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A Pilot Study Evaluating the Effectiveness of Dual-Registration Image-Guided Radiotherapy in Patients with Oropharyngeal Cancer

Simon Goldsworthy, MSc[ab*], Marcus Leslie-Dakers, BSc[a], Steven Higgins, BSc[a], Terri Barnes, BSc[a], Petra Jankowska, MD[a], Sanja Dogramadzi, PhD[c] and Jos M. Latour, PhD[de]

[a] *Radiotherapy, Beacon Centre, Musgrove Park Hospital, Taunton and Somerset NHS Foundation Trust, Taunton, UK*
[b] *Faculty of Health and Applied Sciences, University of the West of England, Bristol, UK*
[c] *Bristol Robotics laboratory, University of the West of England, Bristol, UK*
[d] *Clinical School, Musgrove Park Hospital, Taunton and Somerset NHS Foundation Trust, Taunton, UK*
[e] *School of Nursing and Midwifery, Faculty of Health and Human Sciences, Plymouth University, Plymouth, UK*

ABSTRACT

Purpose: The purpose of the article was to determine the impact of Dual Registration (DR) image-guided radiotherapy (IGRT) on clinical judgement and treatment delivery for patients with oropharyngeal cancer before implementation.

Methods: Ninety cone beam computed tomography images from 10 retrospective patients were matched using standard clipbox registration (SCR) and DR. Three IGRT specialist radiographers performed all registrations and evaluated by intraclass correlation to determine inter-rater agreement, Bland-Altman with 95% limits of agreement to determine differences between SCR and DR procedures, changes in clinical judgment, time taken to perform registrations, and radiographer satisfaction.

Results: Inter-rater agreement between radiographers using both SCR and DR was high (0.867 and 0.917, $P \leq .0001$). The 95% limits of agreement between SCR and DR procedures in the mediolateral, cranial–caudal, and ventrodorsal translational directions were −6.40 to +4.91, −7.49 to +6.05, and −7.00 to +5.44 mm, respectively. The mediolateral direction demonstrated significant proportional bias ($P \leq .001$) suggesting non-agreement between SCR and DR. Eighty percent of DR matches resulted in a change in clinical judgement to ensure maximum target coverage. Mean registration times for SCR and DR were 94 and 115 seconds, respectively, and radiographers found DR feasible and satisfactory.

Conclusion: The standard method using SCR in patients with oropharyngeal cancer underestimates the deviation in the lower neck. In these patients, DR is an effective IGRT tool to ensure target coverage of the inferior neck nodes and has demonstrated acceptability to radiotherapy clinical practice.

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* Corresponding author: Simon Goldsworthy, MSc, Beacon Centre, Musgrove Park Hospital, Taunton and Somerset NHS Foundation Trust, Parkfield Drive, Taunton TA1 5DA, UK.

E-mail address: simon.goldsworthy@tst.nhs.uk (S. Goldsworthy).

RÉSUMÉ

But : Déterminer l'incidence de la radiothérapie guidée par imagerie (IGRT) à double registration sur le jugement clinique et l'administration du traitement pour les patients avec un cancer oropharyngé avant la mise en œuvre.

Méthodologie : Quatre-vingt-dix images de TDM à faisceau conique ont été appariées en utilisant une registration « clipbox » standard (SCR) et la double registration. Trois radiographes spécialisés en radiothérapie guidée par imagerie ont effectué toutes les registrations et procédé à l'évaluation par corrélation intraclasse afin de déterminer l'accord entre les noteurs. Ils ont également utilisé les graphiques de Bland Altman avec une limite d'accord à 95% pour détecter les différences entre les méthodes SCR et DR, les changements dans le jugement clinique, le temps requis pour effectuer la registration et le degré de satisfaction du radiographe.

