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Study of dosimetric variation due to interfraction organ movement in High Dose Rate Interstitial (MUPIT) brachytherapy for gynecologic malignancies

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Ten patients with cancer of uterine cervix who underwent interstitial brachytherapy using MUPIT templates were CT scanned (CT1) using which bladder, rectum and CTV were delineated. The treatment plan PCT1 was generated and optimized geometrically on the volume. CT scan (CT2) was repeated before the second fraction of the treatment CTV and critical organs were delineated. The plan (PCT2) was created by reproducing the Plan PCT1 in the CT2 images and compared with PCT1. Bladder, Rectum and CTV percentage volume variation ranges from +28.6% to -34.3%, 38.4% to -14.9% and 8.5% to -15.2% respectively. Maximum dose variation in bladder was +17.1%, in rectum was up to +410% and in CTV was -13.0%. The dose to these structures varies independently with no strong correlation with the volume variation. Hence it is suggested that repeat CT and re-planning is mandatory before second fraction execution.

Key words: interstitial brachytherapy, MUPIT implant, inter-fraction dose variation.

Introduction

Cancer of uterine cervix is most the common cancer in women among developing countries. Management of the early staged disease can be done either by surgery or radiation therapy while radiation therapy is the primary treatment in locally advanced

diseases [12, 13]. Three dimensional conformal radiotherapy (3DCRT) and intensity modulated radiotherapy (IMRT) is being used to reduce the dose to rectum and bladder considerably. The margin for the CTV to PTV includes part of rectum and bladder so the dose to these structures will be higher than the desirable. The advantage of steep dose gradient between the critical structures and that target makes brachytherapy advantageous than the external radiation therapy. Two types of brachytherapy is being used for the carcinoma of uterine cervix i.e. Intracavitary brachytherapy and Interstitial brachytherapy [1]. Intracavitary brachytherapy (ICBT) requires a good geometry, including a patient cervical os and adequate space in the vagina, which may not be possible in some patients. Interstitial implantation is a brachytherapy technique performed by inserting radiation sources into the needles or catheters placed directly into the tumor [8]. It has been used to overcome limitations of Intracavitary brachytherapy.

In interstitial brachytherapy different templates were designed in order to get a better target volume coverage. Combination of Intracavitary and interstitial brachytherapy is possible. The combination of Interstitial and Intracavitary brachytherapy is called the sandwich technique which allows to deliver a high dose to the tumour with sparing the healthy tissues. The templates commonly used in interstitial brachytherapy for the carcinoma of cervix are Martinez Universal Perineal Interstitial Template (MUPIT) and Syed-Neblett template [2, 4]. For the carcinoma of cervix, 50Gy in 25 fractions is given using the external radiotherapy and the boost dose of 5Gy/fraction in 3 fractions is delivered using interstitial brachytherapy [5]. After the intraoperative procedure of implantations the hyper fractionated treatment with six hours gap is given in high dose rate (dose rate > 12 Gy/hr) [10, 11].

Traditionally computerized dosimetry has been generated from orthogonal films, rendering limited information about the spatial relationships between the bladder, and rectum, and implanted sources and no information about the relationship of the needles to the tumor volume [9]. After the introduction of the computed tomography, dosimetry and analysis in the interstitial brachytherapy is being carried out using computed tomography based on 3D brachytherapy treatment planning.

Three hyper fractionated treatments are being delivered for the interstitial brachytherapy using the same implantation. The second fraction is delivered with the plan created using the first day computed tomography information. The change in the volume of rectum and bladder may lead to change in the positions to organs and CTV

during the course of the treatment. The change in positions of bladder and rectum may cause the variation in dose [15].

The purpose of the study is to quantify the inter-fractional uncertainties during the interstitial brachytherapy in the target, bladder and rectum. The changes include the volume and dose to the tumour and critical structures.

