAIR: Fluid Attenuated Inversion Recovery,
§ FIESTA: Fast Imaging Employing Steady State Acquisition

Table 2: Comparative planning evaluation of target and organs at risk dose constraints of three techniques in a right sided orbital lymphoma.

	3D CRT*	IMRT†	VMAT‡
GTV D100%	91.6%	99.57%	99.57%
PTV D95%	95.52%	95.91%	95.54%
Right eye D2cc	32.55Gy	32.75Gy	32.73Gy
Left eye D2cc	9.73Gy	12.99Gy	8.94Gy
Anterior chamber Dmax	31.78Gy	30.14Gy	25.21Gy
Right lens Dmax	32.08Gy	10.30Gy	8.16Gy
Brainstem D2cc	25.09Gy	21.32Gy	16.35Gy
Optic chiasm Dmax	31.02Gy	31.52Gy	31.02Gy
Right optic nerve Dmax	11.29Gy	13.18Gy	12.31Gy
Left cochlea Dmean	7.09Gy	6.55Gy	1.95Gy
Right cochlea Dmean	18.10Gy	7.77Gy	7.56Gy

*3DCRT: 3 Dimensional Conformal Radiotherapy, †IMRT: Intensity Modulated Radiotherapy, ‡VMAT: Volumetric Modulated Arc Therapy, §OARs: Organs at Risk.

Table 3: Comparative analysis of different radiation planning techniques for orbital lymphoma based on the data from Table 2.

	3D CRT*	IMRT†	VMAT‡
Planning	Simple plan	Complex plan	Complex plan
Precision	Less precise	More precise	High precision
Dose Distribution	Less conformal	More conformal compared to 3DCRT	Best dose distribution
Low dose spillage	Least of all	More than 3DCRT but lower than VMAT	High
OAR§ dose	High	Less as compared to 3DCRT	Least of all
Treatment time	Quicker	Longer	Faster
Treatment cost	Cost effective	Expensive	Expensive

*3DCRT: 3 Dimensional Conformal Radiotherapy, †IMRT: Intensity Modulated Radiotherapy, ‡VMAT: Volumetric Modulated Arc Therapy, §OARs: Organs at Risk.

Figures:
Figure 1 A, B: Patient immobilisation in supine position using a three-clamp thermoplastic mask with eye openings to prevent bolus effect; C: Eyelid fixation utilising adhesive tapes for ocular stabilization; D: Ocular immobilisation technique employing a binocular vision approach, where a paper frill is used to guide the patient's gaze through a central aperture, facilitating consistent eye positioning during radiotherapy.

