Original Research Article

Comparison of CT only contour with MRI guided contouring in external beam radiotherapy for carcinoma rectum

Sudharani P[1], Goutham K.C[2]

[1]Dr. Sudha Rani, Assistant Professor, [2]Dr. Katta Charu Goutham, DNB, Senior Resident, both authors are attached with Department of Radiation Oncology, MNJ Institute of Oncology and Research Centre, Hyderabad, Telangana, India.

Address for Correspondence: Dr. Sudharani, Email: drsudharanimnj@gmail.com

Abstract

Aim: The purpose of the study is to compare CT only contour with MRI guided contour for delineation of the gross tumour volume (GTV) in carcinoma of rectum in external beam radiotherapy. **Materials and Methods:**18 patients who underwent external beam radiotherapy treatment for carcinoma rectum were selected retrospectively. For all the patients, both CT and MRI were done as a part of planning process. Two sets of GTV were generated using only CT and with MRI assistance by a single oncologist. The generated contours were then compared and quantitatively analyzed using volume analysis and dice index. **Results:** The CT mean GTV was larger than the MRI mean GTV volume (68.54 ± 17.56 cc for CT versus 80.95 ± 19.19 cc for MRI). The dice index value between CT only GTV and MRI assisted GTV was 0.71 ± 0.13. The comparison of GTVs showed that the GTV_MRI was comparatively small and inside the GTV_CT except for six patients for whom GTV_MRI was marginally outside the GTV_CT. **Conclusion:** The study showed that using MRI guidance for GTV delineation in carcinoma rectum is preferable and more accurate as compared to CT-only imaging because of superior soft tissue contrast.

Keywords: MRI, gross tumor volume, CT imaging

Introduction

Radiotherapy has progressed from conventional portals to computerized planning with the introduction of computed tomography (CT). Planning based on computed tomography involves generation of contours on the CT scan set [1]. Delineation of gross tumor volume (GTV) is the crucial step in radiotherapy planning process.

Appropriate imaging modality is required to confidently demarcate the GTV [2]. The imaging modality should be selected in such a way that inter-observer variability is negligible in almost all type of cancers. Magnetic resonance imaging (MRI) has gained lot of importance in the field of radiotherapy, especially for delineation of tumors and also organ at risk (OARs)[3]. MRI offers best soft tissue contrast when compared with the computed tomography (CT) imaging. CT images are based on electron density (Hounsfield units) and 3D images are obtained on a gray scale, whereas MRI imaging is based on proton density. With the advent of computerized treatment planning system, CT images are used as a 'standard' in radiotherapy department where dose calculation is performed directly on them and at the same time geometric distortion is absent. MRI cannot be used for dose calculation purpose as they are based on proton densities, but MRI can be used as an additional imaging modality along with CT images so to delineate the GTV [4]. This process is quite important in recent times with the advancement of intensity modulated radiation therapy (IMRT), Adaptive radiotherapy (ART) etc. Thus, simultaneous integrated boost (SIB) or boost dose to GTV in early type of cancers could be confidently delivered if imaging modality like MR is used for delineation purpose. In this study we have compared the GTV delineation with CT image set and on CT image co-registered with MR image set for rectal cancers and to find out the real advantage of using MR-assisted contouring.

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Materials and Methods

Patient selection: 18 rectal carcinoma patients who underwent routine pathology, clinical examinations and treatment for radiotherapy in MNJ institute of oncology from August 2016 to February 2017 were selected retrospectively for this study. Patient were selected such that MR image is also acquired for the patients before radiotherapy treatment.

CT acquisition protocol: Patients underwent routine 4-clamp pelvis mask (orfit) on a flat couch top placed with CT markers. Patients were then shifted to CT scanner (Siemens Somatom Sensation 64 slice) and 3D images are acquired with 3 mm slice thickness at standard pelvic imaging protocol. Both plain and contrast CT images are acquired with same protocol. The CT images are transferred through Picture archiving and communication (PACS) to the treatment planning software (Varian Eclipse version 13.1) platform folder. These images are then imported into the software and are named accordingly for identification.

MRI acquisition protocol: MRI is the most accurate tool for the local staging of rectal cancer and is a powerful tool to select the appropriate treatment [4-6]. Patients are then shifted to MR scanner (Philips Achieva 1.5 Tesla) for MR imaging. T2 weighted images are preferred for rectal carcinomas. High resolution 3D T2-weighted fast spin echo (FSE) sequence in the axial plane was acquired for staging and delineation of rectal cancer [5,6]. The slice thickness of 3 mm was chosen. Contrast MR sequences do not improve diagnostic accuracy and is not included in the study. These images are transferred electronically or by a compact disc. MR images are imported in the treatment planning systems.