Materials and methods

Interstitial Implant

The Martinez universal perineal interstitial template (MUPIT) shown in Figure 1 was designed to treat not only gynecological malignancies but also prostatic, anorectal and perineal tumours. This applicator consists of two acrylic cylinders, one acrylic template and cover plate. The template has arrays of holes used as guides for the needles. Guide holes are designed to allow the inserted trocars lie in parallel horizontal planes, perpendicular to the template plane insuring an adequate geometry of applications. The planes are spaced vertically one centimetre apart. The distal guide hole are angled 13 degree laterally, outward to allow a wider coverage of the external part of the tumor. The 17 gauge needles are stainless steel with a blinded end [4].

The computed tomography imaging is being done after implantation for 10 advanced gynaecologic malignancies. On the day of implantation, patients have an epidural catheter placed both for intraoperative analgesia as well as for postoperative pain management. The MUPIT template was threaded over the obturator and positioned.

Figure 1. The Martinez universal perineal interstitial template (MUPIT)

The average number of implant needles was 18. On the average 70% of the catheters were in the periphery and 30% around the urethra. During the implant care was taken not to put the needles in the urethra and they were kept below the bladder mucosa. The depth of needle insertion is determined through a combination of pre-treatment investigations.

Imaging

Later the implanted day or early next day, the patient undergoes a pelvic Computed tomography scan with intravenous contrast to delineate the bladder and rectal contrast. A dilute contrast is used in the rectum so that needles near or potentially in the rectal wall is not obscured by the contrast [7]. Air in the rectum can also serve as a contrast agent. Thirty to forty tomography images are obtained with a slice thickness of 5 mm (CT1). The axial images are then formatted and reviewed to identify the depth of the needle insertion. Reconstructed sagittal and coronal views are available that give further insight into the appropriateness of needle depth insertion. Figure 2 shows the CT imaging of patient with the MUPIT implant and the frontal and sagittal reconstructed sections.

Figure 2. CT imaging of patient with the MUPIT implant and the frontal and sagittal reconstructed sections

The CT scan was repeated before the second fraction of the treatment (CT2) (i.e. after six hours or next day of 1st fraction of the treatment). The second CT scan was also taken with the same parameters (slice thickness, interval etc.,) and contrast agents to avoid the errors in delineating the CTV, bladder and rectum.

Contouring and Planning

The CT1 images were imported to Varian Eclipse planning system. The bladder, rectum and CTV are contoured in the CT1 images by the Oncologists. Figure 3 shows the cross sectional images of the implant along with the contours of bladder, CTV and rectum. The planning was done using the Brachyvision software in Eclipse planning system. The Catheters were reconstructed with the help of the sagittal and coronal plane views. Active loading of the each catheter was obtained by giving 0.5 to 0.75 mm margin on PTV. Initial plan was generated and optimized geometrically on the volume [14]. Plan was further optimized graphically for optimum target coverage and dose homogeneity which yielded final plan PCT1. Dose rate and total dose distributions are displayed with the appropriate anatomy on axial CT images, and on reconstructed sagittal and coronal images, enabling the direct visualization of the dose distribution throughout the needle

Figure 3. Cross sectional images of the implant along with the contours of bladder, CTV and rectum

Figure 4. The dose distribution along the transverse sections

volume, as well as the rectum and bladder. Figure 4 shows the dose distribution along the transverse sections.

Figure 5. Percentage variation of the bladder volume, maximum, mean and minimum dose for ten patients.

The CT2 images were imported and the CTV, bladder, rectum contoured by the same oncologists to avoid the human errors in delineating the organs. The catheters are tracked using the sagittal and coronal planes. The source activity, dwell positions and dwell times were reproduced manually as same as in the plan (PCT1). The resulted plan (PCT2) was analysed qualitatively and quantitatively.

Analysis

The evaluation of the implantation in the second fraction is done by comparing the volume and dose variation in the PCT2. The volume variation of CTV, bladder and rectum in the CT2 images with respect to the CT1 images which is used for the planning and treatment execution were studied. Due to the volume variation in the bladder, rectum and CTV the maximum, minimum and mean dose variations were studied for all the patients.