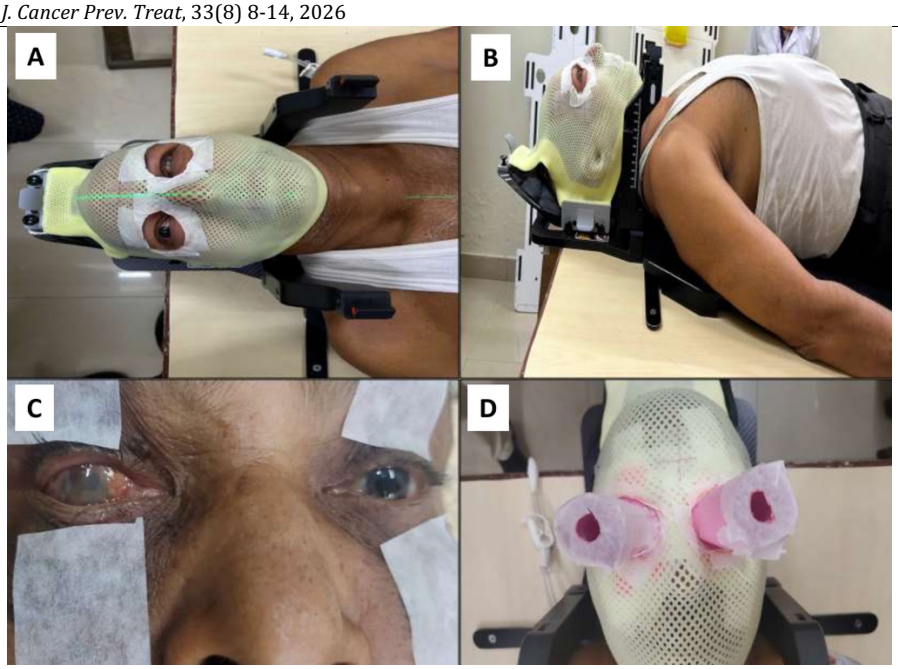


Figure 2: Representation of Gross Tumor Volume (GTV) delineation in red across different imaging planes: (A) axial, (B) coronal, and (C) sagittal views.

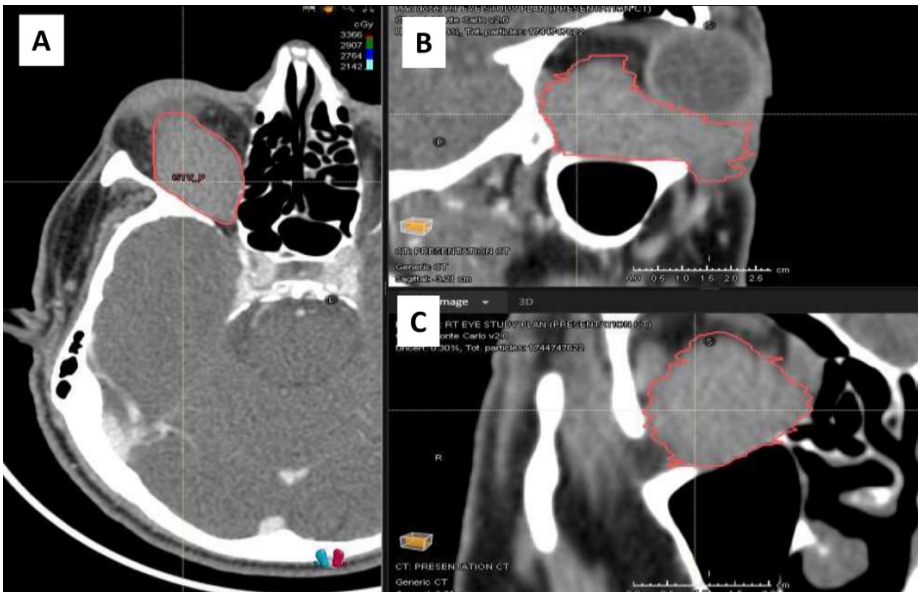


Figure 3: Illustration of Clinical Target Volume (CTV) delineation, encompassing key anatomical structures: (A) superior orbital fissure (deep green), (B) inferior orbital fissure (orange), (C) optic foramen (pink), (D) foramen rotundum (yellow), and (E) cavernous sinus (violet). The final CTV is outlined in green (F), while the Planning Target Volume (PTV) is delineated in blue.

