

Research Article

An Analytical Comparison of Two Daily Pre-Treatment Image Verification Approaches Utilizing Radixact™ Tomotherapy-Based Megavoltage Computed Tomography for Head and Neck Cancer Patients

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Abstract

Introduction: Ensuring accurate patient setup is crucial in radiotherapy for head and neck cancer (HNC) due to the intricate anatomy and the closeness to vital organs. This study aimed to assess and compare the effectiveness of two different daily pre-treatment auto image registration techniques utilizing Radixact Tomotherapy-based megavoltage computed tomography (MVCT) to enhance setup accuracy and treatment consistency. **Materials and Methods:** A prospective analysis was performed on a cohort of twenty HNC patients undergoing treatment with Radixact Tomotherapy. Two image verification techniques were assessed: one focused on aligning bony anatomy (Method A) and the other on adjusting the cross-wire at the center of the planning target volume (PTV) for automatic registration (Method B). Daily MVCT images were taken and analyzed to determine translational setup corrections, which were documented for further analysis. **Results:** Method B exhibited slightly lower mean systematic errors in both the longitudinal and lateral directions, although the differences were not statistically significant. Method A demonstrated significantly lower errors in the vertical (Z-axis) direction ($p = 0.013$). Overall displacement vectors favored Method A, yet multivariate analysis indicated no significant difference between the two methods. Therefore, both methods were found to perform similarly, with Method A showing superior vertical alignment. **Conclusions:** Both auto image registration techniques provide accuracy and dependability, bolstered by reproducible anatomy and clinician supervision. For optimal precision, Method A is suggested for initial gross alignment, followed by Method B for fine-tuning around the target volume, thereby improving dose precision and safety in high-accuracy radiotherapy treatments. **Key Messages:** Combining initial alignment with Method A and refinement with Method B enhances precision and safety in head and neck radiotherapy, optimizing setup accuracy using Radixact Tomotherapy MVCT imaging.

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Keywords

Image Registration, Crosswire, MVCT, Radixact Tomotherapy, Setup Error

1. Introduction

Precision radiotherapy is essential in the curative treatment of various cancers [1]. It can be administered as a standalone therapy or in conjunction with other treatment options, achieving a cure rate of approximately 40% for cancer patients [2, 3]. Recent technological advancements have enabled the customization of radiotherapy to better align with the unique needs of each patient and their specific diagnosis. Online Image guided radiotherapy (IGRT) allows the correction of both systematic (treatment preparation) and random (treatment delivery) errors so that targeting can be more accurate. Providing greater security of target coverage and reducing the dose to surrounding normal tissues [4, 5]. The combination of Image guided intensity modulated radiotherapy (IG-IMRT) allows treatments previously considered impossible [6]. Mega voltage computed tomography (MVCT) on the tomotherapy system allowed daily volumetric evaluation of pre-treatment position of patients [7].

MVCT was found to be an important imaging tool for precise radiation delivery because it provides considerably more anatomical detail than conventional radiation therapy port films used for patient setup verification. There is a growing number of publications comparing treatment plans of different radiotherapy techniques to helical tomotherapy (HT) delivery [8, 9]. During MVCT scanning, the nominal energy of the incident electron beam is reduced from 6 to 3.5 MV, and the radiation field is collimated in the longitudinal direction to 4 mm. All multileaf collimator (MLC) leaves are open during the MVCT acquisition [10]. MVCT images enable radiation therapists (RTT) to assess the precise dose administered during each treatment fraction. The dose for subsequent treatments will be adjusted according to the evaluation findings and the treatment plan, facilitating dose-adaptive and precision radiotherapy [11]. IGRT focuses on obtaining patient anatomical data within the treatment environment to inform decision-making, enhancing treatment quality. With new technical advancements, the development of automated tools for image registration and the quantification of setup errors has become feasible and has significantly advanced the practice of IGRT [12, 13].

Several elements, including auto registration algorithms and matching techniques employed in an image registration software, play a crucial role in maintaining the geometric precision of patient positioning errors throughout the treatment delivery process [14, 15]. At present, we are unaware of any specific data that contrasts the various

matching methods employed in the radixact tomotherapy treatment delivery console. Therefore, this study aims to assess the impact of different auto registration techniques on patient setup inaccuracies in individuals receiving head and neck helical tomotherapy treatment.

This study fills a gap in current research by directly comparing two automatic image registration methods, bone-based and target-centered on the Radixact Tomotherapy system. Previous studies mostly looked at older Tomotherapy or CBCT systems, but very little data exist for the newer Radixact platform. Our work adds new information about how these two techniques perform in daily use and how they can improve setup accuracy for head and neck cancer treatments.

