ELSEVIER

Journal of Medical Imaging and Radiation Sciences xx (2017) 1-8

Journal of Medical Imaging and Radiation Sciences

Journal de l'imagerie médicale et des sciences de la radiation

www.elsevier.com/locate/jmir

Evaluation of Bony Anatomy Versus Endobiliary Stents as Surrogates for Volumetric Image Guidance in Pancreatic Cancer

Christos Chortogiannos, BSc, MRT(T)[a], Douglas Moseley, PhD[ab], Jasmine Chen, BSc, MRT(T)[a], Alana Pellizzari, BSc, MRT(T)[a], James Brierley, MB, BS[ab] and Winnie Li, MSc, MRT(T)[ab*]

[a] *Radiation Medicine Program, Princess Margaret Cancer Centre, Toronto, Ontario, Canada*
[b] *Department of Radiation Oncology, University of Toronto, Toronto, Ontario, Canada*

ABSTRACT

Purpose: Online treatment setup verification through cone-beam computed tomography (CBCT) in pancreatic cancer patients is limited by low soft tissue contrast. This study aims to quantify the relative positional displacements between bony anatomy and endobiliary stents as surrogates for pancreatic cancers.

Methods: Under ethics approval, 258 localization CBCT images from 15 pancreatic patients with endobiliary stents were evaluated. CBCTs were registered through two methods to assess translations and rotations: target adjacent bony anatomy through automatic registration and automatic stent registration through a shaped region of interest. Displacement vector differences between surrogate registrations were calculated and analysed.

Results: Mean (±standard deviation) translational displacements in the right/left, superior/inferior, anterior/posterior directions were 0.9 ± 3.1 mm, 1.8 ± 4.2 mm, and 0.4 ± 2.5 mm for bone registrations, respectively, and 0.9 ± 5.6 mm, −1.5 ± 5.7 mm, and −0.5 ± 4.3 mm for stent registrations, respectively. Mean (±standard deviation) rotational displacements for pitch, roll, and yaw were 0.16 ± 0.97°, −0.32 ± 0.96°, and −0.77 ± 1.8° for bone registrations, respectively, and −0.94 ± 4.6°, −0.4 ± 7.4°, and −0.13 ± 6.64° for stent registrations, respectively. Mean displacement vector between surrogates was 4 mm, with 43% of fractions measuring displacement vectors >5 mm. A maximum displacement vector of 22.6 mm between surrogates was observed.

Conclusions: Varying positional differences were observed between bone and stent registration for pancreas CBCT–image-guided radiation therapy. Setup errors for stent matching were larger than bone registrations. Further research is required to determine if endobiliary stent position is equivalent to the pancreas' location to determine its suitability as a surrogate.

RÉSUMÉ

But : La vérification en ligne de l'installation de traitement par tomodensitométrie à faisceau conique (CBCT) chez les patients atteints d'un cancer du pancréas est limitée par le contraste des tissus mous. Cette étude vise à quantifier les déplacements positionnels relatifs entre l'anatomie osseuse et les endoprothèses endobiliaires comme substituts des cancers du pancréas.

Méthodologie : Avec l'approbation du comité d'éthique de la recherche, 258 images de localisation CBCT prises chez 15 patients atteints d'un cancer du pancréas et ayant une endoprothèse endobiliaire ont été évaluées. Les images CBCT ont été superposées en utilisant deux méthodes pour évaluer la translation et la rotation; la superposition automatique pour l'anatomie osseuse adjacente cible et la superposition automatique des endoprothèses par la forme de la région d'intérêt. Les écarts de vecteur de déplacement entre les superpositions des substituts ont été calculés et analysés.

Résultats : Les déplacements translationnel moyens (±écart-type) dans les directions gauche/droite, supérieur/inférieur et antérieur/postérieur étaient respectivement de 0,9±3,1 mm, 1,8±4,2 mm et 0,4±2,5 mm pour les superpositions osseuses, et de 0,9±5,6 mm, −1,5±5,7 mm et −0,5±4,3 mm pour la superposition des endoprothèses. Le déplacement rotationnel moyen (±écart-type) en tangage, roulis et lacet était respectivement de 0,16±0,97°, −0,32±0,96° et −0,77±1,8° pour la superposition osseuse et de −0,94±4,6°, −0,4±7,4° et −0,13±6,64° pour la superposition d'endoprothèses. Le vecteur de déplacement moyen entre les substituts était de 4 mm, avec 43% des fractions mesurant les vecteurs de déplacement >5 mm. Un facteur de déplacement maximal de 22,6 mm entre les substituts a été observé.

Conclusions : Des écarts positionnels variés ont été observés entre les superpositions de structures osseuses et d'endoprothèses en examen CBCT-IGRT du pancréas. Les erreurs de positionnement pour l'appariement des endoprothèses étaient plus élevées que pour la

* Corresponding author: Winnie Li, MSc, MRT(T), Research Radiation Therapist, Radiation Medicine Program, Princess Margaret Cancer Centre, 610 University Avenue, Cobalt Lounge, Level 2B, Toronto, ON, Canada M5G 2M9.
E-mail address: winnie.li@rmp.uhn.on.ca (W. Li).