Résultats : L'accord entre les noteurs chez les radiographes qui utilisent les deux méthodes (SCR et DR) était élevé (0,867 et 0,917 $P \leq 0{,}0001$). La limite d'accord à 95% entre les deux procédures dans les directions médiolatérales, crâniale caudale et ventrudorsale était respectivement de −6,40 à +4,91, −7,49 à +6,05 et −7,00 à +5,44 mm. La direction médiolatérales affichait un biais proportionnel significatif ($P \leq 0.001$), ce qui semble indiquer une absence d'accord entre les méthodes SCR et DR. Quatre-vingt pour cent des correspondances DR ont entraîné un changement de jugement clinique pour assurer une couverture maximale de la cible. Le temps de registration moyen pour les méthodes SCR et DR était respectivement de 94 et 115 secondes et les radiographes ont jugé la méthode DR faisable et satisfaisante.

Conclusion : La méthode standard utilisant l'approche SCR pour les patients avec un cancer oropharyngé sous-estime la déviation de la partie inférieure du cou. Pour ces patients, l'approche DR devient un outil IGRT efficace pour assurer la couverture de la cible pour les ganglions de la partie inférieure du cou, et son acceptabilité dans la pratique clinique de la radiothérapie a été démontrée.

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Keywords: Dual registration; critical structure avoidance; multiple regions of interest; stability; reproducibility; systematic and random errors; head and neck radiotherapy

Introduction

Accurate localization of soft tissue volumes is vital for the effective delivery of radiotherapy in patients with oropharyngeal cancer. There have been many advances in image-guided radiotherapy (IGRT) [1], including cone beam computed tomography (CBCT). The practice of using CBCT for IGRT allows tumour volumes to be precisely localized and avoid healthy tissues [2,3]. This is important for patients receiving head and neck radiotherapy for primary and locoregional lymphatic nodal involvement because the inferior neck nodes can move independently of the primary tumour volume. Several studies have described and evaluated the problem of regional anatomical differences in the head and neck using megavoltage portal imaging [4–6], stereoscopic kilovoltage [7], CBCT [4, 8], and computed tomography (CT) on rails [9].

The problem of deviations in different regions of the head and neck is compounded by the increasing use of intensity-modulated radiotherapy techniques [10], which require CBCT scans to visualize soft tissues. It is common for commercial CBCT software packages to only allow for one region of interest (ROI) [1, 11], which inevitably encompasses a large volume comprising the primary cancer site, inferior regional neck nodes that may degrade the effectiveness of the image matching algorithm. Registering such a large ROI fails to accurately quantify larger setup errors in the inferior neck [4–9]. This could lead to a suboptimal treatment to the inferior neck nodes that may result in recurrence for the patient [10–13].

A study by van Beek et al [12] addressed this problem through the development of an automated multiple ROI algorithm for CBCT and tested their first clinical experience undertaken by radiographers. Radiographers found the multiple ROI easy to use with little additional workload and that it helped to identify patients for replanning [12]. This software is not commercially available for routine clinical use; however, Elekta Dual Registration (DR) is available [14]. DR allows the registration of two separate regions of anatomy, calculating their positional offsets independently, and proposing joint correction that best fit both ROIs. Manual corrections can be made to the proposed correction via applying a sliding-scale weighting to favour one ROI's over the other before applying the correction. Preset limits also alert the radiographer if a treatment target structure has moved closer to a critical structure [14]. In anatomical sites other than head and neck, Campbell et al [14] demonstrated in postprostatectomy patients that DR can be a more efficient registration, which could improve patient experience such as comfort [15] while also reducing interobserver variability. There is limited evidence to demonstrate the clinical impact and processes of using DR in head and neck patients. Therefore, the aim of this pilot study was to evaluate the impact of DR on clinical judgement and treatment delivery for patients with oropharyngeal cancer before clinical implementation.

Materials and Methods

A retrospective pilot study was planned and reported as per Standards of Quality Improvement Reporting Excellence (SQUIRE 2.0) guidelines [16]. The pilot study was considered a service evaluation by the Department of Clinical research at Taunton and Somerset NHS Foundation Trust following good clinical practice [17].