2. Materials and Methods

In this prospective study, twenty patients with head and neck cancer received a total dose of 60 Gy in 30 fractions using a 6 MV FFF photon beam delivered via the Tomo Helical technique on the Radixact X9 system (Table 1, Figure 1). Daily image verification was performed using MVCT according to the institutional image guidance protocol, resulting in 40 MVCT scans for setup verification. Two different auto-registration methods were evaluated for image alignment accuracy. Each MVCT image verification incorporated a crosswire to facilitate precise alignment across the sagittal, coronal, and axial views. To assess the effectiveness of crosswire-based auto-registration, daily offset data were collected for both registration methods. In Method A, the acquired volumetric image was auto-matched using the Bone T algorithm to determine translational offset corrections (Figure 2). In Method B, a crosswire was positioned at the center of the planning target volume (PTV) before performing auto-matching (Figure 3). The resulting offset data from both techniques were analyzed to identify the optimal image registration approach.

The treatment delivery console allows radiation therapists (RTTs) to manage all aspects of the treatment process, including initiating, pausing, and monitoring treatment delivery, as well as handling patient imaging and positioning. It serves as a central component of the TomoTherapy system, integrating treatment planning, CT-based image guidance, and delivery. The console enables registration of patient imaging data to ensure congruence between the treatment plan and patient anatomy. Both automatic and manual registration

options are available to align daily scans with planning images, with updates reflected in all three anatomical views.

The Bone T algorithm relies exclusively on high-density bone data points for accurate alignment during auto-registration.

Table 1. Patient demographics and clinical details for 20 head and neck cancer cases treated with 60 Gy/30 fractions using 6 MV FFF Tomo Helical on Radixact X9 with daily MVCT verification.

Characteristic	Category / Unit	Number of Patients (n)	Percentage (%)
Age (years)	Mean $\pm$ SD = 58.4 $\pm$ 8.6 (Range: 42-73)	-	-
Gender	Male	10	50
	Female	10	50
Primary Tumor Site	Oropharynx	7	35
	Larynx	5	25
	Hypopharynx	4	20
	Nasopharynx	2	10
	Oral cavity	2	10
Laterality of Lesion	Right	9	45
	Left	8	40
	Midline	3	15
Prescribed Dose	60 Gy in 30 fractions	20	100
Beam Energy	6 MV FFF photon beam	20	100
Treatment Technique	Tomo Helical (Radixact X9 system)	20	100
Image Guidance Modality	MVCT (Daily pre-treatment)	20	100
Immobilization Device	4 Clamp H&N Mould	20	100
Treatment Duration (days)	Mean $\pm$ SD = 42.3 $\pm$ 3.1	-	-



Figure 1. The figure illustrates the Radixact X9 tomotherapy system.



Figure 2. Showing Bone T auto-registration interface on the TomoTherapy console (Method A).

