Case report

Impact of Seroma Volume Reduction on Dosimetry in Whole Breast Radiation Therapy: A Case Study and Adaptive Planning Considerations

.

ABSTRACT

Aims: To explore the impact of seroma volume reduction on dosimetry during whole breast radiation therapy (WBRT) and evaluate the significance of adaptive planning.

Presentation of Case: A 71-year-old female with left breast invasive carcinoma underwent lumpectomy and radiotherapy. Initial CT (CT1) showed a seroma cavity, and a second CT (CT2) five weeks later documented a 65% seroma volume reduction (from 217 c.c. to 75 c.c.). Five radiotherapy techniques were evaluated: two-field conventional, three-field conventional, forward IMRT, inverse IMRT, and VMAT.

Discussion: The significant reduction in seroma volume affected dosimetry, highlighting the importance of adaptive planning. Inverse IMRT and VMAT showed better high-dose coverage but higher dose variability compared to conventional techniques. Regular imaging and adaptive planning are crucial to accommodate anatomical changes and ensure accurate dose delivery.

Conclusion: Accounting for seroma volume changes in WBRT planning is essential for optimizing treatment accuracy and patient outcomes. Advanced radiotherapy techniques combined with adaptive planning can significantly improve dosimetric precision and patient safety.

Keywords:Breast cancer, radiation therapy, seroma, dosimetry, breast-conserving treatment, adaptive planning

1. INTRODUCTION

Breast-conserving treatment, which involves tumor excision followed by post-operative adjuvant radiation therapy, aims to preserve the breast while ensuring the remaining tissue is free of cancerous cells. However, the formation of seromas—fluid-filled cavities at the tumor bed—complicates radiation planning. Seromas can significantly alter the breast's shape and volume, posing a challenge in radiation therapy by shifting the target area, potentially leading to underdosing of the tumor bed or overdosing surrounding healthy tissue.[1] [2] The significant 65% volume reduction of seroma was found in this case. This study aims to explore the impact of seroma volume changes on dosimetry during WBRT and evaluate how different treatment techniques can accommodate these changes.

2. CASE REPORT

A 71-year-old female diagnosed with left breast invasive carcinoma underwent lumpectomy as part of her breast-conserving treatment. Following surgery, a computed tomography scan (CT1) revealed a seroma cavity. The proposed radiotherapy regimen included conformal radiotherapy using bilateral tangential photon beams and an anterior photon beam, delivering 46 Gy to the whole breast, followed by a 14 Gy electron beam boost targeting the tumor bed.Notable reduction in palpable breast dimensions prompted a second CT scan (CT2) before the electron beam boost, allowing for a direct comparison between initial and subsequent seroma volumes and dosimetry impact. A 65% volume (from 217 c.c. to 75 c.c.) reduction of seroma was found [Fig. 1].

