Chapter one
Introduction

1.1 Cervical cancer

The cancer has been defined as an abnormal cell growth, the growth of which is uncoordinated with the normal one and persists with same excessive manner after the cessation of the stimuli that evoke it, with a tendency to metastasize to other vital organs via circulatory system, lymphatic system and direct invasion (Yin and Lloyd, 2001). Such fatal disease could involve most of the human tissue and organs depending on specific induction carcinogenic factors or agents, such as physical factors (ionizing radiation, ultraviolet), chemical factors (Benzo [a] pyrene which cause characteristic point mutation in the p53 gene, Ethyl alcohol, Heterocyclic amine in overcooked meat/fish, Biological factors as viruses, Rb1 gene which is responsible for retinoblastoma… etc (Hiroshi and Keizo, 2001), one of these organs is the cervix. Cervical carcinoma represents a second commonest gynecological malignancy in Sudan with an incidence about 12 –15.5% of whole cancer and the risk factors include low socioeconomic status, chronic immunosuppression , age (the highest risk occurs between late teens and mid-thirties), early age at first sexual intercourse, multiple sexual partners, certain strains of the Human Papilloma Virus (HPV, a sexually transmitted disease),sigrate smoking, multiple children, and daughters of women who took DES (hormonal drug) (Miller, and Kunkler, 2004). As well it represents the most common cause of cancer deaths among women in developing countries, despite the fact that cervical cancer is preventable due to screening program. However approximately 80% of all cases of cervical cancer worldwide occur in less-developed

countries, because prevention programs are either nonexistent or poorly executed (Ferlay et al, 2004). It represents the second most common cancer.

It diagnosed in women worldwide after breast cancer and as a third most common cause of death from cancer in women after breast and lung cancer which leads to more than 273,000 as mortality annually and higher in eastern and southern Africa relative to developed world due to screening programs in the developed countries (Nyasha et al, 2012). In 80% to 90% of cases, the histological type is squamous cell carcinoma; the frequency of adenocarcinoma is increasing. Somewhat controversial evidence links adenocarcinoma of the cervix to oral contraceptive use as well as to factors related to corpus cancer such as obesity, diabetes mellitus, nulliparity, and hypertension.

1.2 Radiation therapy of cervical carcinoma:

The effort of radiotherapy equipments manufacture's, Medical physicists, physicians, and radiation technologists have been directed to optimize the radiation therapy dose that should not exceed ± 5% of the prescribed tumor dose (Zhu, 2000) or as mention by ICRU, (1976) that: the error should not exceeds 3-5%, with critical consideration to the normal tissue dose and the adjacent vital organs. The models of treatment for cervical cancer irradiation vary according to types of cancerous tissue and stage of disease, thus for the majority of patients present with organ-confined disease, surgery is the primary treatment. Adjuvant radiotherapy is only indicated for patients at high risk of recurrence (Creutzberg et al, 2004). Patients treated with daily fractions of 1.8-2.0 Gy to a total dose of 45-46 Gy over 4.5-5 weeks show an acceptable level of toxicity in prospective studies (Creutzberg et al, 2001; Churn et al, 1999). Selected

patients may receive a brachytherapy boost to the vaginal vault using low, medium or high dose rate after loading radioactive sources.

The planning target volume for treating pelvic malignancy normally encompasses the whole of the true pelvis and may be extended further, depending on the extent and type of malignancy to include the para-aortic nodes, the inguinal nodes or the vagina. This volume necessarily includes a large volume of small and large bowel. Although beams eye view planning allows increased accuracy in shielding the bowel in uninvolved areas of the pelvis, (Gerstner et al, 1999) the tolerance of the sensitive organs (Rectum, bladder, hip joints and bowels) determines the dose and fractionation in treating gynecological cancer.

Therefore the focus of this study is to estimate the tumor dose (TD) in cervical cancer irradiation as well as the doses at critical organs such as bladder, rectum and the hip joints using brick technique (4 fields-box technique) relative to the applied given dose GD in external radiation therapy by Co-60 teletherapy machine. Since the conventional radiotherapy commonly used in developing countries rather than the most recent equipments and techniques like intensity modulated radiation therapy IMRT and remote after loading radiotherapy; the radiation risks have been as common. In this realm; Beth et al, (2009) found that in external beam radiation therapy EBRT, the biologically equivalent dose for 2Gy fractionation as 2 cc (centimeter cubic) of the bladder wall, rectal wall and sigmoidal wall ranged from 39.47 to 57.12 Gy (median 55.10 Gy); 38.86-54.21 Gy (median 49.83 Gy); and 37.06-51.36 Gy (median 48.67 Gy), respectively. And the attempt reported by ICRP, (1999) to manage the fluctuation of dose received by critical organs and target volume was

the addition of margin to compensate the internal margin motion and the variation in patient position, however also this idea will induce adverse effects by either increasing the dose to rectum and bladder or giving insufficient carcinocidal dose to the tumor. While Elisabeth et al, (2003), reported that: no effect in the dose received by the bladder and rectum when the patient position changed from supine to prone.

One method used to determine the dose at off axis, where the critical organs lie is the utilization of a 3D treatment planning systems (3DTPS) as has been stated by Sethi et al, (2003) in which a designed compensating filters and a missing tissue compensation, can account for tissue in-homogeneities for radiotherapy beams. Such in-homogeneity in dose distribution commonly related to curved patients contour and the dose histogram could be derived from CT or MRI images that have to be fed to the TPS.

If definitive radiotherapy is administered, several techniques are available to combine whole-pelvis external-beam therapy, and intracavitary.

Since the EBRT include the treatment of target volume also some OAR such in this case (bladder, rectum, head of femur) This organ might received substantial amount of dose since the calculation of dose in study was obtain using khan (2003) equations for dose calculation which depend on the separation and the DD%, depth GD and field size.

1.3 Problem of study

Carcinoma of uterine cervix is the commonest cancer among Sudanese women. One of the modality of treatment is external radiation therapy. The patient generally treated by number of fields. The irradiated volume includes some sensitive organs located in the path of radiation, which will include greater variation in the dose received by these organs especially if the planning method were manual**.** For organs within a treatment field, radiation doses are relatively high and attributed mainly to primary radiation. The dose to OAR inside the field can be obtained using the TPS system of dose calculation.

1.4 Objectives

The general objective of this study was to evaluate the dose received by organs inside the field in external beam radiation therapy of cervix in order to match these doses by acceptable tolerance doses as mention in the pervious studies.

Specific Objectives

- To calculate the dose received by the bladder, rectum and hip joint.
- To find the relationship of the total dose received by these organs with the field size, and depth of the bladder, rectum, and femur head.
- To find a linear equation that can be used to estimate the dose in the critical organs.
- To find relationship of back scatter factor with patient separation and equivalent field size.

1.5 Significant of study

This study will provide an information about the radiation doses that received by organs inside treatment field in external beam radiation therapy dose cervical carcinoma patients, so that the treatment will be carried in acceptable dose in order to

reduce complication that may be arise during and after the treatment therefore obtaining a good prognosis at end of treatment course.

1.6 Overview of the study

This study consisted of five chapters, with chapter one is an introduction introduce briefly this thesis and contained (radiotherapy of the cervix, problem of study also contain general objective, specific objectives, significant of study and overview of the study).Chapter two is literature review about dose calculation for sensitive organs and side effects due to the treatment technique. Chapter three will describe the methodology (material, method) will be use. Chapter four included result of doses received by sensitive organs, chapter five is discussion, conclusion and recommendation in addition to references and appendices.

Chapter two

Literature review

Dietmar et al. (2008) stated that in order to evaluate the potential benefit of proton therapy and photon based intensity-modulated radiotherapy in comparison to 3-D conformal photon radiotherapy (3D-CRT) in locally advanced cervix cancer. Study was in five patients with advanced cervix cancer 3D-CRT (four-field box) was compared with intensity modulated photon (IMXT) and proton therapy (IMPT) as well as proton beam therapy (PT) based on passive scattering. Planning target volumes (PTVs) included primary tumor and pelvic and para-aortic lymph nodes. Dose-volume histograms (DVHs) were analyzed for the PTV and various organs at risk (OARs) (rectal wall, bladder, small bowel, colon, femoral heads, and kidneys). In addition dose conformity, dose inhomogeneity and overall volumes of 50% isodoses were assessed. Results for all plans were comparable concerning PTV parameters. Large differences between photon and proton techniques were seen in volumes of the 50% isodoses and conformity indices. DVH for colon and small bowel were significantly improved with PT and IMPT compared to IMXT, with D_{mean} reductions of 50–80%. Doses to kidneys and femoral heads could also be substantially reduced with PT and IMPT. Sparing of rectum and bladder was superior with protons as well but less pronounced. Proton beam RT has significant potential to improve treatment related side effects in the bowel compared to photon beam RT in patients with advanced cervix carcinoma. In addition to design a consistent set of criteria for acceptability of photon beam dose calculations of treatment planning systems. The set should be applicable in combination with a test package used for evaluation of a treatment planning system, such as the ones proposed by the AAPM Task Group 23 or by the Netherlands Commission on Radiation

Dosimeter. According to obtained result tolerances have been defined for the accuracy with which a treatment planning system should be able to calculate the dose in different parts of a photon beam: the central beam axis and regions with large and small dose gradients. For increasing complexity of the geometry, wider tolerances are allowed, varying between 2 and 5%. For the evaluation of a large number of data points an additional quantity, the confidence limit, has been introduced, which combines the influence of systematic and random deviations. The proposed tolerances have been compared with other recommendations for a number of clinically relevant examples, showing considerable differences, which are partly due to the way the complexity of the geometry, is taken into account. Furthermore differences occur if criteria for acceptability of dose calculations are related either to the local dose value or to a normalized dose value. Although it is acknowledged that the general aim must be to have good agreement between dose calculation and the actual dose value, e.g. within 2% or 2 mm, current day algorithms and their implementation into commercial treatment planning systems result often in larger deviations. A high accuracy can at present only be achieved in relatively simple cases. The new set of tolerances and the quantity confidence limit have proven to be useful tools for the acceptance of photon beam dose calculation algorithms of treatment planning systems.