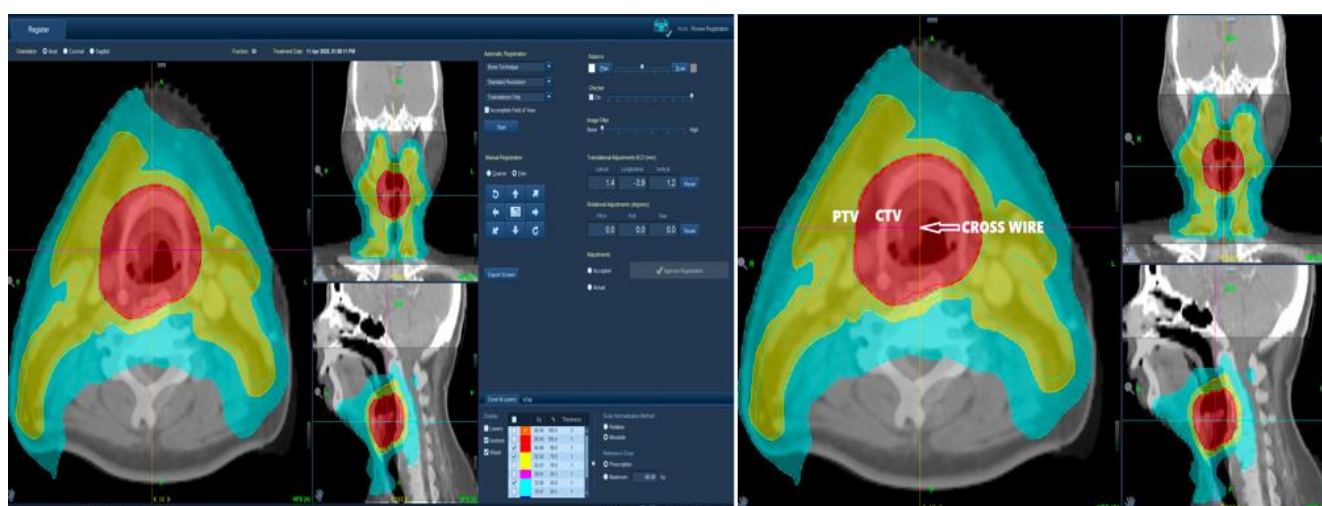


Figure 3. Interphase of Bone T auto-registration (Method B) after cross-wire alignment at PTV center on the TomoTherapy.

2.1. Patient Selection

A total of twenty patients diagnosed with HNC participated in this study. These individuals underwent intensity-modulated (IM) helical tomotherapy at our facility from July 2024 to December 2024. The age range of the patients was between 42 and 73 years, encompassing all genders, and they received a dosage of 60 Gy over 30 fractions during their initial radiotherapy sessions. Patients who required a replan were excluded from the study due to significant anatomical alterations, as neither registration technique was able to fulfil the clinical treatment criteria.

2.2. Image Acquisition

The primary objective of obtaining MVCT images before the commencement of treatment is to confirm and adjust the patient's positioning for the procedure. This procedure

requires the alignment of daily images with the planning images. A variety of image registration tools are available at the tomotherapy treatment delivery console, including blending tools, contrast adjustments, image enlargement tools, and crosswire alignments. RTT's are responsible for selecting the superior-inferior extent of the MVCT scan, which offers two parameters for selection. First, the scan range must be established, which is adaptable and typically includes the PTV treatment area. A wider scan range will inherently require more time to complete. The second parameter relates to the image pitch, which affects the nominal slice thickness. There are three available options: fine, normal, and coarse, corresponding to nominal slice thicknesses of 2 mm, 4 mm, and 6 mm, respectively. Since the gantry operates at a constant speed during all imaging procedures, scanning the same volume will take longer in fine mode than in normal mode.

2.3. Image Registration

Bone (T) matching (Translational) (BM): Automates the alignment of reference and onboard CT images by allowing the crosswire to be positioned randomly within the image dataset. This technique utilizes chamfer matching algorithms to ascertain the required translation and rotation, relying on densities that are indicative of bone densities. (Method A)

Bone (T) with the Crosswire placing at the Center of the PTV (Translational): This method aligns reference and onboard CT images by ensuring that the crosswire is positioned centrally within the PTV volume of the image dataset. Calculation of Setup errors denotes the difference between the planned and actual positioning of a patient during treatment. (Method B)

These errors are typically evaluated by comparing an onboard treatment image with its corresponding reference image, with a focus on the patient's setup error within the treatment field. Setup errors are classified into two primary categories: (1) Systematic error and (2) Random error. Systematic patient error (Σ) is calculated by averaging the measured setup errors for each imaged fraction across all directions, using three different matching methods. Conversely, random error (σ) is determined by the root mean square of the standard deviations of errors recorded for each patient, also utilizing three matching methods. The mean setup error (M) indicates the average setup error across all directions, while the maximum error (E) is defined as the largest deviation observed in each direction, again employing three matching methods.

Following the guidelines set forth by ICRU 50, 62, and 83, Radiation oncologists and RTTs were identified the gross tumor volume (GTV), clinical target volume (CTV), and organ at risk volume (OAR). To mitigate uncertainties in patient setup during treatment, the planned target volume (PTV) was established around the CTV. RTTs conducted a comparison between the onboard MVCT images and the registered CT images to determine the final setup error, which received approval from the radiation oncologist. Adjustments were made through couch offset corrections at the treatment delivery console.

2.4. Significance of Setup Errors

Setup errors in MVCT-based image matching during radiotherapy can significantly compromise treatment accuracy, potentially resulting in insufficient tumor dose coverage or excessive radiation exposure to healthy tissues. Accurate alignment is vital for effective therapy, as it reduces the risk of complications. Implementing regular corrections and adaptive planning strategies can help alleviate these errors, thereby ensuring optimal radiation delivery and enhancing patient outcomes. In the context of MVCT-based image matching for radiotherapy, such errors can severely impact the precision of treatment. Therefore, maintaining precise alignment is crucial for effective dose administration, as it

minimizes exposure to healthy tissues while maximizing the targeting of the tumor. Even slight misalignments can jeopardize treatment effectiveness, highlighting the need for stringent quality assurance measures and corrective interventions to uphold therapeutic precision.

