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Analysis of Online and Offline Head and Neck Image-guided Radiation Therapy

Amanda Waldon, BMedRadSc[a*], Ash Plank, PhD[b] and Mark Middleton, MBA[a]

[a] *Radiation Oncology Queensland, Toowoomba, Cairns & Gold Coast, Queensland, Australia*
[b] *Oncology Research Australia, Toowoomba, Cairns & Gold Coast, Queensland, Australia*

ABSTRACT

Purpose: The introduction of a daily image-guided radiation therapy (IGRT) program is an important step. It has implications for the radiation therapy team in terms of accuracy, workflow, and decision making. This study assesses how successful a radiation therapy department has been in using this technology and the accuracy of individual decision making when comparing online and offline image match data.

Methods: Twenty intensity-modulated radiation therapy head and neck patients had their IGRT data assessed retrospectively. Online analysis was completed based on a 0-mm action threshold. Offline analysis was then conducted on the same data. Any discrepancies in decision making were then assessed.

Results: Results indicated that the treating radiation therapy team was able to image match consistently when benchmarked against their colleagues in the offline environment. Analysis of online versus offline corrections in each of the three orthogonal directions showed strong agreement. Further analysis revealed no statistically significant differences for systematic errors, whereas a statistically significant but small difference was present for random error.

Conclusion: In this age of sophisticated equipment, daily IGRT is a valuable modality. However, the introduction of daily online IGRT inclusive of a 0-mm action threshold for head and neck IGRT requires careful consideration and evidence that such accuracy can be achieved. Ultimately, it is still the radiation therapist who must make the decision, which places great importance on the competency of the treating radiation therapy team.

RÉSUMÉ

Objet: La mise en place d'un programme quotidien de radiothérapie guidée par l'image (RTGI) est une étape importante. Elle entraîne des répercussions pour l'équipe de radiothérapie en termes de précision, de flux du travail et de prise de décision. Cette étude évalue le degré de succès d'un service de radiothérapie dans l'utilisation de cette technologie et la précision des décisions individuelles prises lors de la comparaison des données d'appariement des images en ligne et hors ligne.

Méthodes: Les données de RTGI de vingt patients ayant reçu des traitements de radiothérapie par modulation d'intensité (RTMI) de la tête et du cou ont fait l'objet d'une évaluation rétrospective. L'analyse en ligne a été réalisée sur la base d'un seuil d'intervention de 0 mm. Une analyse hors ligne a ensuite été effectuée sur les mêmes données. Les différences dans la prise de décision, s'il y a lieu, ont ensuite été évaluées.

Résultats: Les résultats indiquent que l'équipe de radiothérapie a été en mesure d'apparier les images de façon constante en comparaison de leurs collègues dans l'environnement hors ligne. L'analyse des corrections en ligne par rapport aux corrections hors ligne dans chacune des trois directions orthogonales indique un accord fort. Des analyses plus poussées n'ont pas permis de révéler des différences statistiquement significatives pour les erreurs systématiques, alors qu'un écart statistiquement significatif mais faible apparaissait pour l'erreur aléatoire.

Conclusion: À notre époque d'équipement sophistiqué, la RTGI quotidienne est une modalité intéressante. Cependant, la mise en place d'un programme en ligne quotidien de RTGI avec un seuil d'intervention de 0 mm pour la RTGI de la tête et du cou demande un examen attentif et la preuve que ce degré de précision peut être atteint. En bout de ligne, c'ent encore au radiothérapeute qu'il incombe de prendre la décision, ce qui donne une grande importance à la compétence de l'équipe de radiothérapie.

Keywords: Image-guided radiotherapy; kV imaging; online corrections; offline corrections; action threshold

Introduction

When delivering intensity-modulated radiation therapy (IMRT) for head and neck patients, it is accepted that

* Corresponding author: Amanda Waldon, BMedRadSc, Radiation Oncology Queensland, Gold Coast University Hospital, 1 Hospital Boulevard, Southport, Queensland, Australia 4215.
E-mail address: amanda.waldon@roq.net.au (A. Waldon).