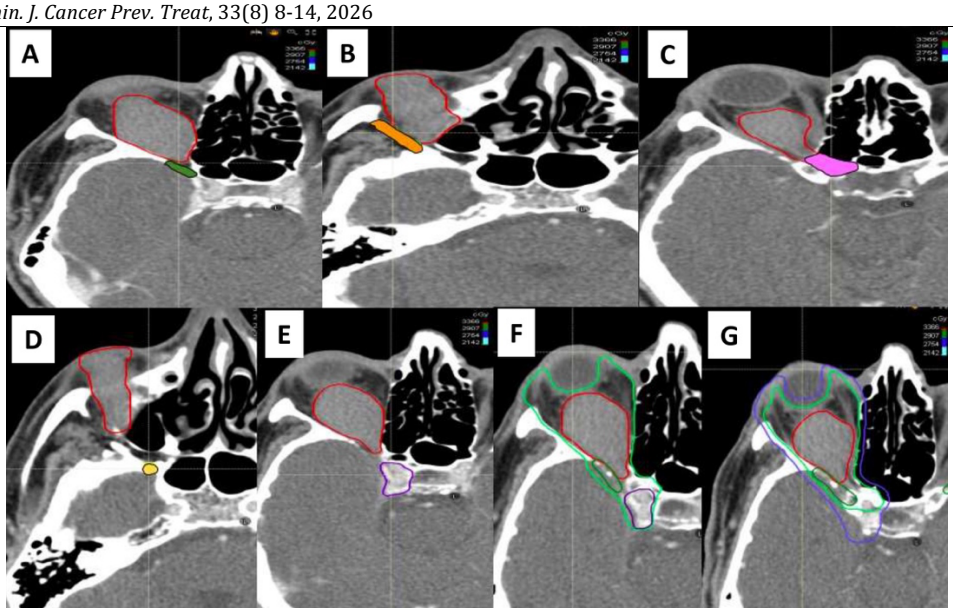
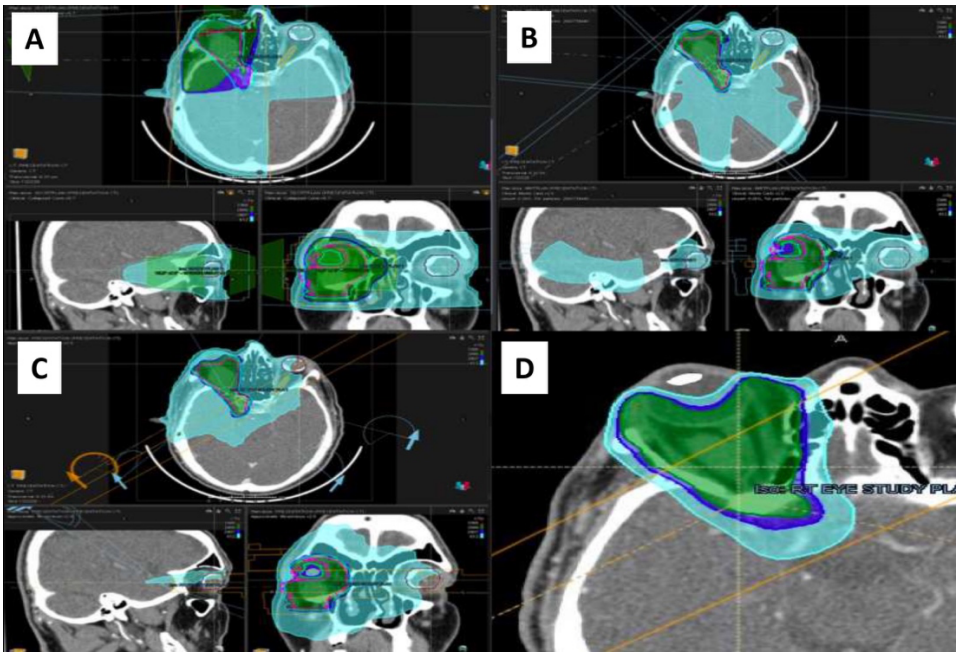


Figure 4: Representation of radiotherapy treatment planning techniques for orbital lymphoma: (A) Three-Dimensional Conformal Radiotherapy (3D-CRT), (B) Intensity-Modulated Radiotherapy (IMRT), and (C) Volumetric Modulated Arc Therapy (VMAT). (D) Demonstrates the characteristic "Bowman's Capsule"-like isodose distribution, effectively sparing the ipsilateral lens (white).



Conclusion

Radiotherapy is a key modality in the management of orbital lymphoma, requiring precise planning to optimise tumour control while preserving critical ocular structures. This guide outlines a systematic approach to treatment planning, emphasising target delineation, organ-at-risk sparing, and the "Bowman's Capsule" isodose distribution. Advances in IMRT, VMAT, and image-guided verification have enhanced treatment accuracy and reduced toxicity. Radiation oncology residents must adhere to evidence-based dose recommendations, immobilisation techniques, and quality assurance protocols for optimal outcomes. Regular follow-up is essential to monitor for complications, recurrence, and secondary malignancies, ensuring long-term patient well-being.

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