Random error, which reflects unpredictable day-to-day variations in patient setup, was intentionally excluded from this study to maintain a focused evaluation of systematic errors, those consistent deviations that can be corrected with proper alignment protocols. Systematic error has a more direct impact on long-term dose delivery accuracy and treatment planning, as it affects every fraction in a similar way. Since our objective was to compare the precision of two auto-registration techniques in establishing consistent patient positioning across fractions, focusing solely on systematic error provided a clearer and more clinically relevant assessment of setup accuracy. Additionally, the limited sample size and uniform imaging protocol reduced the variability typically needed to analyze random error reliably.

2.5. Ethics Statement

This study was conducted in accordance with the ethical principles and adhered to all applicable national and institutional guidelines for human research. All patients included in this study provided written informed consent before participation, allowing the use of their anonymized imaging and treatment data for research and publication purposes. No additional procedures or interventions beyond routine clinical care were performed. The confidentiality and privacy of all patient information were strictly maintained throughout the study.

3. Results

Box and Whiskers Plot illustrating the distribution of setup error between Method A and Method B across longitudinal (X), lateral (Y), and vertical (Z) axes. Shown in Figure 4. The analysis of the effects of two distinct auto-matching techniques on patient setup errors revealed both commonalities and divergences, with the findings illustrated through tables and graphs. (Table 2) presents the mean systematic errors (Σ) in patient setup across three axes: Method A recorded a longitudinal direction (X) of -0.85 mm, a lateral direction (Y) of -0.77 mm, and a vertical direction (Z) of 0.01 mm, while Method B showed a longitudinal direction (X) of -0.785 mm, a lateral direction (Y) of -0.465 mm, and a vertical direction (Z) of 0.475 mm, as depicted in Figure 5. Method B exhibited a marginally lower mean systematic error compared to Method A in both the longitudinal (X) and lateral (Y) directions; however, this difference was not statistically significant ($P > 0.05$). In contrast, a statistically significant difference was identified in the mean systematic error between Method A ($\Sigma = 0.01$) and Method B ($\Sigma = 0.475$) in the vertical (Z) direction ($P = 0.013^*$), indicating that Method A

had a lower mean systematic error than Method B. The maximum errors were slightly lower in Method A than in Method B shown in Figure 6.

The average displacement vector outcomes were lower in Method A compared to Method B. Statistically, no significant difference was identified between the two methods ($P > 0.05$). (Table 2) presents the results of paired samples t-tests conducted to evaluate the individual error components (X, Y, Z) for both Method A and Method B shown in Figure 7. The analysis indicated no significant difference in the X-component errors between the two methods, $t(19) = -0.831$, $p = 0.416$. Likewise, the differences in Y-component errors did not reach significance, although a trend was observed, $t(19) = -1.756$, $p = 0.095$. Conversely, a statistically significant difference was noted in the Z-component errors,

$t(19) = -2.758$, $p = 0.013^*$, with Method A exhibiting lower error rates. (Table 3) demonstrates the interdependence between Method A and Method B.

Furthermore, a multivariate analysis (Hotelling's T^2 test) was performed to assess the overall impact of the error vector (X, Y, Z) between Method A and Method B across 20 patients. The findings indicated a test statistic of 2.3884, with 3 numerator degrees of freedom and 36 denominator degrees of freedom. The associated p-value was 0.5271, suggesting no significant difference in the overall effect of error components between the two methods ($p > 0.05$). Paired t-test was performed for the comparison between two auto matching methods A and B, to evaluate the P value for measured results using JAMOFI (version 2.3.28) software. A comprehensive summary of the results is presented in Table 4.

Table 2. Comparison of systematic error (Σ) between two auto matching methods for head and neck cancer.

Setup Error	Mean (Method A)	Mean (Method B)	Mean Difference (A-B)	Std. Error	Sig.
X (Lateral)	-0.85	-0.785	-0.065	0.0782	0.416 ^{NS}
Y (Longitudinal)	-0.77	-0.465	-0.305	0.1737	0.095 ^{NS (TREND)}
Z (Vertical)	0.01	0.475	-0.465	0.1686	0.013*

X - Lateral, Y - Longitudinal, Z - Vertical, Σ - Systematic Error, * The mean difference is significant at the 0.05 level, NS - Non Significant, NS (TREND) - Non Significant, but shows a trend towards significance.

Table 3. Illustrating the dependency relationship between Method A and Method B.

