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Assessing the Efficiency and Consistency of Daily Image-guided Radiation Therapy in a Modern Radiotherapy Centre

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ABSTRACT

Background: Patients at Radiation Oncology Queensland Toowoomba are treated using the assistance of daily image-guided radiation therapy (IGRT). Each patient's daily setup is exposed to a number of variables. This study investigates the effect that these variables have on the total time taken to analyse field placement and the total time taken for treatment, as well accessing setup error across a variety of treatment types.

Methods: This is a retrospective study of 80 patients across a variety of treatment sites where daily IGRT was undertaken using kilovoltage and megavoltage orthogonal images. Variables investigated include the treatment type, the imaging modality used, and the setup error of each session. Statistical analysis was then performed on the data.

Results: Patients being treated in the thoracic region had the greatest random setup error. The mean matching times were also longer for chest patients (197 seconds), whereas there were minimal differences in times regarding modality. Treatment times were longest for head and neck variables (399–405 seconds).

Conclusions: Pretreatment daily IGRT is beneficial to all patients and can be performed efficiently. Pelvic variables were the strongest performer, with fiducial markers providing the most consistent and rapid match times. Chest variables were the worst performer specifically regarding random setup error and match times indicating future work required on chest stabilization.

RÉSUMÉ

Objectifs: Les patients en oncoradiologie du Queensland Toowoomba sont traités quotidiennement au moyen de la radiothérapie guidée par l'image (IGRT). Chaque traitement est assujetti à de nombreuses variables. La présente étude examine l'effet de ces variables sur le temps consacré à analyser le déplacement du champ, le temps total de traitement et de l'évaluation des erreurs de réglage entre les différents traitements.

Méthodologie: Il s'agit dune étude rétrospective de 80 patients dans différents lieux de traitement où on a utilisé l'IGRT et des images orthogonales kV et MV. Les variables examinées étaient notamment le type de traitement, la modalité de l'image et l'erreur de réglage pour chaque séance. On a ensuite effectué une analyse statistique des données.

Résultats: On a relevé le plus grand taux d'erreurs aléatoires chez les patients traités dans la région thoracique. La moyenne des temps de rapprochement était également plus élevée pour les patients traités à la poitrine (197 s), alors que les différences étaient moins élevées en matière de modalité. Les temps de traitement étaient plus élevés pour la tête et le cou (399–405 s).

Conclusions: Le pré–traitement quotidien en IGRT profite à tous les patients et peut être exécuté efficacement. Les variables pelviennes affichaient le meilleur rendement, les repères de cadre assurant les temps de rapprochement les plus consistants et les plus rapides. Les variables de la poitrine ont donné les pires résultats, surtout en ce qui a trait à l'erreur aléatoire de réglage et les temps de rapprochement donnant le travail à exécuter pour la stabilisation de la poitrine.

Introduction

Image-guided radiation therapy (IGRT) is now considered an essential technique to ensure accurate field placement in radiation therapy [1–4]. As such, all patients across all treatment sites are treated with the assistance of daily IGRT at Radiation Oncology Queensland (ROQ), Australia. Currently, ROQ's Toowoomba site is equipped with two Varian Medical Systems (Palo Alto, CA) iX linear accelerators, one with kilovoltage (kV) on-board imaging and megavoltage (MV) electronic portal imaging (EPI), whereas the other has only MV EPI capabilities. When considering these two imaging modalities there is a vast difference in image quality [5–7]. There are many variables that can affect the efficacy of an IGRT program [8, 9]. It is noted that the time taken for staff

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to analyse images is potentially varied, not only because of imaging modality differences but also the experience level of the staff performing IGRT. For the purposes of this study, IGRT refers to planar MV and 2-dimensional kV orthogonal images. This study aimed to assess the efficiency and consistency of IGRT practice at ROQ by examining some of its variables (such as imaging modalities) and how they affect matching and treatment times across a number of different treatment types. Previous work has shown the positives and negatives of an anatomic site–specific IGRT program [3, 10–14]; however, there is little work in the broader context of a complete IGRT program. An exercise such as this is viewed as valuable because it can potentially reveal both the strengths and weaknesses of a department-wide IGRT program.