Results and discussion

Inter-fractional variations in bladder

In order to avoid the volume variation due to bladder filling, bladder is catheterized. But still with catheterization, volume variations in the range of +28.6% to -34.3% were observed. Out of ten patients selected for this study five shown increase in bladder volume compared with the first fraction and in the remaining five patients the bladder volume was found to be decreasing. The Figure 5 shows the bladder volume variation between two fractions in ten patients.

The variations in the maximum dose (hot spot) in bladder were observed between fractions mainly due to change in volume. In seven patients the maximum dose is found to be decreasing and found increasing in the rest of the three patients. In other words, for eight patients the variation in maximum dose follows the trend of the bladder volume variation i.e., when the bladder volume increases the maximum dose also increases and vice versa. But however, strong correlation cannot be obtained because the maximum dose depends on the direction in which the bladder volume increases/decreases. The

Figure 6. Percentage variation of the CTV volume, maximum, mean and minimum dose for ten patients.

Figure 5 shows the percentage variation of the maximum dose for ten patients. It is observed that the maximum dose varies in the range of +17.1% to −66.2%.

The minimum dose was found to be decreased in seven patients, increased in one patient and no variations were observed in rest of the two patients. The minimum dose variations for ten patients were plotted in Figure 5. Irrespective of the volume change the mean bladder dose got decreased for all the ten patients for the second fraction. Hence no correlation was obtained between the mean dose variation and the volume variation.

Figure 7. Percentage variation of the rectum volume, maximum, mean and minimum dose for ten patients.

Inter-fractional variations in CTV

Out of ten patients, the CTV volume is increased by 1.04% in one patient and in all other patients the volume is decreased. The maximum decrease in volume was found to be 6.9%. The decrease in the volume may be due to decrease in oedema present during the intraoperative procedure. The variation in the CTV volume for ten patients was plotted in the Figure 6. The average volume variation is found to be $-3.4 \pm 2.85\%$.

The highest variation in the maximum dose of −13% was observed in only one patient. In the rest of the nine patients the variation in maximum dose was around 1%.

Since the needles are within the CTV there is no much variation in the maximum dose observed.

The minimum dose in CTV varies from 8.5% to -15.2%. In three patients, there was increase in the minimum dose and found to decrease for the rest of the patients. Other than two patients the variation in minimum dose followed the trend of the volume variation but still no strong correlation is obtained. The mean dose of CTV varies from the 9.8% to -13.3%. The mean dose got increased in 3 patients and decreased for other patients. This shows that under dosage in CTV (mean dose) occurs in the second fraction. The variation of the mean dose is plotted in the Figure 6.

Inter-fractional variations in rectum

Eliminating the rectal volume variation is very difficult in interstitial brachytherapy. For all the ten patients significant volume variations were observed which is mainly due to the rectal filling of gas and faeces. The volume variation in rectum was found to vary from 38.4% to -14.9%. The volume is increased in four patients and in the remaining six patients it was decreased. The variations of rectal volume for ten patients were plotted in Figure 7.

The maximum dose to the rectum experienced high variation. In rectum the maximum dose got reduced to 12.7% in only one patient and for all other patients it got increased. The increase was found upto 410%. This may be due to increase in pressure due to gas or faeces which moves rectum much closer to the needles.

Significant increase in the mean dose is observed for seven patients and a marginal decrease in mean dose is observed for three patients. The range of mean dose was found to vary from 14.0% to -0.8% which is shown in Table 1. There could not be any correlation obtained between the rectal volume variations and the mean/maximum dose variation.

Conclusion

From this study it is concluded that variations in volume observed for bladder, rectum and CTV are patient specific. Also, the dose to these structures varies independently with no strong correlation with the volume variation. Hence it is suggested that repeat CT and re-planning is mandatory before second fraction execution.

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