Patient Data

Ten retrospective patient CBCT datasets, a sample size recommended by Herzog [18] for pilot studies, who completed radiotherapy to an oropharyngeal primary and nodal area in 2015–2016, were anonymized.

Standard Procedures

Patients received their treatment supine immobilized in a Qfix Aquaplast (Avondale) nine-point thermoplastic immobilization mask covering head, neck, and shoulders. The mask is mounted on a Qfix Curve board, which itself was affixed and indexed to the Elekta iBEAM evo Couchtop. Patients were also tattooed on their sternum for mediolateral positional alignment. Radiographers followed a positioning protocol to ensure standardisation across patients [19]. CT planning scans were acquired using 2-mm slices (Philips Brilliance CT Big Bore CT simulator, Guildford, UK) planned using Pinnacle treatment planning system (Philips version 9.10). Before treatment, CBCT scans (XVI [5.02] 2016; Elekta AB Stockholm, Sweden) were acquired using 1-mm slices as per departmental protocol. This is justified by sampling theory which dictates that, in relation to slice thickness of scans, the ideal scenario is to sample at twice the rate of the resolution trying to achieve [20]. The CBCT preset selected was filter F0 and collimator S20 with a lens sparing gantry rotation of 335°–180° with a gantry speed of 360° per minute. The correction reference point was set to the planning target volume (PTV). Goals for PTV doses are guided by recommendations contained in ICRU50/62/83 [21–23], with near minimum (V99%) dose not <95% of the prescription dose and a near maximum dose (V2%) not >107% of the prescription dose. Gross tumour volume outlined includes primary tumour (or resection site/tumour bed, if postoperative) and involved lymph nodes. Clinical target volume (CTV) will usually be taken as gross tumour volume with a margin of 5–10 mm, taking account of normal tissue boundaries and barriers to spread (eg, vertebral body). An appropriate margin for an involved nodal level will be taken as the next inferior nodal level clear of disease if this can be feasibly included. The Oncologist will indicate the high (macroscopic), intermediate (microscopic), and low (prophylactic) risk CTVs as CTV 1, CTV 2, and CTV3, respectively, which will result in multiple phases of photon or concurrent dose regimes using volumetric-modulated arc therapy or intensity-modulated radiotherapy. A margin of 5 mm around all CTVs delineates the PTVs [21–23]

A total of nine CBCT scans for each patient were scheduled for acquisition at treatment fractions 1–5, then weekly. An offline No Action Level correction strategy was standard practice using a 3-mm translational and 3° rotational tolerance to ensure treatment is delivered within the PTV [24]. A 3-mm translational and 3° rotational registration was performed using Elekta 6 degrees of freedom automatic rigid body registrations [25] to autoregister [26].

DR Procedure

DR enables radiographers to register two separate locations of anatomy using a "clipbox" that encompasses a cuboidal area, and a "mask" in one CBCT scan. This technique enables users to have the option to make corrections based on the critical structure registration (mask/clipbox), or on the tumour registration (mask/clipbox), or a combination of the two, based on a clinical decision depending on the priority match structure. Discussions with a consultant clinical oncologist and radiographers determined the most appropriate clipbox and mask structure for clinical practice within the patients' treatment plan [13]. At the host radiotherapy department, CTV 2 was chosen to include the lower neck nodes.

This is confined only to the predefined anatomical structure of interest, delineated on a planning CT scan, with or without a margin depending on tissue contrasts required (Figure 1). A 3-mm translation and 3° rotation image tolerances were set as the registration limits to alert the operator when the differences between the mask or clipbox exceeds the limit and a compromise or clinical judgement needs to be made of whether to treat a patient or not [3].

Data Collection

Three participating IGRT specialist radiographers matched the images and collected the data. All three had undertaken a recognized IGRT training program such as the European Society of Therapeutic Radiology and Oncology IGRT course or an MSc module in IGRT and are designated IGRT specialist radiographers as per National Radiotherapy Implementation Group Report [27]. Their in-depth knowledge and clinically expert skills were deemed appropriate for this study [27].