Jack et al (2002) and Forrest et al. (2010) stated that to compare the dose to organs at risk (OAR) between a conventional four-field whole pelvis radiotherapy (4F-WPRT) plan and an initial single intensity-modulated WPRT (IM-WPRT) plan for definitive treatment of cervical cancer. The magnitude of potential dose sparing of OAR is unknown when planning target volumes are defined to include potential organ motion and microscopic disease extent. By using of Planning computed tomography scans of

50 consecutive, previously treated patients were re-planned using 4F-WPRT and IM-WPRT. Margins compatible with the literature on organ motion were used to create the planning target volume. Dose-volume histograms for target and OAR were compared for each patient with paired t-tests and waterfall plots. Results showed that mean target volume covered by 95% (V47.8) was 99.7% for 4F-WPRT and 98.8% for IM-WPRT (P>0.05, ns). Intensity-modulated radiotherapy (IMRT) was associated with a significant reduction in the dose to OAR at the V50, V45, V40 and V30 level. There was a >20% difference in V50 in most patients: 84% (bladder), 58% (small bowel), 54% (sigmoid) and 84% (rectum).A single, initial IMRT plan with appropriate margins encompassing initial gross and potential microscopic pelvic disease leads to a reduction in the dose to OAR without compromising target coverage. This offers a potential 'class solution' for definitive treatment of patients with cervical cancer. Clinical outcome data are still needed to verify this planning study.

Kim et al. (2008) stated that to evaluate whether doses or dose rates at International Commission on Radiation Units (ICRU) reference points are of value for predicting risks of late rectal and bladder morbidity in patients with uterine cervical cancer who have undergone external beam radiotherapy and intracavitary irradiation in 54 patients who were treated by external beam radiotherapy followed by intracavitary irradiation between January 1996 and December 1999. External beam radiotherapy was delivered in 1.8 Gy daily fractions to a whole pelvis dose of 50.4 Gy followed by intracavitary irradiation at total point A doses ranging from 75 Gy to 85 Gy. Intracavitary irradiation was performed with dose rates of 0.5-0.7 Gy/h to point A in most patients, but 8 patients were treated at a higher dose rate (0.83-1.15 Gy/h) to shorten the hospitalization period. Biologically effective doses for the reference points were calculated using a linear quadratic model. The study result were for grade 3

rectal and bladder morbidity by Radiation Therapy Oncology Group (RTOG) criteria developed in 4 patients (7.4%) and 1 (1.9%), respectively. An age of >60 years (P = 0.01) and a total dose to the rectal reference point of > or =80 Gy (P = 0.03) were found to be correlated with a higher rate of rectal morbidity. Total dose (> or =80 Gy), dose rate (> or = 0.75 Gy/h), and biologically effective doses (> or =135 Gy3) at the bladder reference point were found to be significant factors for the development of late bladder morbidity. By multivariate analysis, age was identified as the only significant factor of late rectal complications, and biologically effective doses at the bladder reference point was the only significant factor of late bladder complications. However RTOG grade 3 late rectal and bladder morbidity developed in respectively 7.4% and 1.9% of the patients. The significant risk factors for late rectal and bladder morbidity were old age and biologically effective doses at the bladder reference point, respectively.

Eng-Yen et al. (2007) described that it is important to evaluated effect of abdominal surgery on the volume effects of small-bowel toxicity during whole-pelvic irradiation in patients with gynecologic malignancies and that help in predication of consequence clinical complications .This obtained throught study of two groups of gynecologic patients without (Group I) or with (Group II) prior abdominal surgery. Through used of a computed tomography (CT) planning system to measure the small-bowel volume and dosimeters. We acquired the range of small-bowel volume in 10% (V10) to 100% (V100) of dose, at 10% intervals. The onset and grade of diarrhea during whole-pelvic irradiation were recorded as small-bowel toxicity up to 39.6Gy in 22 fractions. The final result was that The volume effect of Grade 2–3 diarrhea existed from V10 to V100 in Group I patients and from V60 to V100 in Group II patients on univariate

analyses. The V40 of Group I and the V100 of Group II achieved most statistical significance. The mean V40 was 281 ± 27 cm3 and 489 ± 34 cm3 ($p < 0.001$) in Group I patients with Grade 0–1 and Grade 2–3 diarrhea, respectively. The corresponding mean V100 of Group II patients was 56 ± 14 cm3 and 132 ± 19 cm3 ($p = 0.003$). Multivariate analyses revealed that V40 ($p = 0.001$) and V100 ($p = 0.027$) were independent factors for the development of Grade 2–3 diarrhea in Groups I and II, respectively. So Gynecologic patients without and with abdominal surgery have different volume effects on small-bowel toxicity during whole-pelvic irradiation. Low-dose volume can be used as a predictive index of Grade 2 or greater diarrhea in patients without abdominal surgery. Full-dose volume is more important than low-dose volume for Grade 2 or greater diarrhea in patients with abdominal surgery. By using data from a population-based cancer registry of 1134 prostate cancer patients, 11/264 (4.2%) patients treated with EBRT presented a sCRC. To evaluate the dose delivered to the colon and rectum, each individual index patient was matched with a study case and, using the index case treatment characteristics, dose calculations were carried out on the latter to To estimate the dose to colorectal structures after external beam radiation therapy (EBRT) delivered to prostate cancer patients who developed secondary colorectal cancers (sCRC). The result was that t median maximum, mean and minimum doses delivered to the colon or rectum affected by the sCRC were 39.3 (range 0.2–66.0), 5.4 (range 0.2–41.3) and 0.6 (range 0.2–7.8) Gy, respectively. All but three sCRCs occurred outside the treatment fields. The estimated rectal doses after prostate radiation therapy were substantially higher than those delivered to non-rectal colic structures (mean dose 47.2 ± 16.6 vs 9.4 ± 6.4Gy), but only one (9%) patient presented a rectal cancer. The differential mean doses given to the rectosigmoid junction and sigmoid colon, with or without sCRC, were not different. therefore these

data suggest that the administered dose after EBRT for prostate cancer to the colon, excluding the rectum, may be below the Gy unit in sCRC patients.

Weber et al (2009) and Georg et al. (2006) described the purpose is to evaluate the influence of uterus and bladder size on large and small bowel sparing with intensity modulated whole pelvic radiotherapy (IM-WPRT) in gynecologic patients. Twenty patients were selected; 10 women with cervical cancer treated with definitive radiotherapy (group 'DEF') and 10 endometrial cancer patients treated postoperatively (group 'POST'). Bladder, rectal wall, small (SB) and large bowel (LB) were delineated as organs at risk. A conformal four field technique and a seven field IMRT plan (prescription dose 50.4 Gy) were compared in terms of DVH and various target parameters. Results show at doses between 40 and 50.4 Gy statistically significant improvements ($P<0.05$) were observed for IM-WPRT for irradiated volume of rectal wall and bladder. In both patient groups, with IMRT the average irradiated volume of SB was reduced by a factor of 6 at 50.4Gy. This ratio was 2 for LB. In the DEF group the effect of SB-sparing with IMRT correlated with bladder size (correlation coefficient 0.70) while it did not correlate in the postoperative group. The effect of LB-sparing decreased with increasing bladder size in both groups but the impact of IMRT was larger for postoperative patients. Which mean IMRT significantly reduced the absolute volume of rectal wall, bladder and bowel irradiated at the prescribed dose level in gynecologic patients Main differences between POST and DEF patients receiving IM-WPRT were absolute volumes of LB irradiated to doses between 35 and 50Gy, suggesting an impact of intact uterus on LB volume in the pelvis. POST patients seem to benefit most from elective nodal IMRT. Bladder filling is an important co-factor influencing the benefit of IMRT with respect to OAR sparing.

Loren et al. (2008) Stated that to compare bone marrow-sparing intensity-modulated pelvic radiotherapy (BMS-IMRT) with conventional (four-field box and anteroposterior–posteroanterior [AP–PA]) techniques in the treatment of cervical cancer. Using the data from 7 cervical cancer patients treated with concurrent chemotherapy and IMRT without BMS were analyzed and compared with data using four-field box and AP–PA techniques. All plans were normalized to cover the planning target volume with the 99% isodose line. The clinical target volume consisted of the pelvic and presacral lymph nodes, uterus and cervix, upper vagina, and parametrial tissue. Normal tissues included bowel, bladder, and pelvic bone marrow (PBM), which comprised the lumbosacral spine and ilium and the ischium, pubis, and proximal femora (lower pelvis bone marrow). Dose–volume histograms for the planning target volume and normal tissues were compared for BMS-IMRT vs. four-field box and AP–PA plans. Results showed BMS-IMRT was superior to the four-field box technique in reducing the dose to the PBM, small bowel, rectum, and bladder. Compared with AP–PA plans, BMS-IMRT reduced the PBM volume receiving a dose >16.4 Gy. BMS-IMRT reduced the volume of ilium, lower pelvis bone marrow, and bowel receiving a dose >27.7, >18.7, and >21.1 Gy, respectively, but increased dose below these thresholds compared with the AP–PA plans. BMS-IMRT reduced the volume of lumbosacral spine bone marrow, rectum, small bowel, and bladder at all dose levels in all 7 patients. Thus mean BMS-IMRT reduced irradiation of PBM compared with the four-field box technique. Compared with the AP–PA technique, BMS-IMRT reduced lumbosacral spine bone marrow irradiation and reduced the volume of PBM irradiated to high doses. Therefore BMS-IMRT might reduce acute hematologic toxicity compared with conventional techniques.

Peter et al. (2013) stated that to estimate the prevalence of rectal and urinary dysfunctional symptoms using image guided radiation therapy (IGRT) with fiducials and magnetic resonance planning for prostate cancer. Study were done the implementation stages of IGRT between September 2008 and March 2010, 367 consecutive patients were treated with prostatic irradiation using 3-dimensional conformal radiation therapy with and without IGRT (non-IGRT). In November 2010, these men were asked to report their bowel and bladder symptoms using a postal questionnaire. The proportions of patients with moderate to severe symptoms in these groups were compared using logistic regression models adjusted for tumor and treatment characteristic variables. Results of the 282 respondents, the 154 selected for IGRT had higher stage tumors, received higher prescribed doses, and had larger volumes of rectum receiving high dosage than did the 128 selected for non-IGRT. The follow-up duration was 8 to 26 months. Compared with the non-IGRT group, improvement was noted in all dysfunctional rectal symptoms using IGRT. In multivariable analyses, IGRT improved rectal pain (odds ratio [OR] 0.07 [0.009-0.7], *P*=.02), urgency (OR 0.27 [0.11-0.63], *P*=<.01), diarrhea (OR 0.009 [0.02-0.35], *P*<.01), and change in bowel habits (OR 0.18 [0.06-0.52], *P*<.010). No correlation was observed between rectal symptom levels and dose-volume histogram data. Urinary dysfunctional symptoms were similar in both treatment groups. In comparison with men selected for non-IGRT, a significant reduction of bowel dysfunctional symptoms was confirmed in men selected for IGRT, even though they had larger volumes of rectum treated to higher doses.

