CHAPTER 1

Introduction

1.1 Historical Background

Modern radiation therapy has the ability to utilize multimodality imaging technologies for disease definition, patient setup and treatment assessment (Hardcastle *et al*., 2012). Whereas, the helical megavoltage computed tomography (MVCT) is the kind of volumetric imaging modalities, have been adopted with the primary purpose of more accurate target localization (Lee *et al*., 2008). Moreover, the information about inter-fractional anatomical variations have become more accessible due to some head and neck cancer patients undergo significant anatomical changes, and these may result in unforeseen changes in delivering a dose (Lee *et al*., 2008). In ideal practice when a patient's anatomy changes, a new adaptive plan must be developed, as the concept of adaptive radiotherapy (ART) (Castelli *et al*., 2015). These procedures include the modification of an initial plan according to the changes in target volume or normal organs, the manual contouring can be used to modify the deformation to evaluate the dosimetric effect (Kupelian *et al*., 2006; Langen *et al*., 2005; Morin *et al*., 2007). However, the process of manual contouring is time-consuming. Therefore, a deformable image registration (DIR) can be used to resolve these challenges (Ramadaan *et al*., 2013). By registering multiple daily CTs to the planning CT, the algorithm can automatically generate deformed contours on daily CTs while creating cumulative doses by tracking the dose to the tissue voxels throughout a course of radiation therapy (Lee *et al*., 2008).

Deformable image registration attempts to provide the mapping between volume elements in one image to the corresponding volume between 2 different image sets the source and target images. There are many automated DIR algorithms that can provide a mapping or a deformation vector field (DVF) between two images (Bender *et al*., 2012).

Regarding the transformation frameworks, *the asymmetric transformation* constitutes the majority of the existing registration algorithms. As a consequence, when interchanging the order of input images, the registration algorithm does not estimate the inverse transformation. The statistical analysis that follows registration is biased on the choice of the target domain, whereas *symmetric transformation* simultaneously estimates both the forward and the backward transformation. The data matching term quantifies how well the images are aligned when one image is deformed by the forward transformation and the other image of the backward transformation (Sotiras *et al*., 2013). For the deformation algorithms, *Original Horn & Schunck optical flow* and *Original Demons* are the non-parametric algorithms based on a vector per voxel that describe the displacement and attempt to model the deformation of the anatomy regarding well-studied models of fluid flow or the deformation of a viscoelastic material (Kristy *et al*., 2013). The Original Horn & Schunck optical flow algorithm can perform an accurate DIR in low contrast regions (Yeo *et al*., 2013), however, the Original Demons is the well-known algorithm for intensity-based DIR (Weistrand *et al*., 2015). Both the optical flow and the Demons algorithms were used in deformable registration for commercial software (Yeo *et al*., 2013; Weistrand *et al*., 2015). Regarding the mapping direction, when the *forward mapping* is estimated, every voxel of the source image is pushed forward to its estimated position in the target image. On the other hand, when the *backward mapping* is estimated, the pixel value of a voxel in the target image is pulled from the source image (Sotiras *et al*., 2013). Therefore, the sequences of the target domain were the effect of the deformable registration process.

Regarding DIR accuracy, besides the deformation model, the accuracy depends on the image quality. The DIR in kVCT images demonstrated good agreement between the automatically deformed and the physician drawn ROIs for OARs (Hardcastle *et al*., 2012; Hardcastle *et al*., 2013), and the DIR in kVCT has been shown to be a clinically useful method for automatic contour propagation in adaptive radiotherapy (Hardcastle *et al*., 2013). Nowadays, daily MVCT images on helical tomotherapy units (Tomotherapy Inc., Madison, Wisconsin, USA) have become the standard guidance for most tomotherapy users, and it is mainly for the alignment of the patient. However, the ability to resolve soft-tissue contrast differences in MVCT is fundamentally limited by the number of photons used to create the image. If the number of photons is too low, noise will predominate, and that precludes the visibility of low-contrast objects (Keller et al., 2002). These issues may be behind the degradation of deformable registration accuracy (Yang *et al*., 2009).

For the application of MVCT in deformable dose accumulation routinely, accurate structure deformation even in low contrast regions is required (Yeo *et al*., 2013) because the accuracy of DIR may have a significant dosimetric impact on radiation treatment planning (Bissonnette *et al*., 2009). Accuracy of DIR which is studied in MVCT images is still lacking adequate information (Kristy *et al*., 2013). Thus, this study aims to quantify the accuracy of deformable image registration on MVCT images, which assess in phantom and clinical cases by using different deformation methods, which include (i) transformation frameworks, (ii) DIR registration algorithms, and (iii) mapping direction. Moreover, the weekly cumulative doses were analyzed to assess the dosimetric impact of the DIR methods for the dose accumulation. The dosimetric variations from the initial plan were reported, and correlations of these variations with anatomic changes and DIR methods were explored.

1.2 Research Objectives

1.2.1 To quantify the accuracy of deformable image registration when using eight deformation methods in the original Horn & Schunck optical flow or Demons algorithms by asymmetric or symmetric transformations with forward or backward mapping on MVCT images by using DIRART software which evaluate in geometric phantom and nasopharyngeal carcinoma (NPC) patients.

1.2.2 To evaluate the dosimetric impact of the deformation methods for estimating the dose accumulation on MVCT images by assessing dose in the target and normal organ for NPC patients.