A preliminary evaluation of local setup errors for two regions [28], the superior neck (location of the oropharynx primary tumour) and the inferior neck, was undertaken (Figure 2) [6–9].

Three separate clipbox ROIs (Figure 2) were prepared and checked independently by two of the IGRT specialist radiographers and offline registrations were performed by two radiographers. For standardisation, each ROI clipbox was prepared by one IGRT specialist radiographer (Figure 2) and verified by a second IGRT specialist radiographer following a local study protocol to ensure consistency. ROI 1, ROI 2, and ROI Total were generated from one reference CT dataset and individually registered and matched against the treatment localization CBCT dataset. Multiple ROI registration is not available at the host radiotherapy department; therefore, each CBCT scan was registered and matched three times for each ROI.

The evaluated geometric displacements were those captured before correction to observe the effect of geometric error for each ROI [3, 28]. The values obtained were compared with the available evidence before proceeding to the pilot study.

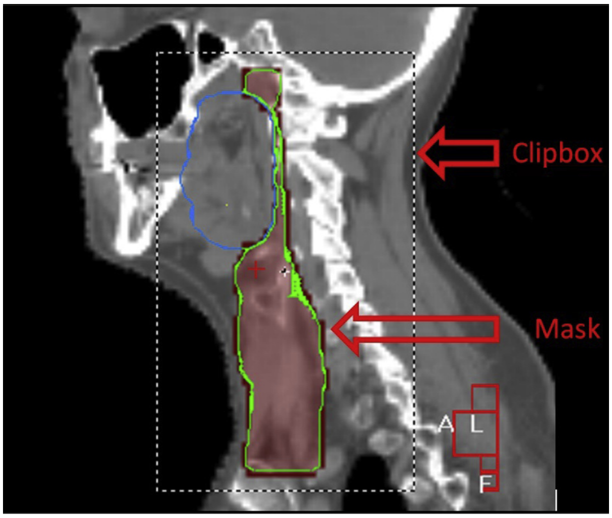

Figure 1. Example of dual registration.

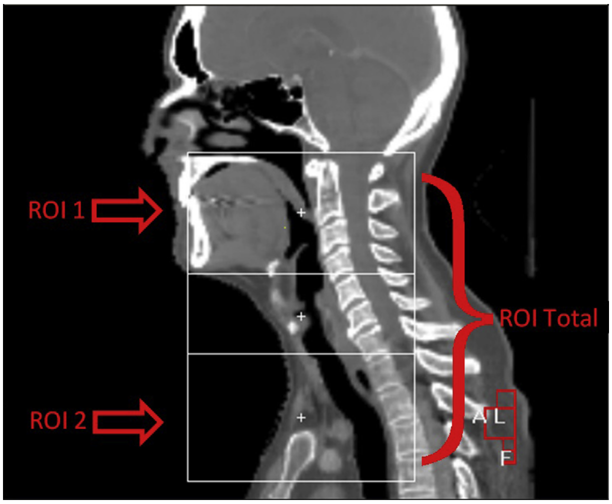

Figure 2. Separate regions of interest (ROI); ROI1, ROI2, ROI-Total. Three ROI (clipboxes) were selected; upper neck; base of skull to C4 (ROI1), lower neck; T1–T4 (ROI2), and standard large clipbox (ROI Total) for comparison.