Aspect	Method A	Method B	Dependency
Initial Setup	Refines this initial setup using image registration	Used to position the patient close to treatment isocenter	Bone T&R depends on accurate initial crosswire setup to minimize correction magnitude
Error Correction	Corrects for internal (bony) positional errors	Cannot detect internal misalignments	Bone T&R corrects the shortcomings of crosswire-only alignment
Workflow Efficiency	Requires MVCT imaging and processing	Faster, requires no imaging	Crosswire helps reduce scan length and registration time by starting close to the target
Use in Adaptive Therapy	Crucial	Not used	Adaptive workflows require precise registration; bone T&R is foundational

Table 4. A detailed overview of the results.

Parameter	Axis / Component	Method A	Method B	Statistical Test / Value	p-value	Interpretation
Mean Systematic Error (Σ)	Longitudinal (X)	-0.85 mm	-0.785 mm	Paired t-test	>0.05	No significant difference
	Lateral (Y)	-0.77 mm	-0.465 mm	Paired t-test	>0.05	Comparable accuracy

Parameter	Axis / Component	Method A	Method B	Statistical Test / Value	p-value	Interpretation
	Vertical (Z)	0.01 mm	0.475 mm	Paired t-test	0.013*	Method A more accurate
Average Displacement Vector	—	Lower in Method A	Higher in Method B	Paired t-test	>0.05	No significant difference
Maximum Error Magnitude	—	Slightly lower	Slightly higher	Descriptive comparison	—	Method A marginally better
Paired Sample t-Test Results	X-component	—	—	$t(19) = -0.831$	0.416	Not significant
	Y-component	—	—	$t(19) = -1.756$	0.095	Trend, not significant
	Z-component	—	—	$t(19) = -2.758$	0.013*	Significant difference
Multivariate Analysis (Hotelling's T^2)	Combined (X, Y, Z)	—	—	$T^2 = 2.3884$ (df = 3,36)	0.5271	No significant overall difference
Software Used	—	—	—	JAMOV v2.3.28	—	Statistical analysis platform
Summary Interpretation	—	—	—	—	—	Method A showed lower mean and vertical errors; only Z-axis difference was statistically significant.

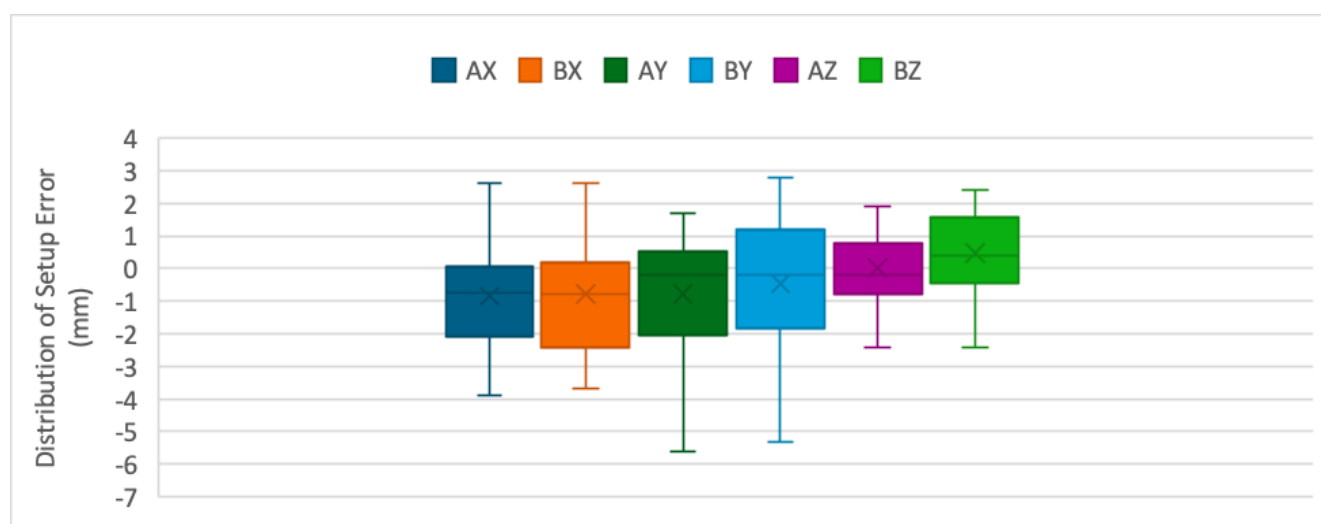


Figure 4. Box and Whisker Plot showing setup error distribution for Method A and Method B across X (lateral), Y (longitudinal), and Z (vertical) axes.