Methods

Treatment Types

This project was designated as a quality assurance activity/clinical audit after internal review and received low-risk/negligible ethical approval from the Darling Downs Human Research Ethics Committee on April 24, 2013. Five treatment types were selected for the study. These included chest (kV), pelvic patients (MV and kV), gold seed pelvis, and head and neck (H&N) (MV and kV). Gold seed pelvis patients were included as a separate treatment type because the matching process is different to other anatomic sites with the inclusion of fiducial markers in comparison to bony anatomy.

Patient Selection

For each of the five treatment types, 10 patients were randomly selected for each modality from a time period ranging from 2007 until 2012. Daily image guidance and kV image guidance commenced in 2007. Unfortunately, there were not enough chest patients treated with the assistance of MV IGRT because these patients are preferentially treated with kV imaging in the department. No MV pelvic gold seed data exist for the same reason. This meant eight treatment variables were used for a total of 80 patients. Only patients who fit set criteria were considered for the study. Therefore, each patient needed to be treated with the same imaging modality for the whole course of treatment as well as having orthogonal images taken daily.

Matching and Treatment Images

Treatment images used in the study were either MV or kV orthogonal images, and they were taken on a daily basis. All image sizes corresponded to the discretion of the planner who sets the field size as large as needed to be able to visualize enough information to make an accurate match. However, the maximum field size possible is 18.0 × 18.0 cm. Online matching was completely manual and conducted by the treatment radiation therapist. The planning digitally reconstructed radiograph was overlaid with the treatment image and matched to the corresponding bony anatomy. For the gold seed pelvis patients, a manual match to fiducial markers was used instead. Table 1 summarizes the different treatment types of patients, number of patients for each type, immobilization equipment used, image modality used for IGRT, and match technique.

Data Collection and Analysis

Once selected, each patient had his/her raw session data exported directly from Varian's Offline Review, giving rise to a total of 1,575 treatment sessions across the 80 patients. This export recorded the treating radiation therapists for each session, the session times in respect to each field treated, and online and off-line (pre- and postinterventional) match data in lateral, longitudinal, and vertical directions for each fraction. For this study, matching times have been defined as the time taken for the acquisition and analysis of the setup fields, whereas treatment time is the time between the first and last treatment beam. These data then underwent statistical analysis.

Statistical Methodology

Interest is in describing the distributions of the response variables (x, y, z errors, treatment, and matching times) by site and modality. A multilevel analysis is used to simultaneously account for both within and between patient variability, treating patients as a random factor, and site and modality as fixed factors. Specifically, a normal-based linear model is fitted to each response variable allowing for differences in mean response and differences in both within and between patient variances across the six modality by site levels. The models are fitted using restricted maximum likelihood to minimize bias in parameter estimates. Normality of estimated random effects and residuals were checked visually using q-q plots.

Table 1
Patient Demographic Summary

Treatment Type	Patient Number	Immobilization Equipment	Imaging Modality	Match Technique
Chest (kV)	10	Wing board, grip bar, knee cushion	kV orthogonal images	Bony anatomy
Pelvis (kV)	10	Headrest, vacuum immobilization bag, pelvic board	kV orthogonal images	Bony anatomy
Pelvis (MV)	10	Headrest, vacuum immobilization bag, pelvic board	MV orthogonal images	Bony anatomy
GS pelvis (kV)	10	Headrest, vacuum immobilization bag, pelvic board	kV orthogonal images	Fiducial Markers
H&N (kV)	10	Headrest, thermoplastic shell, knee cushion	kV orthogonal images	Bony anatomy
H&N (MV)	10	Headrest, thermoplastic shell, knee cushion	MV orthogonal images	Bony anatomy

H&N, head and neck; kV, kilovoltage; MV, megavoltage.