All three IGRT specialist radiographers retrospectively registered and matched the CBCT datasets of 10 patients using a standard clipbox registration (SCR) and then each dataset was rematched using DR procedures as described, and the final correction values were evaluated. A custom Excel sheet was created to collect the geometric displacement data, and IGRT specialist radiographers were asked to select whether an adjustment has been made for DR. First, each CT reference scan was prepared according to DR procedures (Figure 1) by one IGRT specialist radiographer and verified by a second IGRT specialist radiographer following a study protocol. Each IGRT specialist radiographer followed a local IGRT protocol for SCR registration match criteria and a study protocol for the registration match criteria for DR. The SCR criteria for image matching are to autoregister using the bone translation and rotation (Bone T&R) algorithm which is a chamfer match registering to the high electron density regions such as bone. If the Bone T&R registration fails, then autoregistration is performed using the grey translation and rotation (Grey T&R) algorithm which is a voxel to voxel match of the entire ROI. IGRT specialist radiographers then review the registration of the clipbox area, focusing on bony anatomy such as the vertebrae and mandibular arch then review the PTV coverage and making a manual adjustment if required based on their judgement. The DR criteria for image match registration are to first register the clipbox (Figure 1) using the Bone T&R algorithm, asses the match using the previously mentioned criteria as for SCR, and then register the mask which is CTV 2 which covers the lower neck nodes. IGRT specialist radiographer will then review the match to the mask ensuring that the lower neck nodes are covered and then checking the clipbox to ensure primary tumour coverage and making a compromise if required before converting to correction. For both SCR and DR, the IGRT specialist radiographer also review contour changes and avoidance of organs at risk such as the spinal cord or lacrimal glands.

An evaluation of inter-rater agreement between radiographers was followed by the evaluation of agreement between the SCR and DR procedures. Percentage of occasions DR changes radiographers' clinical judgement, along with the time taken to perform registrations, and validated radiographer satisfaction [29, 30] were completed for both SCR and DR. The validated radiographer satisfaction questionnaire was an adapted four-item Likert scale with a scoring scale of 0–3 (0, least satisfactory; 1, slightly satisfied; 2, moderately satisfied; 3, most satisfactory). Satisfaction scores were calculated for SCR and DR for each patient.

Finally, correction errors were calculated for SCR and DR for comparison (Figure 1).

Statistical Analysis

Systematic (Σ) and random (σ) geometric errors were analyzed as per van Herk [28] with respect to the average geometric displacement with standard deviation per patient and population between the CT reference scan and the CBCT localization scan for the multiple ROI displacements and SCR and DR correction values to determine geometric errors [3]. Systematic errors are a constant observed trend in geometric displacements. Random errors are geometric displacements not consistent with a trend.

Population error used in our study was

Σ_{pop} = The standard deviation of the patient groups' systematic errors;

σ_{pop} = The root mean square of the patient groups' random errors.

Population systematic and random errors were evaluated against a 3-mm local tolerance threshold [3]. This methodology was used for corrective values too.

Intraclass correlation coefficients (ICCs) were used to evaluate agreement between three radiographers using both SCR and DR. An interclass correlation was considered significant at the $P < .05$ level [31]. A Bland–Altman method with 95% limits of agreement (LoA) [32] was then used to determine the agreement of geometric displacement between the registration matches of SCR and DR procedures, using a clipbox and a mask of a suitable inferior neck node CTV.

A modified Bland–Altman approach was used to define the 95% LoA between the two registration procedures. A clinical threshold of 3 mm in each direction was determined as standard clinical practice, as such that the different registrations could be considered equivalent or used interchangeably if the 95% LoA were within 3 mm [33]. In the case where there is no obvious relation between the differences and the mean, a summary of the potential lack of agreement was completed by a calculation of bias estimated by the mean difference and the standard deviation of the differences. The rejection of agreement was considered significant at the $P < .05$ [29, 33]. The percentage of occasions that DR changed the clinical judgement of radiographers was also calculated to determine the appropriateness of implementing DR. Efficiency of DR was assessed by measuring the times radiographers' commenced SCR or DR, made a final judgement on the registration including any adjustments were recorded for every fractional image. Mean times for radiographers to complete this were calculated for SCR and using DR.

Statistical analyses were performed using SPSS Statistics Version 23 (IBM, Portsmouth, UK).