To evaluate the influence of uterus and bladder size on large and small bowel sparing with intensity modulated whole pelvic radiotherapy (IM-WPRT) in gynecologic patients. Twenty patients were selected; 10 women with cervical cancer treated with

definitive radiotherapy (group 'DEF') and 10 endometrial cancer patients treated postoperatively (group 'POST'). Bladder, rectal wall, small (SB) and large bowel (LB) were delineated as organs at risk. A conformal four field technique and a seven field IMRT plan (prescription dose 50.4 Gy) were compared in terms of DVH and various target parameters. Results show at doses between 40 and 50.4 Gy statistically significant improvements ($P<0.05$) were observed for IM-WPRT for irradiated volume of rectal wall and bladder. In both patient groups, with IMRT the average irradiated volume of SB was reduced by a factor of 6 at 50.4Gy. This ratio was 2 for LB. In the DEF group the effect of SB-sparing with IMRT correlated with bladder size (correlation coefficient 0.70) while it did not correlate in the postoperative group. The effect of LB-sparing decreased with increasing bladder size in both groups but the impact of IMRT was larger for postoperative patients.Which mean IMRT significantly reduced the absolute volume of rectal wall, bladder and bowel irradiated at the prescribed dose level in gynaecologic patients. Main differences between POST and DEF patients receiving IM-WPRT were absolute volumes of LB irradiated to doses between 35 and 50Gy, suggesting an impact of intact uterus on LB volume in the pelvis. POST patients seem to benefit most from elective nodal IMRT. Bladder filling is an important co-factor influencing the benefit of IMRT with respect to OAR sparing (Georg et al. 2006).

Ashman et al. (2005) described that to investigate the correlations between observed clinical morbidity and dosimetric parameters for whole pelvic radiotherapy (WPRT) for prostate cancer using either three-dimensional conformal radiotherapy (3D-CRT) or intensity-modulated radiotherapy (IMRT). This obtain between December 1996 and January 2002, 27 patients with prostate adenocarcinoma were treated with conformal WPRT as part of their definitive treatment. WPRT was delivered with 3D-CRT in 14

patients and with IMRT in 13 patients. For each of the patients treated with IMRT, optimized conventional two-dimensional (2D) and 3D-CRT plans were retrospectively generated for the whole pelvic phase of the treatment. Dose-volume histograms for the bowel, bladder, and rectum were compared for the three techniques. Acute toxicities were evaluated for all 27 patients, and late toxicities were evaluated for 25 patients with sufficient follow-up. Toxicities were scored according to the Radiation Therapy Oncology Group morbidity grading scales. Median follow-up was 30 months. The results Three-dimensional-CRT resulted in a 40% relative reduction ($p < 0.001$) in the volume of bowel receiving 45 Gy compared with 2D, and IMRT provided a further 60% reduction relative to 3D-CRT ($p < 0.001$). Compared with either 2D or 3D-CRT, IMRT reduced the volume of rectum receiving 45 Gy by 90% ($p < 0.001$). Overall, 9 patients (33%) experienced acute Grade 2 gastrointestinal (GI) toxicity, and only 1 of these patients was treated with IMRT. Antidiarrhea medication was required for 6 patients (22%). However, 5 of these 6 patients also received chemotherapy, and none were treated with IMRT. No Grade 3 or higher acute or late GI toxicities were observed. No cases of late radiation enteritis were observed. Acute and late genitourinary toxicity did not appear significantly increased by the addition of conformal WPRT. In addition compared to conventional 2D planning, conformal planning for WPRT resulted in significant reductions in the doses delivered to the bowel, rectum, and bladder. IMRT was superior to 3D-CRT in limiting the volume of bowel and rectum within high-dose regions. These dosimetric findings correlated with low rates of acute and late GI morbidity.

Forrest et al. (2010) stated that to compare the dose to organs at risk (OAR) between a conventional four-field whole pelvis radiotherapy (4F-WPRT) plan and an initial single

intensity-modulated WPRT (IM-WPRT) plan for definitive treatment of cervical cancer. The magnitude of potential dose sparing of OAR is unknown when planning target volumes are defined to include potential organ motion and microscopic disease extent. By using of Planning computed tomography scans of 50 consecutive, previously treated patients were re-planned using 4F-WPRT and IM-WPRT. Margins compatible with the literature on organ motion were used to create the planning target volume. Dose-volume histograms for target and OAR were compared for each patient with paired t-tests and waterfall plots. Results showed that mean target volume covered by 95% (V47.8) was 99.7% for 4F-WPRT and 98.8% for IM-WPRT (P>0.05, ns). Intensity-modulated radiotherapy (IMRT) was associated with a significant reduction in the dose to OAR at the V50, V45, V40 and V30 level. There was a >20% difference in V50 in most patients: 84% (bladder), 58% (small bowel), 54% (sigmoid) and 84% (rectum).A single, initial IMRT plan with appropriate margins encompassing initial gross and potential microscopic pelvic disease leads to a reduction in the dose to OAR without compromising target coverage. This offers a potential 'class solution' for definitive treatment of patients with cervical cancer. Clinical outcome data are still needed to verify this planning study.

Pourquier H, et al (1996). Two successive series of invasive carcinoma of the cervix (268 and 307 patients) were treated by radiation alone between 1973 and 1977 and 1978 and 1985. The main difference between these periods was the method used to determine the definitive dose delivered by intracavitary therapy. The treatment in all cases consisted of external and intracavitary radiotherapy. Computerized dosimetry was performed in all patients with determination of dose rate, maximum and mean cumulated doses at the reference points of the rectum and bladder. The tolerance doses to the rectum and bladder previously established and represented graphically were used

prospectively for the patients from 1978 to 1985, permitting better coordination of the two treatments. The graph takes into account the fractionated tolerance to external irradiation and intracavitary radiotherapy. The systematic use of this method yielded results at six years for all stages which were comparable from one series to another. Parallel to this, the improvement in the number and gravity of the complications was significant, especially for grade 2 complications (P = 0.001) and, to a lesser degree, for grade 3 and 4 complications (P = 0.04). In conclusion, the respect of tolerance doses to the critical organs close to the principal tumoral volume represents an effective method for optimizing radiotherapeutic treatment for cervical cancer.

Jong et al. (2008) the purpose of this study was to assess the prevalence and distribution of radiation-induced insufficiency fractures and to investigate other bony complications of the female pelvis associated with radiation therapy using MR images. Two radiologists retrospectively evaluated pelvic MR images of 510 patients (mean age, 54.7 years) who underwent pelvic irradiation for uterine cervical cancer for the presence and location of insufficiency fractures by consensus. We calculated the cumulative prevalence of pelvic insufficiency fractures on the basis of their results. In addition, we identified other associated bony complications of the female pelvis by reviewing the MR images. Insufficiency fractures were diagnosed in 100 patients; the 5-year cumulative prevalence was 45.2%. An insufficiency fracture was diagnosed a median of 16.9 months after radiation therapy. The fracture sites were the sacrum body and alae, medial side of the iliac bone, the roof of the acetabulum, superior rami of the pubic bone, femoral heads, and L5 vertebra. Sixty-one patients (61%) developed multiple fractures, and among them, 40 (40%) had bilateral symmetric lesions of the sacral alae. Other complications associated with the radiation therapy, as determined by evaluation of the MR images, were osteolysis and avascular necrosis of the femoral

head. Radiation-induced pelvic insufficiency fractures are a frequent complication of radiation therapy for uterine cervical cancer. Osteolysis and avascular necrosis of the femoral head were also diagnosed using MRI after radiation therapy.

Kamal et al. (2011) assessed the morbidity and complications of treatment among long-term survivors of cervical cancer. Ninety-eight female patients who were diagnosed and treated from invasive carcinoma of the cervix uteri 5 years or more are included in this study. All the cases were free of disease and had survived up to December 2010. Forty-one cases were treated with radical hysterectomy with removal of the lymph nodes (Wertheim's surgery) (42%). Radical radiation therapy was given to 57 cases (58%) according to our treatment protocol; weekly cisplatin was given concomitantly with radiation. Although urinary adverse effects were more prevalent among the radiation group, the difference was not statistically significant. Bowel dysfunction was more prevalent and statistically significant ($p < 0.001$) among the radiotherapy arm. Dysfunctions recorded included change in bowel habit, diarrhea, constipation, tenesmus, soiling of clothes and or flatulence. However, their severity was grade 1–2 only. The frequency of small intestinal obstruction was comparable in both arms. Pelvic vein thromboses had a tendency to occur among the surgical group especially in obese females (p value 0.005). The frequency of sexual dysfunction was comparable in both groups with no statistical difference. It was age related. The younger the patients' ages, the more was the sexual complaint irrespective to the treatment modality. Sexual problems included dyspareunia from vaginal stenosis shortening or dryness, vulval soreness from itching and dryness. Bearing in mind that many patients had more than one health complaint, the remaining cases denied the presence of any complications and stated that they had a normal life style.

Carlos et al. (1998) measured the impact of total doses of irradiation, dose rate, and ratio of doses to bladder or rectum and point A on sequelae in patients treated with irradiation alone for cervical cancer. Records were reviewed of 1456 patients (Stages IB–IVA) treated with external-beam irradiation plus two low-dose rate intracavitary insertions to deliver 70 to 90 Gy to point A. Follow-up was obtained in 98% of patients (median, 11 years; minimum, 3 years; maximum, 30 years). The relationships among various dosimetry parameters and Grade 2 or 3 sequelae were analyzed. In Stage IB, the frequency of patients developing Grade 2 morbidity was 9%, and Grade 3 morbidity, 5%; in Stages IIA, IIB, III, and IVA, Grade 2 morbidity was 10% to 12% and Grade 3 was 10%. The most frequent Grade 2 sequelae were cystitis and proctitis (0.7% to 3%). The most common Grade 3 sequelae were vesicovaginal fistula (0.6% to 2% in patients with Stage I–III tumors), rectovaginal fistula (0.8% to 3%), and intestinal obstruction (0.8% to 4%). In the bladder, doses below 80 Gy correlated with less than 3% incidence of morbidity and 5% with higher doses ($p = 0.31$). In the rectosigmoid, the incidence of significant morbidity was less than 4% with doses below 75 Gy and increased to 9% with higher doses. For the small intestine, the incidence of morbidity was less than 1% with 50 Gy or less, 2% with 50 to 60 Gy, and 5% with higher doses to the lateral pelvic wall ($p = 0.04$). When the ratio of dose to the bladder or rectum in relation to point A was 0.8 or less, the incidence of rectal morbidity was 2.5% (8 of 320) vs. 7.3% (80 of 1095) with higher ratios ($p \leq 0.01$); bladder morbidity was 2.3% (7 of 305) and 5.8% (64 of 1110), respectively ($p = 0.02$). The incidence of Grade 2 and 3 bladder morbidity was 2.9% (10 of 336) when the dose rate was less than 0.80 Gy/h, in contrast to 6.1% (62 of 1010) with higher dose rates ($p = 0.07$). Rectal morbidity was 2% to 5% in Stage IB, regardless of dose rate to the rectum; in

Stages IIA–B and III, morbidity was 5.2% (28 of 539) with a dose rate of 0.80 Gy or less and 10.7% (37 of 347) with higher dose rates ($p < 0.01$). Multivariate analysis showed that dose to the rectal point was the only factor influencing rectosigmoid sequelae, and dose to the bladder point affected bladder morbidity. Various dosimetric parameters correlate closely with the incidence of significant morbidity in patients treated with definitive irradiation for carcinoma of the uterine cervix. Careful dosimetry and special attention to related factors will reduce morbidity to the lowest possible level without compromising pelvic tumor control.