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image-guided radiation therapy (IGRT) is an essential tool [1–4]. Currently, more and more departments are using daily IGRT to ensure precise daily field placements [5–11]. Daily IGRT involves online and offline image assessment, in which the offline image review process either confirms the correct positional shift occurred or identifies a discrepancy with the previously performed online correction. With all the image reviews that occur comes the inherent risk that an incorrect field placement could be made because of differing levels of therapists' experience and/or training [12–14]. These variables may influence the effectiveness of an IGRT program, highlighting the increased pressures placed on departments that use daily IGRT. One avenue to assess correct online isocentre placement is to retrospectively analyse both image match data performed online and offline. For this study, 20 head and neck patients receiving IMRT at Radiation Oncology Queensland (ROQ), Toowoomba, Australia, had their online and offline images assessed retrospectively. The results will ascertain if consistency was achieved between the recorded online and offline corrections, indicating that the treating radiation therapy team is capable of safe and efficient daily online IGRT.

Methods

Ethics Approval

This study received low-risk ethics approval from the Darling Downs Hospital and Health Service Human Research Ethics Committee in June 2013. All patients gave informed consent for their course of radiation therapy inclusive of IGRT.

Patient Selection

Patient selection eligibility required completion of a bilateral head and neck IMRT treatment course during the period June 2009–June 2011. Each patient had orthogonal images taken daily using kV onboard imaging for the entire course of their treatment. Imaging data from 20 randomly chosen patients fitting these criteria were chosen for the study. The cancer sites varied; however, all patients had involvement of the lower half of the head and bilateral neck nodes.

All patients were treated and imaged on a Varian (Palo Alto, CA) Clinac iX with kV onboard imaging using CIVCO Medical Solutions (Kalona, IA) stabilization equipment (Figure 1). This included, along with the use of the Varian Type-S head extension, an IMRT-reinforced thermoplastic Type-S mask, a Type-S Vac-Lok cushion customized to the patient's shape to immobilize the head, neck, and shoulders and an indexed knee support. The use of this stabilization solution is the subject of ongoing research at ROQ.

Prescribed fractionations varied slightly with one patient receiving 66 Gy in 33 fractions, four patients receiving 70 Gy in 35 fractions, and the remaining 15 receiving 60 Gy in 30 fractions. On review of the patient image sets, one of the 30 fraction patients did not complete the treatment course, which resulted in only 27 image sets.

Figure 1. CIVCO stabilization equipment.

Online and Offline Review

Online review refers to image analysis undertaken pretreatment at the treatment console by two radiation therapists and includes analysis, decision making, and intervention in field position if required. Offline review occurs after treatment has taken place and is performed away from the treatment console-removed from the pressure and potential time constraints of the online environment.

Image acquisition parameters were defined by the bony anatomy required to be visualized for an accurate match, although the maximum field size possible is 26.0 × 20.0 cm. Typically, the anterior image extends from the zygomatic arch to the clavicle heads inferiorly. Laterally, the field size for the anterior image is set to 26.0 cm for visualization of clavicle displacement. The lateral image parameters are set to the inferior aspect of the orbit extending through the humeral head, to visualize the cervical vertebrae to gauge any neck flexion present. Anteriorly to posteriorly, the maximum width is set to 26.0 cm to visualize the entire skull. Manual matching was performed for kV onboard imaging using template matching, which involved the planning digitally reconstructed radiograph being overlaid with the treatment image and matched to the corresponding outlined bony anatomy.

Departmental protocol states the anterior image dictates the superior-to-inferior (SI) and left-to-right (LR) displacements, whereas the lateral orthogonal image dictates the anterior-to-posterior (AP) displacement only. Anatomic matching structures involved matching to cervical spine 1 (C1) and the clivus initially to gauge head tilt and neck flexion [15]. More than a 5-mm discrepancy between the positions of C1 and C7 involved the patient to be repositioned. Straightness was assessed on the anterior image, matching the lateral edge of the skull and the spinous processes and edges of the cervical vertebral bodies. Discrepancies greater than 5-mm resulted in the patient being repositioned. The matching action threshold for head and neck IMRT patients is 0-mm.

For this retrospective analysis, all treatment images used were kV orthogonal images taken on a daily basis. The online and offline positional shift data logged within Varian's offline