Table 1
Patient Demographics

Patient Demographics	Mean/Standard Deviation or Count
Participants	10
Age in years	69 (9)
Sex	
Female	3
Male	7
Primary tumour	
Tonsil	6
Tongue	2
Parotid	2

Table 2
Systematic and Random Displacement Errors of Three ROI (ROI-Total, ROI-1, ROI-2)

ROI	ML (mm)		CC (mm)		VD (mm)		Roll (Rot°)		Pitch (Rot°)		Yaw (Rot°)	
	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}
Total	1.03	0.73	1.20	1.47	1.43	1.14	0.5	1.0	0.26	0.43	0.31	0.43
1	1.17	1.30	1.25	1.90	1.39	1.97	0.61	0.55	0.82	0.63	0.70	0.63
2	2.89	2.30	3.00	2.50	3.37	3.01	1.44	1.25	0.86	0.85	0.70	0.85

CC, cranio–caudal; ML, mediolateral; VD, ventrodorsal; Rot, rotation; Σ_{pop}, the standard deviation of the patient groups' systematic errors; σ_{pop}, the root mean square of the patient groups' random errors.

Results

Ten selected patient datasets consisting of seven male and three female patients with diagnosed oropharyngeal cancers, mean age of 69 years (standard deviation = 9), were included (Table 1). All received volumetric-modulated arc radiotherapy of 66 Gy in 30 fractions to a primary tumour in the head and neck including the inferior neck nodes. A total of 90 CBCT images were registered and matched.

A preliminary evaluation of setup errors found systematic errors in the total and superior ROI were within a 3-mm imaging threshold tolerance, although in the mediolateral and ventrodorsal (VD) direction, the random error breached the threshold in some patients. In the mediolateral, cranial–caudal, and VD directions, errors up to 5 mm were measured. In the inferior ROI, the systematic errors were within the 3 mm tolerance in the mediolateral and cranial–caudal directions although breaching the 3 mm tolerance in the VD direction. Rotational errors were within a local clinical threshold tolerance of 3° (Table 2).

Inter-rater agreement between radiographers was analysed finding an ICC for the SCR was 0.867 and for DR 0.917 demonstrating statistically significant agreement ($P \leq .000$).

The 95% LoA between SCR and DR procedures in the mediolateral, cranial–caudal, and VD translational directions were −6.40 to +4.91, −7.49 to +6.05, and −7.00 to +5.44 mm, respectively (Figure 3). Variation existed in the mediolateral and VD directions (mean differences −0.57 to −0.77 mm) suggesting that there are systematic differences between registrations mainly in mediolateral direction. This can be observed in the Bland–Altman Plot with many values beyond the clinical threshold with some outlier's plotted beyond the LoA. There is an observed trend suggesting that a larger geometric displacement results in a greater difference between registrations, which is more pronounced in mediolateral direction. The mediolateral direction demonstrated proportional bias which was statistically significant ($P \leq .001$) suggesting non-agreement between registrations. In the cranial–caudal and VD directional, there was no proportional bias which was not statistically significant ($P = .074$–$.207$) suggesting agreement between registrations. To compare the consistency of registrations, the percentage of values within a 3-mm clinical threshold was evaluated for the mediolateral, cranial–caudal, and VD direction. The percentage of registrations within the clinical 3 mm threshold was 32%–65% demonstrating variation in all directions (Figure 3). The 95% LoA between SCR and DR procedures in the roll, pitch, and yaw rotations were −2.09 to +1.86, −3.24 to +2.06, and −1.74 to +1.57°, respectively (Figure 4). Little variation existed in the roll, pitch, and yaw rotations (mean differences −0.08 to −0.59) suggesting systematic differences between registrations in the pitch rotation. This can be seen in the Bland–Altman plot with tight clusters of data points around the mean and difference lines in the roll and yaw rotations. The pitch rotation plot demonstrates a greater spread of data. However, there are a few outliers outside the clinical threshold and LoA. Roll and Yaw rotations demonstrated no proportional bias which was not statistically significant ($P = .493$–$.453$) suggesting agreement. However, the pitch rotation demonstrated proportional bias which was statistically significant ($P \leq .001$) suggesting non-agreement between registrations. Eighty percent of DR image matches resulted in a change in clinical judgement to ensure the inferior nodes were sufficiently covered. Mean registration and