** AX- The lateral direction offset shifts in Group A, AY- The longitudinal direction offset shifts in Group A, AZ- The vertical direction offset shifts in Group A, BX- The lateral direction offset shifts in Group B, BY- The longitudinal direction offset shifts in Group B, BZ- The vertical direction offset shifts in Group B.

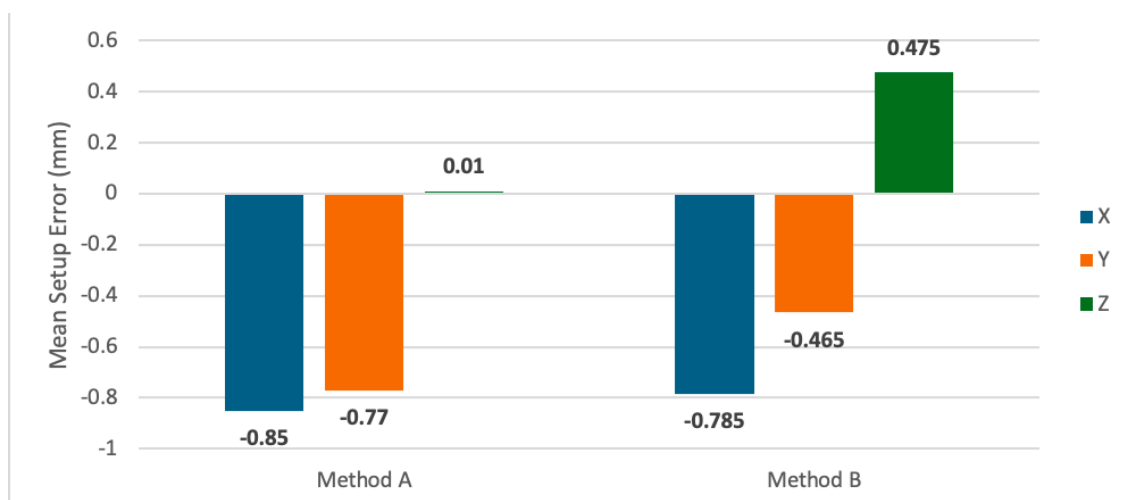


Figure 5. Graphical depiction of the mean setup error in the lateral (X), longitudinal (Y), and vertical (Z) directions for both methods.

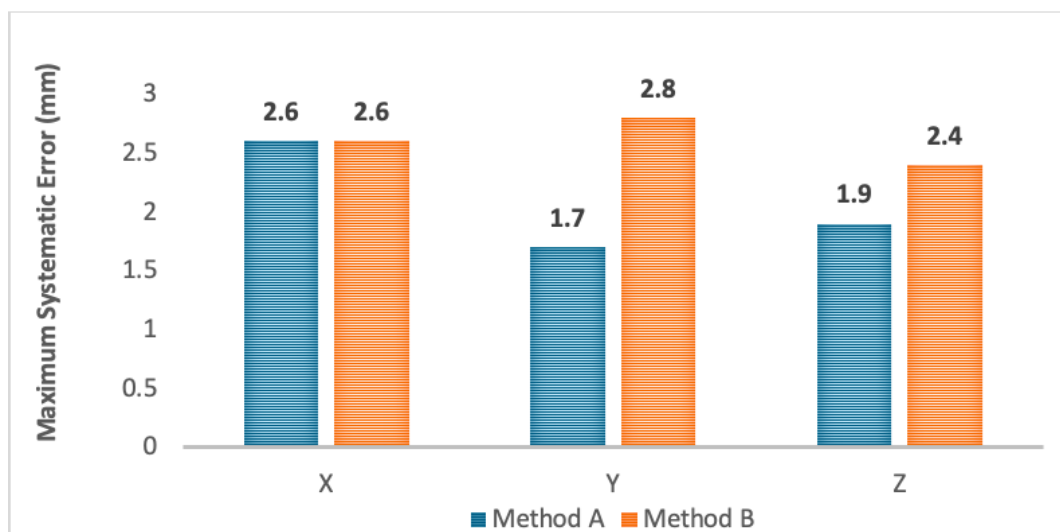


Figure 6. Represents a graphical depiction of the maximum systematic errors along the X, Y, and Z axes for both auto-registration techniques.