Linda van de Bunt, et al, (2006) Investigating the impact of tumor regression on the dose within cervical tumors and surrounding organs, comparing conventional, conformal, and intensity-modulated radiotherapy (IMRT) and the need for repeated treatment planning during irradiation. Fourteen patients with cervical cancer underwent magnetic resonance (MR) imaging before treatment and once during treatment, after about 30 Gy. Target volumes and critical organs were delineated. First conventional, conformal, and IMRT plans were generated. To evaluate the impact of tumor regression, we calculated dose–volume histograms for these plans, using the delineations of the intratreatment MR images. Second conformal and IMRT plans were made based on the delineations of the intratreatment MR images. First and second plans were compared. The average volume receiving 95% of the prescribed dose (43 Gy) by the conventional, conformal, and IMRT plans was, respectively, for the bowel 626 cc, 427 cc, and 232 cc; for the rectum 101 cc, 90 cc, and 60 cc; and for the bladder 89 cc, 70 cc, and 58 cc. The volumes of critical organs at this dose level were significantly reduced using IMRT compared with conventional and conformal planning ($p < 0.02$ in all cases). After having delivered about 30 Gy external beam radiation therapy, the primary gross tumor volumes decreased on average by 46% (range, 6.1–

100%). The target volumes on the intratreatment MR images remained sufficiently covered by the 95% isodose. Second IMRT plans significantly diminished the treated bowel volume, if the primary gross tumor volumes decreased >30 cc. Intensity-modulated radiation therapy is superior in sparing of critical organs compared with conventional and conformal treatment, with adequate coverage of the target volumes. Intensity-modulated radiation therapy remains superior after 30 Gy external beam radiation therapy, despite tumor regression and internal organ motion. Repeated IMRT planning can improve the sparing of the bowel and rectum in patients with substantial tumor regression.

Kathryn et al. (1991) analyzed the complications in 310 patients with pathologically documented endometrial carcinoma who received adjuvant radiation therapy (RT) at Fox Chase Cancer Center between 1970 and 1986. Variables included timing of treatment, technique, total dose, age, diabetes, previous abdominal surgery, hypertension, prior bowel pathology, and lymphadenectomy. According to the FIGO (1985) system, 258 patients had Stage I disease, 48 had Stage II, and one had Stage III. One hundred seventy patients received preoperative (preop) RT, 138 received postoperative (postop) RT, and 2 received preop and postop RT. A 4-field technique was used for 212 of 235 patients receiving external-beam (EX) RT, and 75 patients were treated with intracavitary (IC) RT only. Median follow-up was 5.5 years. Actuarial survival of all 310 patients was 78% at 5 years. Thirty-two complications occurred, involving the rectum, small bowel, femur, or lower extremity. Complications were graded according to the ECOG scoring system as grade 2 (mild) and grades 3, 4, or 5 (serious). One of 75 patients treated with IC RT only experienced a grade-2 complication (proctitis). Of 71 patients receiving 4-field EX RT only, 25 preop (16%) and 14 postop (14%) patients had complications. Of 139 patients treated with both EX

and IC RT, grade-2 complications were seen in 5% of 87 preop patients and 12% of 52 postop patients ($p = 0.17$), whereas serious complications were observed in 4% of each group. Univariate analysis of the variables of interest revealed that the incidence of complications was associated with a lymphadenectomy ($p = .03$), use of external RT ($p < .01$), and decreasing age ($p = .04$). Multivariate analysis confirmed that use of external RT was the most significant predictor for complications. In conclusion, similar complication rates were found in patients treated with either preop or postop 4-field EX RT. While pelvic RT clearly decreases pelvic relapse in patient with endometrial carcinoma, the risk benefit ratio for treatment of these patients should be carefully considered when recommending adjuvant RT for pelvic control.

Heron et al. (2002) evaluated the feasibility of pelvic intensity-modulated radiotherapy (IMRT) in the adjuvant treatment of gynecologic malignancies and to compare the dose–volume histograms (DVHs) and determine the potential impact on acute and long-term toxicity based on the dose to target and nontarget tissues for both planning techniques. Ten consecutive patients referred for adjuvant radiotherapy for gynecologic malignancies at the University of Pittsburgh School of Medicine and Magee–Womens Hospital were selected for CT-based treatment planning using the ADAC 3D version 4.2g and the NOMOS Corvus IMRT version 4.0. Normal tissues and critical structures were contoured on axial CT slices by both systems in conjunction with a gynecologic radiologist. These regions included internal, external, and common iliac nodal groups, rectum, upper 4 cm of vagina, bladder, and small bowel. Conventional treatment planning included 3D four-field box using 18-MV photons designed to treat a volume from the L_5/S_1 border superiorly to the bottom of the ischial tuberosity on the AP/PA field and shaped blocks on the lateral fields to minimize the dose to the rectum and small bowel. A seven-field technique using 6-MV photons was used for IMRT.

Restraints on small bowel for IMRT were set at 23.0 Gy ± 5% and 35.0 Gy± 5% for the rectum and 37.5 Gy ± 5% for the bladder while simultaneously delivering full dose (45.0 Gy) to the intrapelvic nodal groups in 1.8-Gy daily fractions. The dose–volume histograms where then compared for both treatment delivery systems. The volume of each organ of interest (small bowel, bladder, and rectum) receiving doses in excess of 30 Gy was compared in the 3D and IMRT treatment plans. The mean volume of small bowel receiving doses in excess of 30 Gy was reduced by 52% with IMRT compared with 3D. A similar advantage was noted for the rectum (66% reduction) and the bladder (36% reduction). The nodal regions at risk and the upper vagina all received the prescribed dose of 45.0 Gy. Intensity-modulated radiotherapy appears to offer several advantages over conventional 3D radiotherapy (3D CRT) planning for adjuvant radiotherapy for gynecologic malignancies. These include a significant reduction in treatment volume for bladder, rectum, and small bowel. It is anticipated that this reduction in volume of normal tissue irradiated would translate into overall reduction in acute and potentially late treatment-related toxicity. Prospective trials are necessary to better evaluate the advantages in a larger group of patients the femoral head were also diagnosed using MRI after radiation therapy.

André et al. (1999) determined the impact of the filling status of the organs at risk (bladder and rectum) on the uterus mobility and on their integral dose distribution in radiotherapy of gynaecological cancer. In 29 women suffering from cervical or endometrial cancer two CT scans were carried out for treatment planning, one with an empty bladder and rectum, the second one with bladder and rectum filled. The volumes of the organs at risk were calculated and in 14 patients, receiving a definitive radiotherapy, the position of the uterus within the pelvis was shown using multiplanar reconstructions. After generation of a 3D treatment plan the dose volume histograms

were compared for empty and filled organs at risk. The mobility for the corpus uteri with/without bladder and rectum filling was in median 7 mm (95%-confidence interval: 3–15 mm) in cranial/caudal direction and 4 mm (0–9 mm) in posterior/anterior direction. Likewise, cervical mobility was observed to be 4 mm (−1–6 mm) mm in cranial/caudal direction. A full bladder led to a mean reduction in organ dose in median from 94–87% calculated for 50% of the bladder volume ($P<0.05$, Wilcoxon's matched-pairs signed-ranks test). For 66% of the bladder volume the dose could be reduced in median from 78 to 61% ($P<0.005$) and for the whole bladder from 42 to 39% ($P<0.005$), respectively. No significant contribution of the filling status of the rectum to its integral dose burden was noticed. Due to the mobility of the uterus increased margins between CTV and PTV superiorly, inferiorly, anteriorly and posteriorly of 15, 6 and 9 mm each, respectively, should be used. A full bladder is the prerequisite for an integral dose reduction.

Gustavo (1989) evaluated 527 patients with epidermoid carcinoma of the cervix received radical radiation therapy at North Carolina Memorial Hospital (NCMH). The treatment was designed to deliver a combined dose (external beam plus intracavitary) of 7000–8000 cGy to Point A and 5000–6500 cGy to the pelvic lymph nodes depending upon the stage of the disease. The maximum dose to the bladder and to the rectum were calculated from the orthogonal intracavitary placement films with contrast material in these organs. Thirty-three cases of cystitis and fifty-eight cases of proctitis were recorded. The mean bladder dose for the group of patients with cystitis was higher, 6661 ± 1309 cGy, than that for the patients without cystitis, 6298 ± 1305 cGy, $p = .19$. The risk of cystitis increased as a function of bladder dose ranging from 3% for patients receiving ≤5000 cGy to the bladder to 12% for patients receiving ≥8001 cGy to the bladder. A similar correlation was also found for rectal dose and proctitis. The

mean rectal dose for the group of patients with proctitis was higher, 6907 ± 981 cGy, than that for the patients without proctitis, 6381 ± 1290 cGy, p = .003. The risk of proctitis increased as a function of rectal dose ranging from 2% for patients receiving ≤5000 cGy to the rectum to 18% for patients receiving ≥8001 cGy to the rectum. A study of the severity of the cystitis as a function of bladder dose revealed a relationship between bladder dose and the severity of the complication (Grade I cystitis = 6600 ± 1318 cGy vs Grade III cystitis = 6856 ± 853 cGy). A dose-response relationship was found between the rectal dose and the severity of the complication (Grade I proctitis = 6810 ± 906 cGy vs Grade III proctitis = 6997 ± 1137 cGy). This relationship was statistically significant, p = .003. While there was no difference in the frequency of cystitis as a function of dose to the whole pelvis, the risk of proctitis did increase with increasing doses of external beam to the whole pelvis. It ranged from 3% for patients who received 2000 cGy or less to the whole pelvis to 14% for patients who received >4000 cGy to the whole pelvis, p = .02.