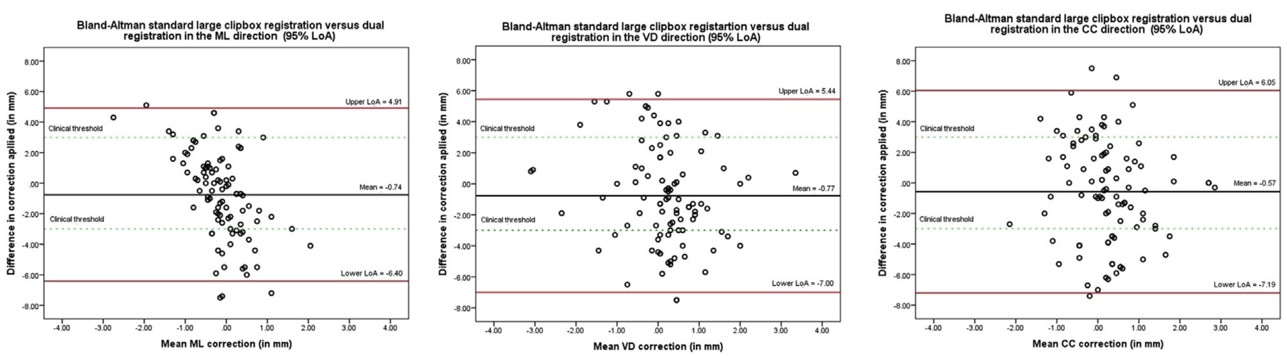

Figure 3. Agreement between SCR and DR the mediolateral (ML), cranio–caudal (CC), and ventrodorsal translational directions using a Bland–Altman approach.

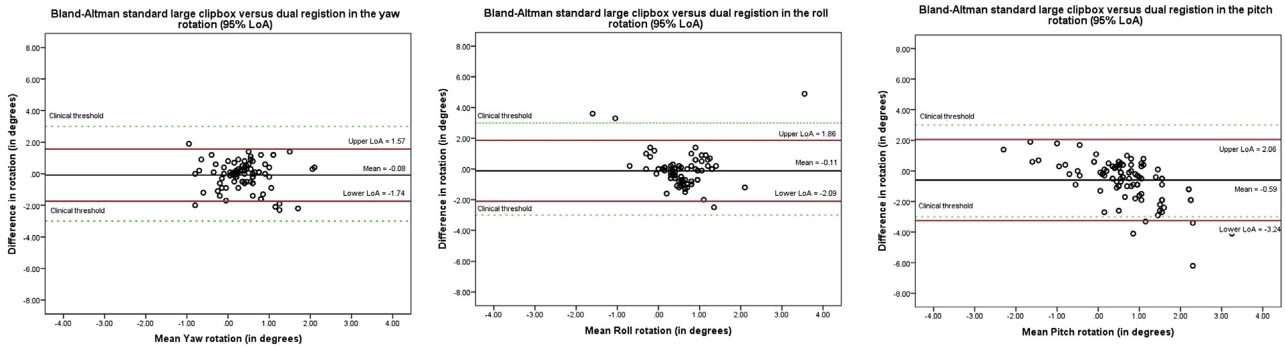

Figure 4. Agreement between a SCR and DR in the roll, pitch, and yaw rotations using a Bland–Altman approach.

matching times (seconds) for SCR and DR were 94 and 115, respectively. The radiographer satisfaction scores were 73% (3, most satisfied), 26% (2, moderately satisfied), 1% (1, slightly satisfied), and 0 (0, least satisfactory) for DR and 46% (3, most satisfied), 33% (2, moderately satisfied), 18% (1, slightly satisfied), and 3% (0, least satisfactory) for SCR. The use of DR resulted in greater geometric correction values demonstrating that SCR could underestimate the correction required (Table 3).