Image registration and Contouring: The MR images were co-registered with CT images using the help of eclipse software on the registration platform. CT image set was selected as the reference and MR images were mapped onto it. Either Auto or manual matching is done. Auto-matching of images is done by appropriately selecting the region of interest (ROI) and is preferable to finish the process faster. This matching is then visually verified and further fine adjustment are done manually [8]. Manual adjustments are warranted in pelvic image registrations especially in rectal carcinomas where soft tissue visibility is an important criterion. After successful registration, radiation oncologist contoured GTV with help of CT (GTV_CT) only images. Another GTV with MR assistance (GTV_MR) was also contoured on the same structure set, with the guidance of registered MR images. Contouring platform of eclipse gives volume information for all structures contoured. The GTV_CT was taken as the baseline contour to which the GTV_MR was studied. All statistical analysis was done using Microsoft Excel.

Statistical Methods: After the contouring was completed, the GTV_CT and GTV_MR volumes were compared qualitatively to see if GTV_MR volumes were outside the GTV_CT volumes. First, the volumes of the both GTV_CT and GTV_MR were noted down for all patients. Secondly, for patients whom GTV_MR was outside GTV_CT, a combined GTV were created. For quantitative analysis, dice index was calculated for CT and MR generated contours [9].Dice index can be defined as Dice index =

$$\frac{2|A \cap B|}{|A|+|B|}$$

Where, A and B are numbers from two different samples. A dice index value of 0 indicates no overlap of the chosen contours whereas a value of 1 indicates perfect overlap between the two.

Statistical analysis: The results from the study were analyzed using Microsoft Excel (Microsoft corporation, USA) and were presented in terms of cubic centimeter (cc) for volume analysis and as a factor between ‘0’ and ‘1’ for dice similarity index.

Results

Volume information of GTV contoured using CT only image set and with help of MR data set are shown in figure 1. The mean volume of GTV_MR and GTV_CT are 68.54 cc and 80.95 cc respectively. The volume difference data is represented in Table 1. The mean of volume difference between GTV_CT and GTV_MRI is 12.42 cc. The range of difference in the volume varies from 4.50 cc – 22.00 cc. The dice index between GTV_CT and GTV_MR is also shown in table 1. Mean dice index value for all the patients were 0.71 ± 0.13. It was also inferred that in 6 out of18 cases GTV_MR contour was outside the GTV_CT contour. The combined GTV for these six cases is depicted in the figure 2.

Table-1: Volume difference and dice index data.

Patient No.	Volume difference (cc)	Dice Index
1	5.73	0.85
2	17.92	0.64
3	21.94	0.49
4	21.5	0.53
5	12.2	0.71
6	11.5	0.80
7	4.55	0.87
8	16.25	0.69
9	15.6	0.61
10	9.49	0.75
11	9.69	0.77
12	10.02	0.70
13	8.28	0.80
14	6.38	0.83
15	17.46	0.44
16	7.71	0.89
17	17.34	0.57
18	9.95	0.79