Lorraine et al. (2001) used combined modality approach (chemotherapy and radiation therapy) for the treatment of patients with cervical cancer is associated with significant gastrointestinal and genitourinary toxicity. Intensity-modulated radiation therapy (IMRT) has the potential to deliver adequate dose to the target structures while sparing the normal organs and could also allow for dose escalation to grossly enlarged metastatic lymph node in pelvic or para-aortic area without increasing gastrointestinal/genitourinary complications. We conducted a dosimetric analysis to determine if IMRT can meet these objectives in the treatment of cervical cancer. Computed tomography scan studies of 10 patients with cervical cancer were retrieved and used as anatomic references for planning. Upon the completion of target and critical structure delineation, the imaging and contour data were transferred to both an

IMRT planning system (Corvus, Nomos) and a three-dimensional planning system (Focus, CMS) on which IMRT as well as conventional planning with two- and four-field techniques were derived. Treatment planning was done on these two systems with uniform prescription, 45 Gy in 25 fractions to the uterus, the cervix, and the pelvic and para-aortic lymph nodes. Normalization was done to all IMRT plans to obtain a full coverage of the cervix with the 95% isodose curve. Dose-volume histograms were obtained for all the plans. A Student's *t* test was performed to compute the statistical significance. The volume of small bowel receiving the prescribed dose (45 Gy) with IMRT technique was as follows: four fields, 11.01 ± 5.67%; seven fields, 15.05 ± 6.76%; and nine fields, 13.56 ± 5.30%. These were all significantly better than with two-field (35.58 ± 13.84%) and four-field (34.24 ± 17.82%) conventional techniques ($p < 0.05$). The fraction of rectal volume receiving a dose greater than the prescribed dose was as follows: four fields, 8.55 ± 4.64%; seven fields, 6.37 ± 5.19%; nine fields, 3.34 ± 3.0%; in contrast to 84.01 ± 18.37% with two-field and 46.37 ± 24.97% with four-field conventional technique ($p < 0.001$). The fractional volume of bladder receiving the prescribed dose and higher was as follows: four fields, 30.29 ± 4.64%; seven fields, 31.66 ± 8.26%; and nine fields, 26.91 ± 5.57%. It was significantly worse with the two-field (92.89 ± 35.26%) and with the four-field (60.48 ± 31.80%) techniques ($p < 0.05$). In this dosimetric study, we demonstrated that with similar target coverage, normal tissue sparing is superior with IMRT in the treatment of cervical cancer.

Chapter three
Methodology

The study were evaluated the dose to sensitive organs (bladder, rectum, and head of femur) in treatment of cervix carcinoma by external beam radiation therapy .The sample was collected at RICK from 2012 to 2013.

3.1. Materials:

This study was carried -out using Co-60 teletherapy machine with average energy 1.25 and percentage depth dose at 10cm with d_{max} at 0.5cm depth, Tray factor 0.98 , maximum field size is $45\times45cm^2$, ruler, CT spiral machine Toshiba Aquilion 64…… .

3.2. Methods:

3.2.1. The population:

The study sample was consisted of (69 patients) treat with external beam radiation therapy for cervical carcinoma in RICK.

3.2.1.1. Inclusion criteria:

The study was included all patients undergoing radical treatment of EBRT of cervical cancer.

3.2.1.2. Exclusion criteria:

All patients have blocked field or treated with brachytherapy will exclude from this study.

3.2.2. Study duration:

The study was done between may-2012 to December 2013.

3.2.3. Study area:

The study was performed on RICK.

3.2.4. Variables of the study:

3.2.4.1. Data collection variables:

Infield organs are: Cervix, Rectum, Bladder, hip joint.

3.2.5. Method of data collection:

The data were collect on master data sheet from the static office which was include all parameters need for calculation

3.2.6. Method of data analysis:

This data were analysis using an excel Microsoft office program and SPSS 16.0 and storage in personal computer with password.

3.2.7. Ethical issues:

2 There was official written permission to RICK to take the data.

3 No patient data were published.

Chapter four
Results

4.1. Table show the (everge of dose received by the bladder, rectum and head of femur) mean ±SD

The organs	Dose Mean ±SD
Bladder	4611cGy±400.3
Rectum	444.9cGy±553.7
Head of femur	4611cGy±439.7

4.2. Table show the mean ±SD of the treatment parameters (AP depth)cm

The parameters	Mean ±SD
Cervix depth	10.9±1.5
Bladder AP depth	7.3±1.5
Rectum AP depth	14.2±1.8
Head of femur AP depth	7.2±2.1

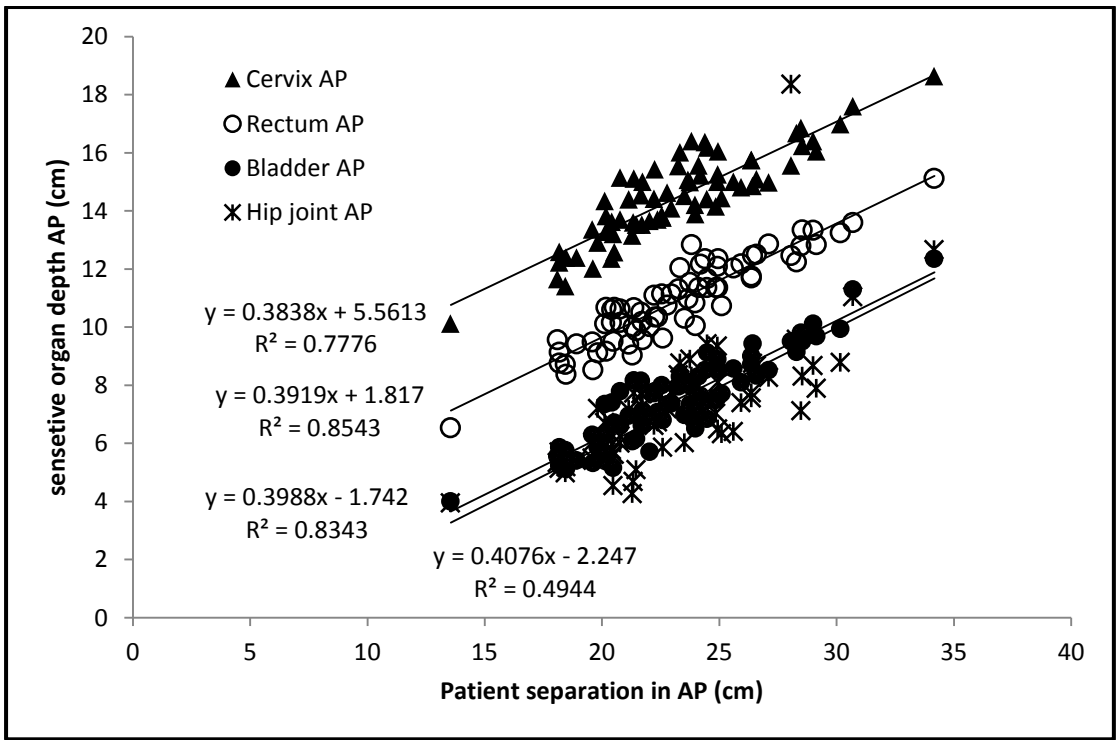

Figure 4-1 scatter plots shows a direct linear association between the female pelvic organs depths from anterior aspect (AP-view) and patient AP separation with a trend lines reveals a significant correlation.

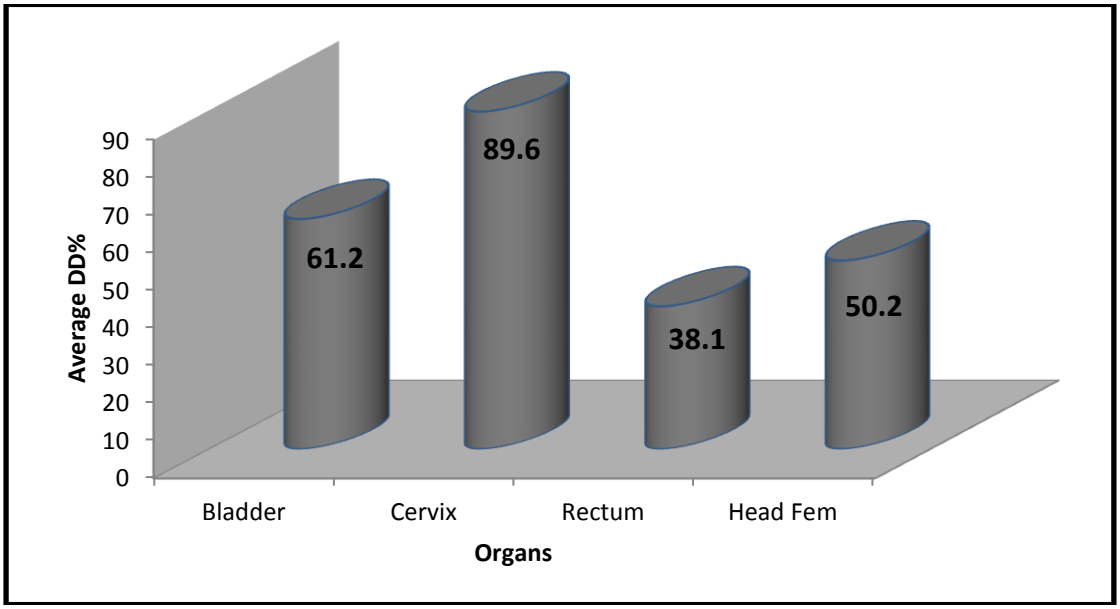

Figure 4-2 a bar plot shows the radiation percentage depth dose DD% for female pelvic organs receiving radiotherapy course for cervical carcinoma using box technique.

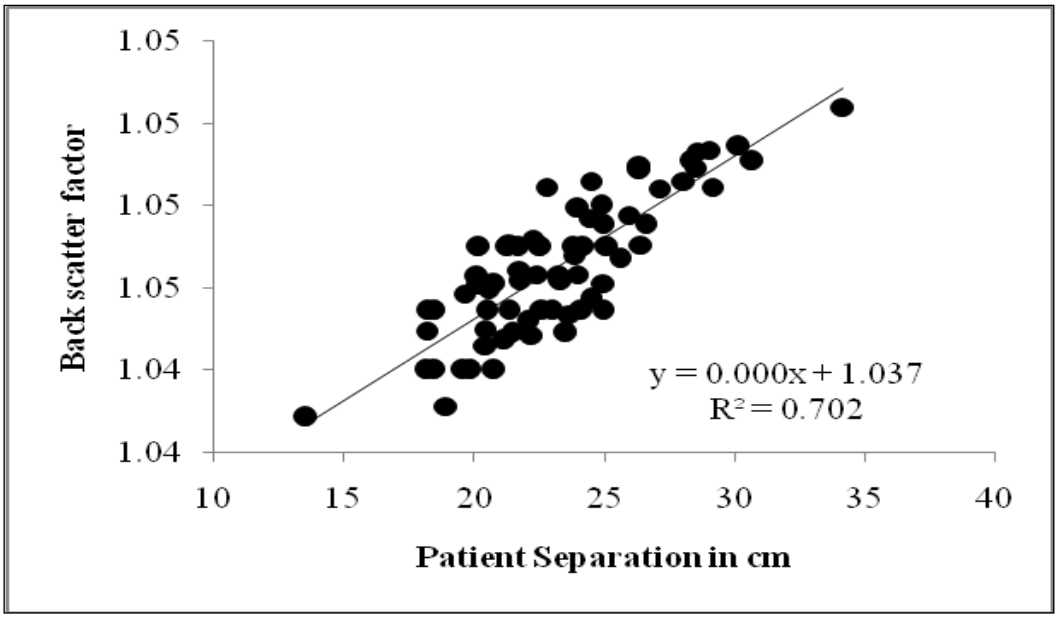

Figure 4-3 scatter plot shows the correlation between the back scatter factor and patients separation in cm.