Discussion

The results of this pilot study demonstrate there is a clinical difference between using a SCR and DR in patients with oropharyngeal cancer based on these parameters. Consistent with other studies [4–9], the preliminary setup error data demonstrated that there is a distinct variation in head and neck anatomy in regards to systematic and random errors. Systematic and random errors were greater in the lower neck. The preliminary data justified piloting DR as a viable method for IGRT in patients with oropharyngeal cancer.

ICC inter-rater reliability demonstrated statistically significant agreement between radiographers using either an SCR or DR. This is encouraging as DR is designed to be a thorough method of image guidance, and good levels of agreement suggest reliability among radiographers comparable to results demonstrated by Campbell et al [14] in patients with prostate cancer. A Bland–Altman analysis evaluated the differences between the two registration procedures finding that in mediolateral direction, there was proportional bias suggesting non-agreement between the SCR and DR. A difference between the two registration procedures was demonstrated, which corresponded to an 80% change to radiographers clinical judgement after using DR. The data suggest the change in clinical judgment using DR was mainly to ensure that the lower neck nodes were adequately covered by the PTV in 70% of cases. This is consistent findings from Hawkins et al suggesting that the image volume chosen has an impact on the overall registration. The timing data demonstrate that DR takes on average 21 seconds longer than the SCR, which is logistically acceptable to clinical practice. Considering that DR is new to our department, it was encouraging that radiographers took little time in learning to become independent operators of this procedure as well as finding DR a little more satisfactory than SCR.

Our findings contrast with Campbell et al [14] who found no change in clinical judgement, but did demonstrate that DR was a more efficient procedure. However, these authors were evaluating the use of DR in patients with prostate cancer which could explain the difference in results. There are no known studies evaluating the use of DR in head and neck cancer; therefore, the present study should help to fill this gap. Furthermore, this work builds on Hawkins et al [13] in optimizing the registrations of CBCTs to maximize clinical outcomes. However, it is acknowledged that DR is a feature only available in Elekta systems.

The setup error data using DR were lower than using large clipbox ROI. This could be because of the precision of DR, specifically the focus on soft tissue which is known to move independently of bony anatomy and in this case resulting in lower correction errors. The data from Tables 1 and 2 contrast, but are demonstrating different clinical implications. Using large ROI, specifically in the lower neck suggest that there is need to develop the thermoplastic mask immobilization to improve stability which will reduce setup errors. This is consistent with other studies finding thermoplastic immobilization to lack stability in

Table 3
Systematic and Random Correction Values for Standard Clipbox Registration and Dual Registration

Registration Method	ML (mm)		CC (mm)		VD (mm)		Roll (Rot°)		Pitch (Rot°)		Yaw (Rot°)	
	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}	Σ_{pop}	σ_{pop}
SCR correction	1.03	0.73	1.20	1.47	1.43	1.14	0.5	1	0.26	0.43	0.31	0.43
DR correction	1.56	1.54	1.41	1.79	1.57	1.71	0.40	0.41	0.77	1.40	0.33	0.45

CC, cranio–caudal; ML, mediolateral; VD, ventrodorsal; Rot, rotation; Σ_{pop}, the standard deviation of the patient groups' systematic errors; σ_{pop}, the root mean square of the patient groups' random errors.

the lower neck [34–38]. A recent publication titled "ESTRO ACROP guidelines for positioning, immobilization and position verification of head and neck patients for radiation therapists" [19] gives recommendations to improve methods of producing thermoplastic masks have the potential to improve stability. However, the data from suggest that DR is a highly suitable instrument for IGRT to monitor this variability in patients with oropharyngeal cancer.

Limitations

Some limitations need to be addressed. A sample size of 10 is small. However, this was a pilot study before a larger substantive study which will require effect size calculations. Another limitation is that DR is only available on Elekta systems and not available on other commercial systems which may exclude wide clinical uptake. The implications of the results on whether a replan was required was not undertaken and should be included in future work.

Conclusion

DR might be an effective method of image guidance than using an SCR in patients with oropharyngeal cancer. Adequate inter-rater agreement was found between radiographers using DR. DR was found to deviate from the SCR but supported radiographers' clinical judgement.

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