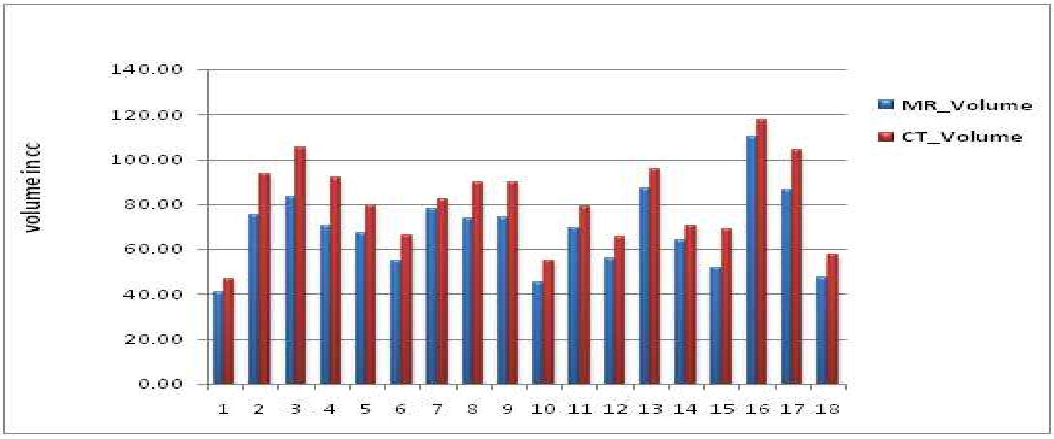

Figure-1: GTV_MR and GTV_CT volumes

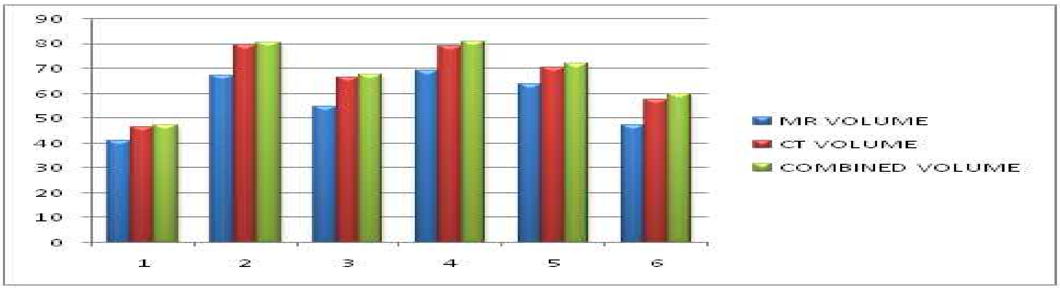

Figure-2: Volume for 6 patients whose GTV_MR was out of GTV_CT

Discussion

MRI is an imaging modality that does not require the use of ionizing radiation. Clinical MRI produces images based on the magnetic properties of tissues rather than their radio-density. CT has been considered the standard diagnostic test in staging and evaluating the anatomic location of soft tissue tumors of the extremities. The advent of CT brought considerable advantage over more traditional modalities by more accurate display of relative radio-densities and tomographic geometry. This provided good delineation of the tumor's margins with fat, bone marrow, and cortex due to differences in radio-density between fat, non-fatty soft tissues, bone cortex, and calcification[10,11]. However, the contrast between tumor and muscle commonly remains poor and their interfaces obscure.

MRI data offers excellent soft tissue contrast thereby delineation of GTV_MR is accurate [11, 12]. In CT image due to relatively poor soft tissue resolution, the volume of GTV_CT is over estimated. That is the reason for the GTV_CT volumes being larger than the GTV_MR volumes. This over contouring in GTV_CT occurred especially in the superior and inferior parts of the GTV. This is because the clinician could not establish exactly where the GTV ends. For most of the patients it is observed that the GTV_MR was inside the GTV_CT [12].O'Neill et al have clearly demonstrated that CT significantly and consistently overestimates rectal tumour volume and the width, length and height of low rectal cancers from the anal verge, compared with the same measurements defined on MR [13].

They have also stated that MR-defined tumour volumes for radiotherapy are smaller and further from the anal sphincter, and therefore MRI of tumour volumes for radiotherapy is likely to contribute to the sparing of normal tissues. The results from our study are also similar to that reported by O'Neill etal.In six patients it was found that GTV_MR was outside GTV_CT especially in lateral direction and this may be attributed to poor soft-tissue contrast in CT and/or CT-MR registration errors [13, 14]. However, this slight miss in the GTV will not result in under-dosage of tumour because of the concept of margin based clinical target volume (CTV) and planning target volume (PTV) concepts in radiotherapy planning [15-17]. The dice index establishes the agreement between the two set of contours GTV_CT and GTV_MR. The dice index varied from 0.44 to 0.89 indicating that the overall agreement of contours were good. In few patients dice index was less due to the over contouring if GTV in superior-inferior direction in the CT image set. The mean and range values of volume difference clearly tells us MR assisted GTV contouring is more accurate and reduces the overall volumes of CT and PTV. Thus MR assisted contouring helps in reducing the critical structure doses (as overall target volumes is less) especially in intensity modulated simultaneous boost treatments. [18,19]

All the MRI images were acquired in a diagnostic scanner which uses a curved couch in contrast to the flat couch in CT [20, 21]. Some reports suggest that consistency of immobilization has a larger impact on organ position (and thus accuracy of registration) than couch shape, but many immobilization devices will require attachment to a flat therapy-style couch [22]. The benefits of using MRI in radiotherapy planning are well established. However, its application in radiotherapy is also accompanied by concerns over aspects of image quality, such as geometric accuracy of the images. The most widespread current practice, however, is for MRI data to be registered to planning CT data. The MRI data are used to mark up the target and organs at risk and the CT data are used by the treatment planning system (TPS) for dose calculation and generation of digitally reconstructed radiographs (DRRs), which aid in treatment set-up verification [22].

The CT data will have been acquired with the patient set-up in the radiotherapy treatment position on a flat couch, whereas the MRI data will often not be set up in this way, owing to the use of the standard ''curved'' diagnostic couch and the placement of radiofrequency (RF) coils. This mismatch in set-up will affect the accuracy of the image registration, and is counter to the aim of reproducible patient set-up throughout the radiotherapy treatment pathway. Registration errors due to the above reason were not studied in this paper. Also we did not include inter-observer variability in the generation of contours. [22, 23]

Conclusion

Our study showed that using MRI guidance for GTV delineation in carcinoma rectum is preferable and more accurate as compared to CT only imaging. This isbecause of the superior soft tissue contrast information available with MRI. Contouring based on CT imaging does not miss the tumour but over estimates it. Over-contouring in radiotherapy causes increased dose to normal structures thereby causing significant toxicities. Hence, radiotherapy treatment planning with MRI data can improve the accuracy of tumour localization in carcinoma rectum.

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