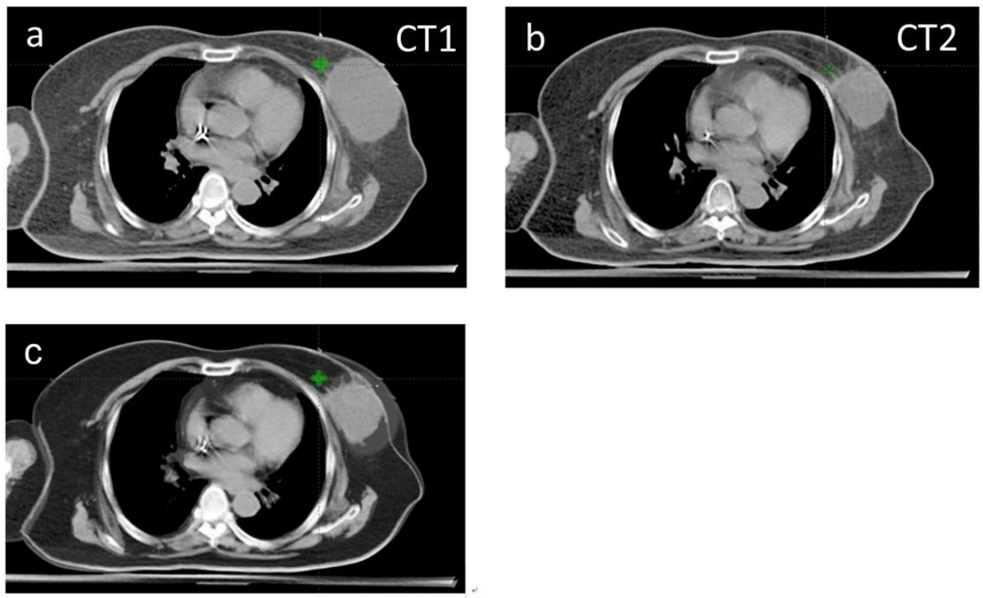

Fig. 1.(a) Initial CT (b) Second CT scan after five weeks (c) Image registration of CT1 and CT2 showing the reduction of seroma

Five different techniques were developed and optimized to ensure the clinical target volume (CTV) received 95% of the prescribed dose for comparison purpose [Fig. 2] [Fig. 3]. These included:

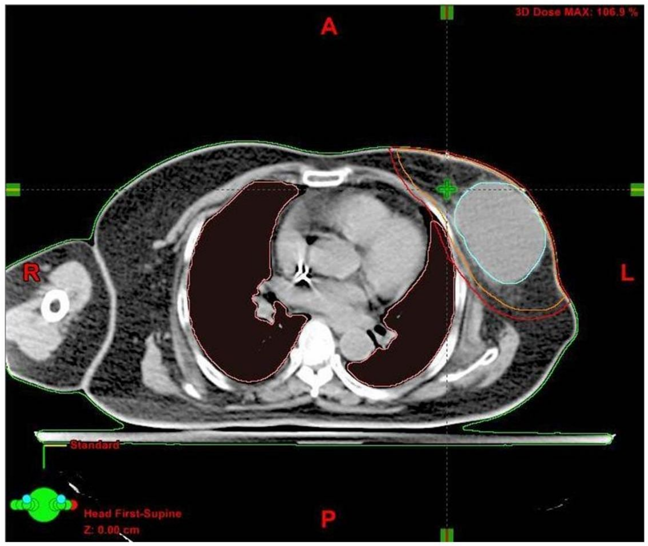

Fig.2.Contouring of seroma(cyan), CTV(orange), and PTV(red)

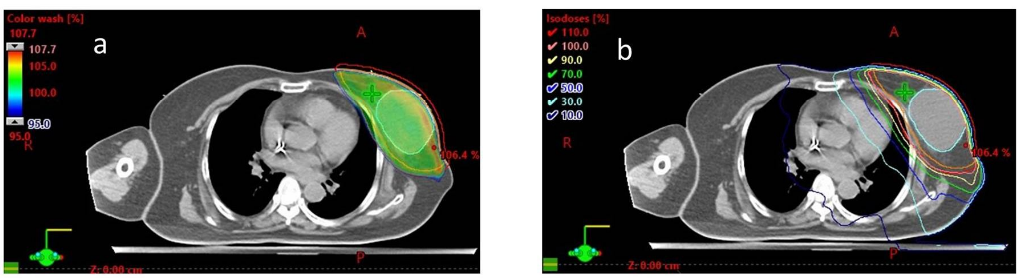

Fig.3.Example of dose distribution using VMAT (a) Color wash (b) Isodose line

1. Two-field Conventional Plan: Adjusted bilateral opposed tangent fields with a multileaf collimator (MLC) to shape the target and shield the lung and heart with physical wedge applied [Fig. 4a].

2. Three-field Conventional Plan: Added an anterior oblique field to mitigate unnecessary dose in the lateral axillary area [Fig. 4b].

3. Forward Intensity-Modulated Radiation Therapy (Forward IMRT): Utilized MLC to conform to the target shape without wedge modulation [Fig. 4c].

4. Inverse Intensity-Modulated Radiation Therapy (Inverse IMRT): Complex plans optimized using planning systems with numerous small segments/fields [Fig. 4d].

5. Volumetric-Modulated Arc Therapy (VMAT): Modulated gantry speed, dose rate, and MLC during treatment delivery using an inverse planning method with a four-arc plan [Fig. 4e].