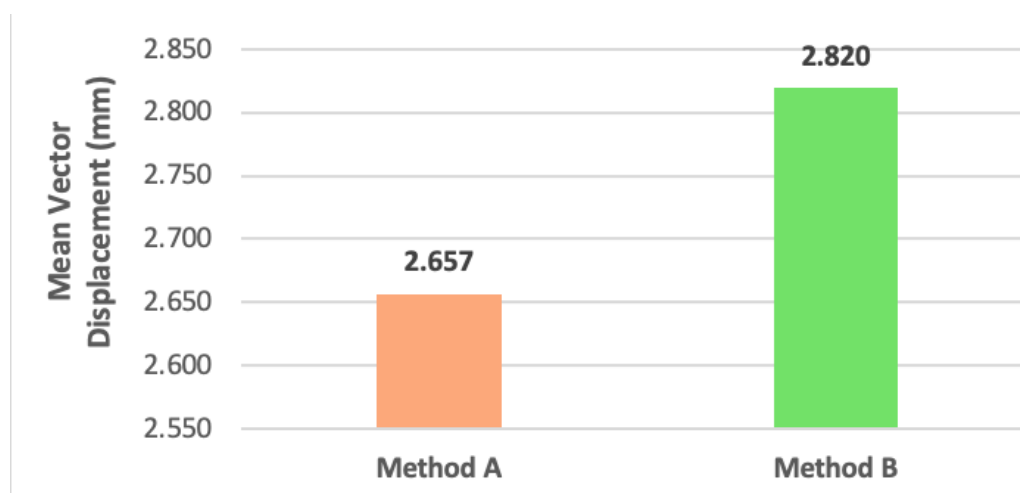


Figure 7. The figure illustrates the mean vector displacement for both Method A and Method B.

4. Discussion

Precise positioning of patients is crucial in image-guided radiotherapy (IGRT), particularly in anatomically intricate areas such as the head and neck. Method A exhibited a significantly reduced error in the vertical (Z) axis, Method B, which employs MVCT-based auto-matching, consistently showed lower errors in both the longitudinal (X) and lateral (Y) axes. These axes are especially important for head and neck cancers due to the closeness of dose-limiting organs like the spinal cord and parotid glands. Although the differences observed in the X and Y axes were not statistically significant, the persistent trend indicates enhanced spatial reliability with Method B.

The difference seen in the vertical (Z-axis) direction is important because it could affect radiation dose to nearby organs such as the spinal cord or brainstem. Even small vertical shifts can change how much dose these organs receive. The better vertical accuracy found with the bone-based method may therefore help reduce unwanted radiation to these sensitive areas. A multivariate analysis (Hotelling's T^2) revealed no significant overall difference between the two methods; however, from a clinical standpoint, the volumetric guidance and reproducibility offered by Method B render it more favorable. Consequently, Method B presents both practical and clinical benefits, advocating for its adoption as a standard method in head and neck IGRT.

Accurate image registration is critical for the safe and effective delivery of radiotherapy, particularly in image-guided treatments where Mega voltage Computed Tomography (MVCT) is used to align patients prior to radiation delivery. Among the various registration techniques, Cross Wire Matching (CWM), Bone Matching (BM), and Grey Scale Matching (GSM) have emerged as widely implemented methods. Each has unique benefits and limitations, but a growing body of evidence and clinical rationale supports the assertion that cross-wire matching (CWM) offers superior reliability, safety, and clinical utility, especially in high-precision treatment contexts. Method B is fundamentally a landmark-based registration technique, often utilizing visible anatomical structures such as vertebral bodies, dental restorations, or implanted fiducial markers. This method allows clinicians to manually align well-defined, reproducible reference points, which leads to high inter-fractional consistency. Unlike GSM, which is highly sensitive to image quality and susceptible to contrast variation, or BM, which performs well only in regions with clearly visible skeletal structures, Method B is less influenced by imaging artifacts or soft tissue deformations.

For example, in prostate radiotherapy, Hashido (2018) reported that manual registration using anatomical landmarks provided more reliable alignment compared to automatic registration, especially in the presence of anatomical variability such as rectal filling. This highlights the robustness of CWM under variable imaging conditions. One of the most

compelling arguments for CWM is its alignment with the principle of "clinician oversight." Unlike fully automated methods, CWM enables RTT's to visually confirm and adjust alignment in real time. This reduces the risk of false-positive registrations [16]. Cao et al. (2019) noted that while grayscale methods could register soft tissues well, manual corrections based on anatomical landmarks were frequently required in thoracic tumors affected by respiratory motion. CWM, therefore, becomes the de facto safety net, allowing for trusted visual confirmation [17]. In high-precision treatments such as stereotactic body radiotherapy (SBRT) or stereotactic radiosurgery (SRS), sub-millimeter accuracy is non-negotiable. Here, even the most sophisticated automatic algorithms may falter under the demands of tight margins and dose escalation.