1939-8654/$ - see front matter
http://dx.doi.org/10.1016/j.jmir.2017.03.002

superposition des structures osseuses. D'autres recherches seront nécessaires afin de déterminer si la position des endoprothèses endobiliaires correspond à l'emplacement du pancréas pour en déterminer l'acceptabilité à titre de substitut.

Keywords: CBCT; Pancreas; Stents; Interfraction motion

Introduction

Patients with pancreatic cancer face a poor 5-year survival rate of approximately 4% [1, 2]. It is expected that 4,800 Canadians will be diagnosed with pancreatic cancer, of which 4,600 will die from their disease [3]. Currently, the preferred curative treatment for pancreatic cancer is surgical resection of the tumour [4]. However, approximately 80% of patients are found to have unresectable disease, one-third of which have no distant metastases [4, 5]. For unresectable pancreatic cancer, a combination of chemotherapy and radiation therapy have shown effective local disease control and increase overall survival [4, 6].

The delivery of radiation therapy to pancreatic cancer is limited by the surrounding organs at risk, in particular, the stomach, duodenum, and small intestines [1, 7]. The use of image-guided radiation therapy (IGRT) through cone-beam computed tomography (CBCT) improves treatment delivery accuracy by reducing geometrical uncertainties, facilitating dose escalation while limiting toxicities [8]. Through the use of kilovoltage (kV) CBCT, bony structures are clearly defined both visually and spatially, with increased visualization of soft tissue targets.

Unfortunately for soft tissue targets in the abdomen such as the pancreas, image quality is obscured by low soft tissue contrast and differential organ motion. Due to the reduced quality of the image, it is difficult to delineate the pancreas or primary disease thus relying on the bony anatomy as a stable surrogate to ensure treatment delivery accuracy [1, 9]. Additionally, it has been shown that the pancreas is a mobile organ and its location is not predictable in correlation with the bony anatomy in 80% of fractions [1, 4, 7]. A suitable surrogate to identify the location of the disease during daily IGRT for pancreatic cancer patients is required [10]. Patients are implanted with endobiliary stents to relieve symptoms of biliary strictures caused by the gross disease [1]. Endobiliary stents have been shown to be a suitable surrogate of motion with equivalent displacement compared to the target during respiration [11]. A large fraction of patients with advanced pancreatic cancer have endobiliary stents due to the increase of stricture of the biliary duct due to the increasing mass.

Interfractional variation of the pancreas has been studied through the use of fiducial markers, revealing significant variation in the cranial/caudal direction [12–14]. It is evident that breathing motion significantly contributes to this cranial/caudal variation [12, 13, 15] as pancreatic motion has been reported to vary between 1.0 mm to 25.6 mm [13]. van der Horst et al [13] reported a mean interfractional displacement of 9.4 mm was observed, and a displacement >10 mm was observed for 39% of fractions relative to the bony anatomy of the patient. Other studies comparing endobiliary stents have found that pancreatic tumor position is improved in 67% of fractions when using endobiliary stents compared to bony anatomy [15]. However, limitations of endobiliary stents have been found in another study, showing a mean displacement vector of 6.6 mm compared to fiducial tumor markers and displacements >10 mm in 20% of fractions [15]. This suggests that planning target volume (PTV) margins may be reduced through the use of the stents; however, a larger margin would still be required relative to the proximity of the pancreas to the stomach and small bowel, limiting dose escalation. However, the study performed by van der Horst et al 2014 focused only on translational displacements of the stent and does not account for the impact of stent rotations or potential effect of amplitude of breathing motion on stent movement.

For pancreatic patients currently treated at our institution, the surrogate used for daily IGRT through CBCT is bony anatomy adjacent to tumor location. Approximately one-third of all pancreas patients treated at our institution have an endobiliary stent implanted. The utilization of endobiliary stents as a surrogate for target location may increase IGRT accuracy, potentially leading to a reduction to the large PTV margins (around visible tumour) to allow dose escalation. This study aims to quantify the relative positional displacements between bony anatomy and endobiliary stents on volumetric images as surrogates for pancreatic cancers.

Methodology

Study Population

Pancreatic cancer patients treated with radiation therapy between January 2013 and July 2015 were included in this Institutional Research Ethics Board approved study. During this period, approximately 90 patients were treated for pancreatic cancer of which 19 patients had an endobiliary stent. Within our population, there were three different types of endobiliary stents: hollow plastic, hollow metallic, and solid plastic (solid surface with side holes). Each stent was placed in the biliary duct as a palliative measure. Exclusions included patients with significant weight loss during course of treatment (difference greater than 2 cm in anterior–posterior direction) and patients who also have extrahepatic drains. Patients with significant weight loss were excluded as this factor affected the ability of the automatic registration to perform reliably; excluding this group reduced potential observer bias as manual registration would be required. Fifteen patients met the inclusion/exclusion criteria. Both palliative and radical treatments were analysed as well as