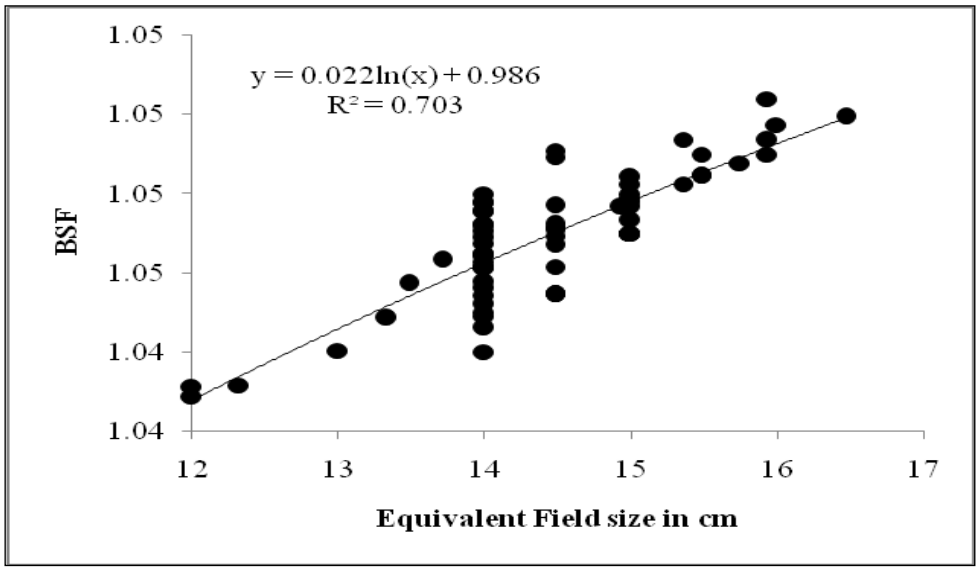

Figure 4-4 scatter plot shows the correlation between the equivalent field size and the back scatter factor.

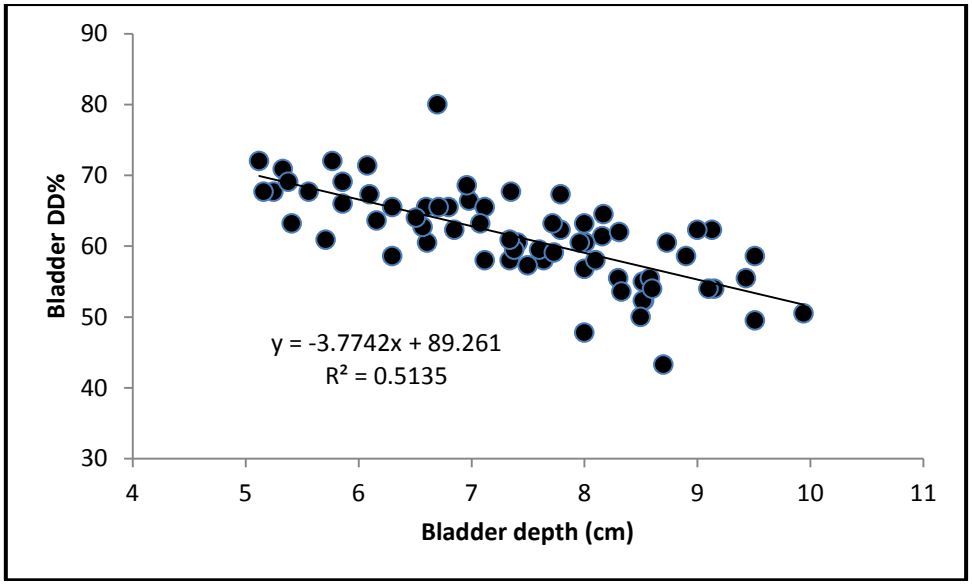

Figure 4-5 scatter plot show an inverse linear association between AP bladder depth and it is DD% with a trend line that depicts a significant correlation.

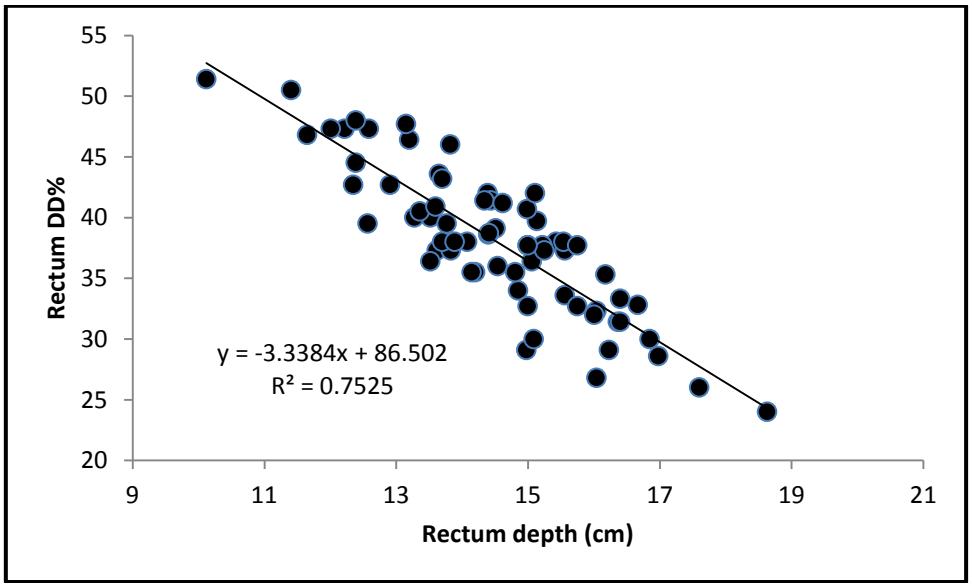

Figure 4-6 scatter plot show an inverse linear association between AP rectum depth and it is DD% with a trend line that depict a significant correlation.

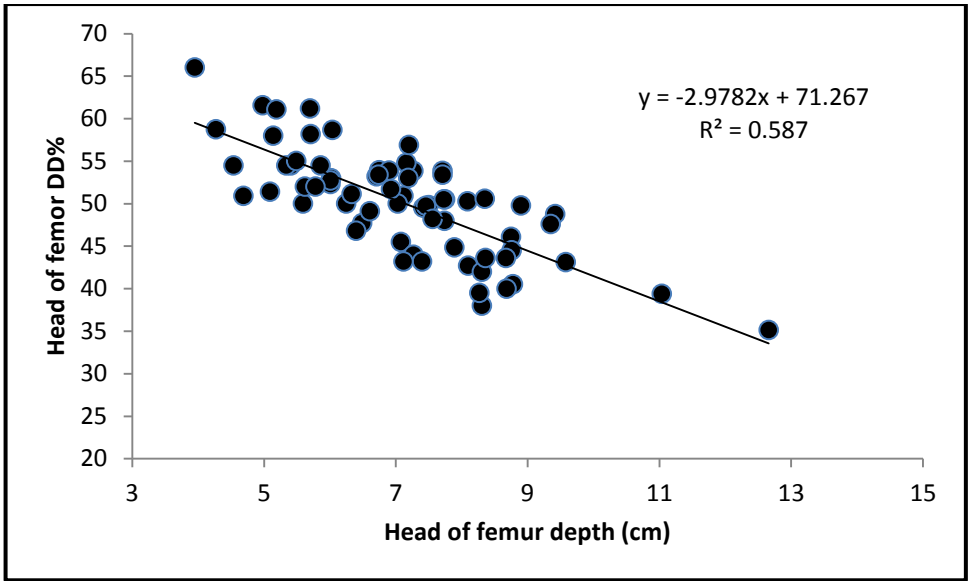

Figure 4-7 scatter plot show an inverse linear association between AP head of femur depth and it is DD% with a trend line that depict a significant correlation.

Chapter five
Discussion, Conclusion and Recommendation

5-1 Discussion

Literature review showed that there is a varieties of methods used to treat cervical carcinoma using radiation in an effort to increase the dose to the target volume while reducing the dose to the critical organs surrounding the target volume with a variable degree of successes, but still using manual planning and box technique lead to substantial amount of radiation dose to OAR.

Table 4-1 showed that the average dose received by bladder, rectum and head of femur were 4611± 400.3, 4449± 553.7 and 4611± 439.7 cGy respectively.

In table 4-2 the pelvic organs (cervix, bladder, rectum and head of femur) have variable depths in average it was 10.9±1.5, 7.3±1.5, 14.2±1.8, 7.2±2.1 cm respectively from anterior aspect (AP-view). Figure 4-1 shows the female pelvic organs depth from anterior view (AP) correlated with patient AP separation. It confirms that: anatomically the rectum situated at most deep to posterior aspect, followed by the cervix and the most anterior organ was the bladder and head of femur (Valerie and Tina, 2007). These organs position have a correlation with patient separation in a linear fashion of the following equations: $y = 0.38x + 5.56$, $y = 0.39x + 1.82$, $y = 0.4x - 1.74$ and $y = 0.41x - 2.25$, respectively, where y refers to organ depth and x refers to patient separation in cm with a significant correlation at $R2 = 0.8$. The data from CT images prove that the cervix is not situated at the mid of patients from AP aspects, this fact should be considered seriously in manual planning of radiation therapy in which they assume that the cervix is a mid-positioning organ leading to overdose in rectum and may give insufficient dose to tumor (cervix).