Mi et al. (2024) conducted a direct comparison between bone and tumor matching in carbon ion therapy for non-small cell lung cancer, concluding that tumor-based registration (analogous to GSM) was less stable in the presence of anatomical shifts, supporting the use of bone-based (and by extension, landmark-based) methods in critical alignments [18]. The AAPM Report by Brock et al. (2017) outlines the importance of matching the registration method to the clinical context and emphasizes that landmark-based methods remain essential for ensuring alignment integrity, particularly in high-risk or high-precision treatments [19]. Recent advances in artificial intelligence (AI) have further transformed registration strategies in image-guided radiotherapy. Deep-learning frameworks have been reported to significantly enhance registration accuracy, reduce inter-observer variability, and accelerate processing time without compromising clinical reliability [20]. AI-based CBCT-MVCT fusion models have demonstrated promising results in automated setup verification and dose recalculation workflows [21]. Furthermore, the 2024 ESTRO-AAPM consensus underscores the importance of validation, interpretability, and clinician oversight in AI-driven registration systems to ensure safe integration into routine radiotherapy [22]. Both auto registration techniques leads to improved treatment accuracy, reduced setup errors, and enhanced patient safety. By enabling precise alignment using stable anatomical landmarks or fiducial markers, Method B is especially crucial in stereotactic radiosurgery (SRS) and other high-precision modalities, where even sub-millimeter deviations can compromise dose delivery or increase toxicity. visual verification capability of this technique makes it indispensable in such critical treatments. Integrating both methods may offer an optimal balance between accuracy and efficiency. While Method A ensures superior vertical precision, Method B provides consistent lateral and longitudinal stability. A combined or hybrid registration strategy using automated MVCT-based alignment followed by manual verification with anatomical landmarks can enhance confidence in setup accuracy. This approach unites the speed of automation with clinician-guided precision, ultimately improving reproducibility, minimizing setup errors, and ensuring safer

dose delivery in high-precision head and neck radiotherapy.

5. Conclusions

Both auto image registration techniques offers a unique blend of precision, resilience, and clinician control. Its reliance on reproducible anatomical features or implanted markers makes it highly reliable across treatment fractions, and its integration with human verification enhances clinical confidence and patient safety. Particularly in stereotactic and high-accuracy radiotherapy. Our recommendation is to initially employ Method A for gross anatomical image registration, which aims to reduce significant errors or offsets. This should be followed by Method B to obtain an estimate of precise alignment of the desired PTV area, thereby ensuring accurate dose delivery to the target region.

6. Limitations of the Study

This research has a number of limitations that need to be recognized. Firstly, the sample size was quite small ($n = 20$), which could restrict the statistical power and the applicability of the results. It is essential to conduct larger multi-institutional studies to confirm these findings across various patient demographics and treatment environments. Secondly, the study focused solely on cases of head and neck cancer, where bony landmarks and anatomical consistency are relatively well established. As a result, the findings may not be directly applicable to other anatomical areas, such as the thoracic or pelvic regions, where the movement of internal organs and variability in soft tissue are more significant.

Abbreviations

AAPM	American Association of Physicists in Medicine
BM	Bone Matching
CTV	Clinical Target Volume
CWM	Cross Wire Matching
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
DOF	Degree of Freedom
FFF	Flattening Filter Free
GTV	Gross Tumor Volume
GSM	Grey Scale Matching
HNC	Head and Neck Cancer
HT	Helical Tomotherapy
IGRT	Image-Guided Radiotherapy
IG-IMRT	Image-Guided Intensity Modulated Radiotherapy
ICRU	International Commission on Radiation Units and Measurements

IMRT	Intensity Modulated Radiotherapy
MLC	Multileaf Collimator
MVCT	Megavoltage Computed Tomography
OAR	Organ at Risk
PTV	Planning Target Volume
QA	Quality Assurance
RTT	Radiation Therapist
SBRT	Stereotactic Body Radiotherapy
SRS	Stereotactic Radiosurgery
Σ (Sigma)	Systematic Error
σ (Sigma)	Random Error
X, Y, Z	Translational Axes (Longitudinal, Lateral, and Vertical Directions)

Author Contributions

Subrata Roy: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing

Rajiv Kumar Singh: Formal Analysis, Software, Supervision, Validation, Writing – original draft, Writing – review & editing

Afnan Paikarathodi: Investigation, Methodology, Validation, Writing – review & editing

Sunil Maurya: Investigation, Methodology, Software, Validation

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Prashik Dube: Software, Writing – original draft, Writing – review & editing

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Data Availability Statement

The data utilized to support the findings of this study can be requested from the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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