Registration was performed between CT1 and CT2, and the CT1 plan was subsequently applied to the CT2 image for dose calculation. Comparisons were then conducted between the two plans/images. The quality of each treatment plan was assessed through various dosimetric parameters, including maximum point dose (Dmax), CTV coverage, and the volume of irradiated normal tissue. The Reproducibility Index (RI) was used to evaluate consistency across different scans. A higher RI value approaching one indicates better reproducibility across different CT images.

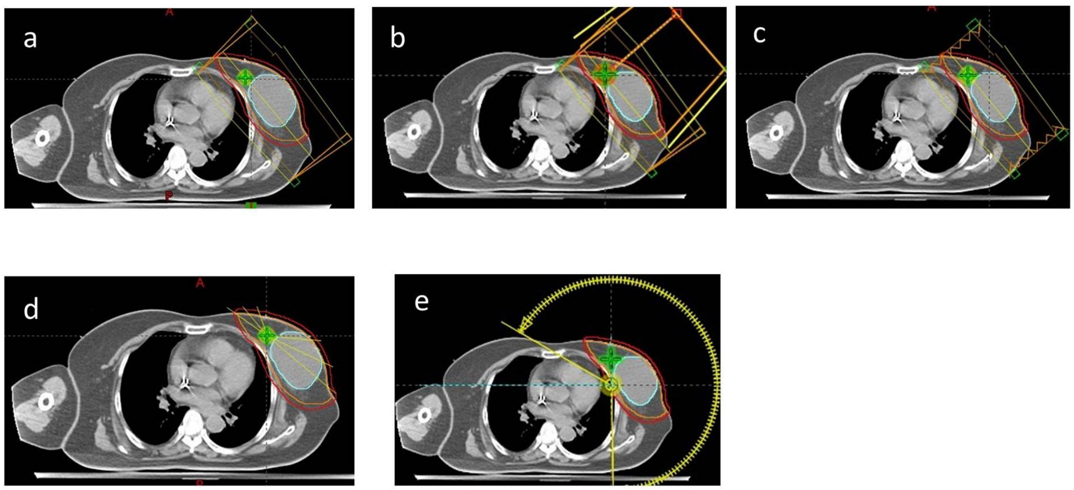

Fig.4.Different techniques of whole breast radiation therapy (WBRT) plans (a) Two-field plan (b) Three-field plan (c) Forward IMRT (d) Inverse IMRT(e) VMAT

Table 1 provides a detailed comparison of various radiotherapy techniques based on parameters assessed on two CT scans (CT1 and CT2). Inverse IMRT and VMAT exhibited higher dose increases in Dmax and increases in hot spots, suggesting potential risks for overdosage. Conversely, the conventional two-field and three-field techniques demonstrated more stable target coverage but lower RI which indicated less favorable high-dose uniformity indices compared to inverse IMRT and VMAT.

Table 1. Comparison of dose metrics and reproducibility indices across different radiotherapy techniques

Technique	Image	Dmax (%)	CTV V_{95} (%)	CTV V_{100} (%)	Hot spots V_{105} (cm^3)	Hot spots V_{100} (cm^3)	CTV_{95} RI	CTV_{100} RI
Two-field	CT1	107.0	94.2	56.9	11.8	156.5	0.812	0.677
	CT2	110.6	94.9	49.0	11.7	142.5		
	CT2-CT1	3.6	0.7	-7.9	-0.1	-14.0		
Three-field	CT1	107.0	94.3	69.1	2.5	79.2	0.812	0.677
	CT2	108.3	95.0	62.0	3.2	77.2		

	CT2-CT1	1.3	0.7	-7.1	0.7	-2.0		
Forward IMRT	CT1	107.1	93.1	50.7	10.5	104.3	0.809	0.663
	CT2	109.8	92.9	47.5	6.8	94.9		
	CT2-CT1	2.7	-0.2	-3.2	-3.7	-9.4		
Inverse IMRT	CT1	107.4	96.5	93.4	0.0	265.9	0.822	0.815
	CT2	124.0	93.1	87.9	17.5	229.5		
	CT2-CT1	16.6	-3.4	-5.5	17.5	-36.4		
VMAT	CT1	107.7	95.1	92.0	1.6	181.3	0.844	0.820
	CT2	115.9	92.7	87.4	2.7	125.5		
	CT2-CT1	8.2	-2.4	-4.6	1.1	-55.8		