The pelvic organ receives a variable amount of radiation dose in respect to their depth from AP and relative to dose received by cervix according to it is depth. Figure 4-2 shows the radiation percentage depth dose DD% for female pelvic organs receiving radiotherapy course for cervical carcinoma using box technique. It revealed that the DD% for the tumor (cervix), Bladder, head of femur and the rectum were 89.6%, 61.2, 50.2% and 38.1% respectively, which were equivalent to 4032, 2308.2, 2333.6 and 2225.6 cGy respectively. The received dose by tumor does not concise with the concept of ICRU, (1976) and Zhu, (2000) which stated that: the tumor dose has to be ±5% from the prescribed dose, as well Withers et al., (1995) stated that: 50 Gy can get 90% probability for local control, even if there are microscopic diseases in pelvic lymph nodes. Therefore such planning would results in ±10.4% as loss of dose, hence leading to recurrence or treatment relapse due to insufficient tumor dose or inadequate pelvic radiation coverage for the draining lymph nodes (Perez et al., 1988). Also there were wide variations have been reported in the pelvic anatomy of individual patients, which implies the different levels of aortic bifurcation, altered sacral curvature, and varying course of pelvic vessels (Greer et al, 1990; Zunino et al, 1999; Justino et al, 2009). These have raised concerns over the adequate coverage of the target volume with conventional two dimensional fields based on standard bony landmarks. The DD% received by these organs usually showed to be considerable due to back scattered radiation which is influenced by the field size and tissue volume (Khan, 2010).

Figure 4-3 shows the correlation between the back scatter factor (BSF) and patient's separation in cm. it indicates that the back scattered radiation increases as the tissue volume increases leading to increment of DD% for all organs at the target volume. The correlation between patient separation and the back scatter could be fitted in the

following equation: $y = 0.0002x + 1.037$, which is significant at $R^2 = 0.7$, where y refers to BSF and x refers to patient separation in cm such proportional relationship has been mention by Khan, (2010); Hassan et al, (2005), Grosswendt, (1990).

Figure 4-4 shows the correlation between the equivalent field size and the back scatter factor. It reveals that there is proportional exponential relationship between equivalent field size in cm and the back scatter factor BSF in a form of equation: $y = 0.022lnx + 0.98$, which is so significant at $R^2 = 0.7$, where y refers to BSF and x refers to equivalent field size in cm. Such proportional relationship has been mention by Khan, (2010), which is so indicative that: the field size is influencing factor in the BSF as well as in the DD%.

In a similar fashion the results in Figure 4-5 to 4-7 showed that there is an inverse linear relationship between the DD% of the pelvic organs and the depth of each of these organs. The DD% is not like the percentage depth dose that used to calculate the given dose from the tumour dose in normal dose calculation; this is why it might look tricky. These percentages were taken by normalizing the dose received by the critical organs with the total given dose i.e. the percentage attributed to the given dose rather than the tumour dose. Therefore As long as the organ lies deep it shows lower DD%; because the given dose at this depth were much here than the outer point; in the same essence lower DD% in fact results in a high dose because it is integral part associated with higher given dose. These relationships also can be used to estimate the DD% of the sensitive organs and hence the received radiation dose since the depth is known as follows: $y = (-3.77x) + 89.26$, $y = (-3.34x) + 86.502$ and $y = (-2.98x) + 71.27$ for the bladder, rectum and head of femur, respectively, where y refers to percentage depth dose 'DD%' x refers to pelvic organ depth in cm with a significant correlation at $R^2 = 0.8$.

5-2 Conclusion

The study was establish to evaluate the amount of dose received by organs at risk (OAR) (bladder, rectum, and femur head) in the treatment of cervical carcinoma using external beam radiation therapy where the data were collected from 200 patient in RICK.

The dose received by the critical organs was with in the permisible dose, and will be save to these organs.

The result of this study showed that the average dose received by OAR 'bladder, rectum, and head of femur', were 4611 ± 400.3, 4449±553.7 and 4611 ± 439.7 respectively.

5-3 Recommendation

- Application of simulator in planning and determination of target volume and critical organs to avoid unnecessary dose.
- Using of multiple field in cervix irradiation (conformal therapy) to avoid over dose in sensitive organ.
- Similar study can be done by comparing the usage of four filed techniques with multiple fields techniques as well as two filed at the same time reporting on the central organ technique and off axis one.

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Appendix (A)

Master data sheet

Given dose	TD	AP separation	Lat separation	field size width	field size Length	SQR
8124	4500	22.04	34.36	14	14	14
10234	4500	24.96	38	14	14	14
9721	4500	21.67	33.39	15	15	15
8744	4500	23.97	37.11	12	12	12
11064	4500	28.3	41.57	14	14	14
7383	4500	18.18	29.33	15	14	14
7872	4500	18.92	30.5	12	12	12
7859	4500	23.52	32.13	14	14	14
8232	4500	21.71	32.49	14	14	14
9731	4500	26.43	37.79	14	14	14
9016	4500	20.78	30.2	14	14	14
7362	4500	18.44	30.71	15	14	14
10276	4500	24.49	37.18	14	20	16
7859	4500	18.11	31.54	14	14	14
8475	4500	20.18	32.95	15	15	15
10128	4500	22.26	34.36	14	17	15
9063	4500	21.74	35.4	14	14	14
6767	4500	18.18	29.17	16	15	15
10297	4500	24.4	39.59	15	14	14
8349	4500	19.59	31.24	14	14	14
9459	4500	24.2	35.56	15	15	15
8479	4500	20.43	31.68	14	14	14
8574	4500	28.55	41.08	14	14	14
9436	4500	24.93	37.77	14	15	14
9943	4500	23.82	32.58	14	16	15
8157	4500	20.78	35.69	15	15	15
7201	4500	18.48	31.09	14	14	14
7239	4500	19.62	34.2	15	15	15
10654	4500	24.12	33.86	14	15	14
8740	4500	21.15	32.91	14	14	14
11210	4500	22.56	34.14	15	15	15
7686	4500	25.1	35.52	15	15	15
7603	4500	19.82	30.96	14	14	14
9355	4500	23.75	36.37	15	15	15
8721	4500	23.67	32.14	14	14	14
7864	4500	22.6	32.22	15	14	14
8943	4500	23.27	34.91	14	14	14
8796	4500	22.96	37.28	15	14	14
9440	4500	23.33	35.38	14	14	14
8897	4500	20.12	34.31	15	15	15
9150	4500	20.54	32.8	15	15	15
10135	4500	22.37	34.5	16	12	14
8208	4500	20.41	33.39	14	14	14

7531	4500	24.48	43.08	13	14	13
9433	4500	28.07	39.81	14	14	14
9076	4500	30.17	46.12	14	14	14
9049	4500	27.11	44.2	15	15	15
9767	4500	26.59	42.09	14	14	14
7176	4500	20.48	26.53	15	14	14
8306	4500	24.86	34.56	14	14	14
7704	4500	24.94	35.89	14	14	14
8093	4500	21.34	29.09	14	15	14
10431	4500	26.37	37.26	16	16	16
8870	4500	29.01	39.81	17	14	15
9394	4500	25.61	37.25	15	14	14
7586	4500	20.18	30.09	15	15	15
7514	4500	21.3	30.68	15	15	15
9810	4500	21.37	32.5	15	17	16
9531	4500	25.94	34.97	14	14	14
11986	4500	30.7	36.92	14	15	14
9727	4500	28.49	39.03	15	14	14
9625	4500	29.15	40.98	16	15	15
8128	4500	21.46	31.8	11	14	12
11697	4500	34.17	44.62	17	15	16
8055	4500	23.99	33.22	14	18	16
8838	4500	22.22	34.1	12	15	13
6331	4500	13.55	22.23	13	13	13
8499	4500	22.78	32.58	15	16	15
10366	4500	26.37	36.9	17	15	16

cervix depth (AP)	SSD	BSF	%DD	bladder depth (AP)	Rectum depth (AP)
10.02	90	1.044	55.4	5.71	13.65
13.14	87	1.044	44.0	8.53	16.04
12.54	87	1.047	46.3	8.16	14.54
10.83	89	1.038	51.5	7.12	13.5
14.19	86	1.044	40.7	9.15	17.56
8.76	91	1.045	60.9	5.86	10.99
9.42	91	1.038	57.2	5.41	12.39
9.57	90	1.044	57.3	5.86	13.51
10.2	90	1.044	54.7	6.61	12.24
12.46	88	1.044	46.2	9.43	14.85
11.43	89	1.044	49.9	7.79	15.14
8.72	91	1.045	61.1	5.77	11.41
13.43	87	1.051	43.8	9.13	16.18
9.57	90	1.044	57.3	5.56	11.65
10.68	89	1.047	53.1	6.3	13.28
13.13	87	1.048	44.4	7.79	15.43
11.5	89	1.044	49.7	7.12	15
7.64	92	1.048	66.5	4.56	10.86
13.27	87	1.045	43.7	9.14	16.37
10.39	90	1.044	53.9	6.3	13.36
12.17	88	1.047	47.6	7.64	15.22
10.6	89	1.044	53.1	9.12	13.62
10.75	89	1.044	52.5	7.05	14.96
12.09	88	1.045	47.7	8.9	15
12.84	87	1.047	45.3	9.35	16.4
10.16	90	1.047	55.2	6.6	12.39
8.38	92	1.044	62.5	5.12	12.39
8.53	91	1.047	62.2	5.33	12.01
13.73	86	1.045	42.2	8.31	16.03
11.01	89	1.044	51.5	6.96	14.39
14.47	86	1.047	40.1	9.05	16.03
9.35	91	1.047	58.5	6.96	13.92
9.12	91	1.044	59.2	5.86	12.91
12.02	88	1.047	48.1	7.34	14.99
10.98	89	1.044	51.6	8.01	15.06
9.62	90	1.045	57.2	5.7	12.98
11.32	89	1.044	50.3	7.96	15.54
11.14	89	1.045	51.2	7.38	14.08
12.05	88	1.044	47.7	8.3	16.01
11.34	89	1.047	50.6	7.35	14.34
11.72	88	1.047	49.2	6.71	12.57
12.98	87	1.043	44.4	7.08	16.39
10.16	90	1.044	54.8	6.57	12.35
8.95	91	1.042	59.7	5.77	12.53
12.04	88	1.044	47.7	7.97	15.56
11.52	88	1.044	49.6	8.49	14.54
11.57	88	1.047	49.7	7.72	14.98
12.51	87	1.044	46.1	7.67	15.09
8.37	92	1.045	62.7	5.16	11.58
10.32	90	1.044	54.2	7.5	14.15

9.3	91	1.044	58.4	5.7	13.14
10.01	90	1.045	55.6	6.1	12.04
13.59	86	1.050	43.1	9	15.75
11.33	89	1.048	50.7	7.5	14.55
12.03	88	1.045	47.9	7.02	15
9.17	91	1.047	59.3	5.38	13.82
9.04	91	1.047	59.9	6.08	11.93
12.75	87	1.050	45.9	8.17	15.11
12.18	88	1.044	47.2	8.1	14.81
15.32	85	1.045	37.5	11.3	18.27
12.5	88	1.045	46.3	7.71	15.23
12.45	88	1.048	46.8	8.48	16.04
9.88	90	1.039	55.4	6.16	12.74
15.14	85	1.050	38.5	12.73	18.63
10.05	90	1.049	55.9	6.51	13.03
11.1	89	1.042	50.9	7.73	14.41
6.54	93	1.041	71.1	4	8.6
10.76	89	1.048	52.9	7.34	14.62
13.5	87	1.050	43.4	8.73	15.75