**CTV V95: percentage volume of CTV covered by 95% prescribed dose*

**CTV V100: percentage volume of CTV covered by 100% prescribed dose*

**Hot spots V105: volume covered by 105% prescribed dose and located outside CTV*

**Hot spots V100: volume covered by 100% prescribed dose and located outside CTV*

**RI (Reproducibility index) = (overlapping volume of CTV' and CTV")^2 / (CTV' x CTV")*

**CTV' represents the overlapping volume of the prescribed 95% dose in CT1*

**CTV" represents the overlapping volume of the prescribed 95% dose in CT2*

3. DISCUSSION

The findings from this study emphasize the dynamic nature of seroma cavities following breast-conserving surgery and the impact of these changes on radiation therapy planning. Seroma volume changes can significantly impact dose delivery accuracy in WBRT.[3] The study documented a 65% reduction in seroma cavity volume over five weeks, emphasizing the evolving nature of post-surgical breast anatomy. Techniques like inverse IMRT and VMAT, while providing better high-dose coverage uniformity, exhibited higher dose variability.

The optimal timing for the initiation of radiation therapy post-surgery remains a balance between allowing seroma stabilization and minimizing the delay to reduce the risk of local recurrence.[4] [5] This study's results suggest that starting radiation therapy within 4-6 weeks post-surgery, combined with adaptive planning, could offer a practical approach. Adaptive radiotherapy techniques that can account for these anatomical shifts.[6] [7]

Regular imaging can help address changes in seroma volume. Techniques such as cone-beam CT (CBCT) during treatment can enable timely adjustments to the radiation plan, ensuring accurate dose delivery and minimizing the risk to surrounding healthy tissue.

Advanced Radiotherapy Techniques: Inverse IMRT and VMAT demonstrated better consistency and reliability in high-dose coverage compared to conventional techniques. These advanced methods, combined with adaptive planning, can enhance treatment precision, particularly in the context of dynamic anatomical changes post-surgery.

The case report's findings are based on a single patient's experience, and future research should focus on evaluating the long-term outcomes of patient with significant seroma volume changes and leveraging technological advancements in imaging and radiotherapy to enhance the treatment precision.

4. CONCLUSION

In conclusion, the study underscores the importance of accounting for seroma volume changes in WBRT planning. Advanced radiotherapy techniques, combined with adaptive planning, can significantly improve treatment accuracy and patient outcomes. Ongoing research and technological advancements are essential to further refine these approaches and ensure optimal care for patients undergoing breast-conserving therapy.

CONSENT

The authors report that they have the patient'sconsent, which is available upon request.

ETHICAL APPROVAL

This study was reviewed and approved by the CGMH Institutional Review Boards (number: 201801223B0). The IRB determined that the study met all ethical guidelines, and that patient consent was not required due to the retrospective nature of the research.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The authors used ChatGPT-4 (OpenAI, version GPT-4o) solely for grammar correction and text refinement in this manuscript. All factual accuracy checks, citations, and content verification were conducted by the authors.

REFERENCES

1. Gonzalez EA, Andonyadis CG, Emery BE, Gibbons RV, et al. Seroma formation following breast cancer surgery. Breast J 2003;9(6):385-89.

2. Woodworth PA, McBoyle MF, Helmer SD, Beamer RL. Seroma formation after breast cancer surgery: incidence and predicting factors. Am Surg 2000;66(5):444-50.

3. Sharma R, Spierer M, Mutyala S, et al. Change in seroma volume during whole-breast radiation therapy. Int J Radiat Oncol Biol Phys 2009;75(1):89-93.

4. Recht A, Come SE, Henderson IC, et al. The sequencing of chemotherapy and radiation therapy after conservative surgery for early-stage breast cancer. N Engl J Med 1991;325(3):153-60.

5. Huang J, Barbera L, Brouwers M, et al. Does delay in starting treatment affect the outcomes of radiotherapy? A systematic review. J Clin Oncol 2003;21(3):555-63.

6. Sonke JJ, Aznar M, Rasch C. Adaptive radiotherapy for anatomical changes. Seminars in radiation oncology, 2019;29(3):245-57.

7. De-Colle C, Kirby A, Russell N, Shaitelman SF, Currey A, Donovan E. et al. Adaptive radiotherapy for breast cancer. Clin Trans Radiat Oncol, 2023;39:100564