Head of femor (AP)	cervix depth (PA)	bladder depth (PA)	Rectum depth (PA)	Head of femor (PA)	Bladder dose AP
6.75	12.02	16.33	8.39	15.29	75.84
8.1	11.82	16.43	8.92	16.86	61.81
7.71	9.13	13.51	7.13	13.96	63.86
7.5	13.14	16.85	10.47	16.47	67.76
9.58	14.11	19.15	10.74	18.72	59.06
5.7	9.42	12.32	7.19	12.48	75.21
5.41	9.5	13.51	6.53	13.51	76.73
6.02	13.95	17.66	10.01	17.5	75.03
7.27	11.51	15.1	9.47	14.44	71.09
8.75	13.97	17	11.58	17.68	57.86
6.25	9.35	12.99	5.64	14.53	65.25
4.98	9.72	12.67	7.03	13.46	75.69
9.42	11.06	15.36	8.31	15.07	59.99
5.34	8.54	12.55	6.46	12.77	76.66
6.01	9.5	13.88	6.9	14.17	73.06
6.9	9.13	14.47	6.83	15.36	65.73
7.71	10.24	14.62	6.74	14.03	68.51
5.14	10.44	13.62	7.32	13.04	82.80
7.08	11.13	15.26	8.03	17.32	59.27
5.49	9.2	13.29	6.23	14.1	72.70
7.27	12.03	16.56	8.98	16.93	66.33
5.59	9.83	11.31	6.81	14.84	59.19
8.31	17.8	21.5	13.59	20.24	68.86
9.35	12.84	16.03	9.93	15.58	60.33
8.31	10.98	14.47	7.42	15.51	58.52
6.01	10.62	14.18	8.39	14.77	71.50
5.19	10.1	13.36	6.09	13.29	79.09
6.04	11.09	14.29	7.61	13.58	78.28
7.12	10.39	15.81	8.09	17	62.99
7.16	10.14	14.19	6.76	13.99	69.31
7.42	8.09	13.51	6.53	15.14	59.85
6.33	15.75	18.14	11.18	18.7	69.67
7.2	10.7	13.96	6.91	12.62	75.03
8.9	11.73	16.41	8.76	14.85	67.78
8.09	12.69	15.66	8.61	15.58	64.21
5.86	12.98	16.9	9.62	16.74	76.07
8.35	11.95	15.31	7.73	14.92	64.45
7.75	11.82	15.58	8.88	15.21	67.40
8.76	11.28	15.03	14.57	14.55	62.86
6.71	8.69	12.77	5.78	13.4	67.74
5.62	8.82	13.83	7.97	14.92	70.94
6.74	9.39	15.29	5.98	15.63	68.61
5.78	10.25	13.84	8.06	14.63	71.30
7.46	15.53	18.71	11.95	17.02	75.33
18.36	16.03	20.1	12.51	9.71	64.40
8.78	18.65	21.68	15.63	21.39	61.99
8.27	15.54	19.39	12.13	18.84	65.94
8.67	14.08	18.92	11.5	17.92	65.83
4.54	12.11	15.32	8.9	15.94	79.04
7.03	14.54	17.36	10.71	17.83	66.65

6.49	15.64	19.24	11.8	18.45	75.90
4.69	11.33	15.24	9.3	16.65	73.93
7.74	12.78	17.37	10.62	18.63	60.40
8.68	17.68	21.51	14.46	20.33	67.13
6.4	13.58	18.59	10.61	19.21	69.19
5.71	11.01	14.8	6.36	14.47	78.01
4.27	12.26	15.22	9.37	17.03	74.22
7.73	8.62	13.2	6.26	13.64	64.14
7.4	13.76	17.84	11.13	18.54	63.79
11.04	15.38	19.4	12.43	19.66	50.56
7.12	15.99	20.78	13.26	21.37	65.81
7.89	16.7	20.67	13.11	21.26	62.56
5.09	11.58	15.3	8.72	16.37	72.81
12.66	19.03	12.44	15.54	21.51	45.94
6.93	13.94	17.48	10.96	17.06	72.23
6.61	11.12	14.49	7.81	15.61	65.29
3.95	7.01	9.55	4.95	9.6	85.16
7.19	11.92	15.34	8.06	15.49	67.95
7.56	12.87	17.64	10.62	18.81	61.58

Bladder dose PA	Total bladder dose	Rectum dose (AP	Rectum dose PA	Total rectum dose
34.69	4489.8	42.34	62.45	4256.2
34.44	4925.2	35.45	60.07	4887.8
43.09	5198.4	39.93	68.82	5285.8
32.78	4395.6	42.14	52.87	4153.8
28.13	4823.4	31.66	52.53	4657.2
46.89	4507.3	51.73	68.34	4432.5
42.11	4677.3	45.80	70.75	4587.2
31.43	4183.1	42.78	55.43	3859.1
38.01	4491.0	47.00	57.69	4309.2
33.01	4421.0	38.73	49.36	4285.9
44.46	4945.9	37.90	76.22	5144.7
45.69	4467.8	50.15	69.14	4390.7
38.00	5034.7	35.78	63.67	5109.5
45.94	4817.1	49.10	71.87	4753.3
41.93	4872.8	43.83	69.98	4822.6
40.25	5366.8	37.49	70.45	5466.6
39.39	4889.8	38.30	70.43	4926.8
42.89	4253.0	52.56	68.05	4081.1
37.71	4993.2	34.73	64.29	5098.1
43.48	4849.8	43.26	73.07	4855.8
34.39	4763.2	37.98	60.15	4640.8
50.36	4644.3	42.43	70.07	4769.6
23.62	3964.6	38.41	42.53	3469.7
35.62	4526.7	38.44	55.93	4452.6
40.12	4904.0	34.78	67.37	5078.4
41.01	4589.0	46.81	62.80	4470.6
43.26	4404.9	46.48	73.81	4330.8
40.68	4305.8	48.14	66.47	4148.3
36.20	5283.9	35.62	64.01	5307.0
40.67	4806.5	40.07	70.33	4824.5
43.09	5769.9	35.77	71.86	6032.9
30.60	3853.5	41.81	51.18	3573.6
41.37	4424.9	44.73	69.57	4344.6
34.77	4797.0	38.63	61.13	4665.8
36.47	4389.8	38.13	61.45	4342.0
33.39	4304.3	44.65	57.22	4005.7
37.43	4555.1	36.79	65.54	4575.6
36.83	4584.3	41.16	60.41	4467.3
38.21	4770.6	35.53	39.54	3543.2
45.51	5038.0	40.53	75.83	5176.1
42.09	5170.9	46.19	64.75	5075.7
37.39	5371.6	34.46	74.29	5510.4
41.74	4639.3	46.62	63.98	4539.0
28.93	3925.9	45.83	47.85	3527.9
26.21	4273.5	36.74	46.07	3905.6
23.31	3871.0	39.63	36.55	3457.0
27.89	4245.6	38.66	47.72	3908.0
28.62	4612.1	38.04	49.65	4282.7
37.54	4182.8	49.52	60.33	3941.1
32.14	4102.2	40.79	52.64	3880.2
27.94	3999.9	43.97	48.56	3564.3

37.77	4519.9	47.87	58.58	4307.5
32.66	4853.4	36.80	53.66	4717.6
23.92	4038.1	40.01	40.28	3560.9
29.46	4633.5	38.44	53.20	4304.5
39.17	4444.5	42.12	72.75	4356.6
37.98	4215.1	48.43	58.46	4015.6
44.38	5322.7	38.56	73.60	5501.1
31.01	4517.7	38.84	51.03	4283.0
27.74	4692.3	30.16	46.51	4594.9
25.04	4418.1	37.79	43.73	3965.0
25.48	4236.8	35.88	44.54	3869.7
36.93	4459.6	44.73	60.34	4269.9
46.93	5431.6	29.74	37.35	3924.2
32.33	4211.3	44.88	52.26	3912.4
39.57	4633.9	39.80	64.91	4627.5
56.99	4499.3	61.13	79.67	4457.0
37.78	4493.4	39.84	64.50	4434.2
32.00	4850.3	36.78	53.64	4686.6

head of femor dose (AP	head of femor dose PA (Rt &Lt)	Total head of femor dose
70.38	37.48	4381.0
63.79	33.35	4971.0
65.99	41.68	5233.2
65.90	33.73	4355.5
57.22	29.05	4772.2
76.07	46.33	4518.8
76.73	42.11	4677.3
74.18	31.80	4164.3
67.77	39.92	4432.9
60.82	31.38	4486.1
72.96	39.66	5076.9
80.05	43.09	4532.7
58.74	38.82	5012.3
77.87	45.19	4835.4
74.59	41.04	4900.0
70.10	37.69	5458.5
65.63	41.16	4839.2
79.51	44.77	4205.2
68.89	32.37	5213.1
77.04	40.95	4925.1
68.13	33.46	4804.6
76.49	38.76	4886.1
62.82	25.94	3804.9
58.37	36.83	4491.2
63.15	37.15	4986.2
74.59	39.26	4643.6
78.70	43.48	4398.9
74.43	42.87	4245.7
68.69	33.15	5424.6
68.32	41.28	4789.4
67.39	38.20	5918.7
72.90	29.35	3929.9
68.12	45.70	4326.4
60.51	39.03	4655.5
63.84	36.68	4383.0
75.21	33.79	4286.1
62.63	38.53	4523.3
65.62	37.85	4550.7
60.78	39.60	4737.6
70.94	43.44	5088.5
76.69	38.83	5285.0
70.32	36.46	5411.1
75.46	39.37	4712.6
66.65	32.81	3745.4
29.83	56.67	4080.0
60.69	23.81	3834.8
63.35	29.05	4180.9
61.18	30.83	4493.1

82.56	35.86	4248.3
68.96	31.03	4152.6
71.71	29.63	3903.8
81.70	34.02	4682.5
66.19	29.76	5004.2
61.61	26.10	3890.1
72.35	28.13	4720.0
76.20	40.14	4412.8
84.30	33.22	4415.0
66.22	42.97	5355.3
67.13	29.44	4602.1
51.54	27.21	4719.2
68.69	23.97	4506.0
65.30	24.40	4316.5
78.63	34.08	4580.7
46.18	24.05	4107.4
70.09	33.34	4165.9
70.85	36.40	4739.3
85.45	56.78	4502.0
68.69	37.36	4507.2
67.04	29.35	4996.0

Appendix (B)
Published paper