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Outfield Dose Calculation in Treatment of Breast Cancer Using Radiotherapy TPs

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Abstract: ***This was analytical study carried out to calculate the amount of radiation dose received by critical organ inside and outside radiation field in external beam radiation therapy of breast cancer to evaluate unnecessary radiation hazard that may arise from it, and to extract the better precaution that should be done in order to manage the unacceptable doses. Conventional radiotherapy is the most method used to treat cancer in developing countries. This study was conducted in radiation and isotopes center of Khartoum (RICK) in December 2014, 85 patient was undergoing dose computation using pinnacle 3 treatment planning system which used to distribute and calculate the dose to point inside and outside radiation field limit for the lung and skin using central axis dose calculation parameters, the variable collected was isodose line at measurement points, %DD, separation SQR, age and the stage of disease. The mean dose was 3168.2±453.3cGy, 539.4±147.8cGy, 2914.167±629.13cGy for lung and skin respectively. This dose is considered significantly high and may exceeding the tolerance of this organ which lead to increase radiation complication to the patient***

Keywords: outfield dose, radiotherapy, breast cancer, lung dose.

1. Introduction

Worldwide, breast cancer is the commonest form of malignancy in women [1, 2]. It accounts for 12% of all cancers, 18% of all female cancers, 10% of all cancer deaths and 20–25% of all female cancer deaths. In England, there are 41 000 new cases per year and, in the UK, over 12 000 women die of the disease per year. The cumulative incidence in women in Europe and North America is approximately 2.7% by the age of 55, 5% by the age of 65 and 7.7% by the age of 75. Male breast cancer is rare, accounting for only 1% of breast cancer, with breast cancer ranking second among cancer deaths in women (after lung cancer) Symonds et.al 2012. In Sudanese population cases comprised 1255 women from central Sudan diagnosed with breast cancer and referred to and treated at Institute of Nuclear Medicine, Molecular Biology, and Oncology, from January 1999 to December 2006. Data revealed that 74% of the women were ≤50 years old or premenopausal. Invasive ductal carcinoma was the most common pathology (82%) and women presenting with stage III or higher tumors that had already metastasized, while ductal carcinoma in situ was the least prevalent (0.5%) {….} the risk of women to develop breast cancer at some stage of her life about one to twelve, The UK has the highest age standardized incidence and mortality for breast cancer in the world{}. Anatomically most of the breast tissue extends from the edge of the sternum to the anterior axillary line and from the second or third to the sixth or seventh costal edge. It overlies the second to the sixth ribs. Breast tissue can be found beyond these areas as high as the clavicle and laterally to the edge of the latissimus dorsi muscle. The three main group of lymphatic drainage are axillary, supraclavicular in addition to internal mammary chain groups. the etiology of breast cancer in not clearly understood, about 10% having the genetic basis as germ line mutation of BRCA1, BRCA2, p53, PTEN and ATM. BRCA1 and BRCA2 genes, recent studies was relieved that the benign breast tumors may lead to cancer and the overall risk was estimated as 1.5–3 for women with previous benign breast disease, age of first pregnancy, lactation, hormonal, family history, radiation exposure, diet, life style and smoking is was correlated with increasing risk of malignancy in women (Symonds et.al 2012). A lump in the breast may be benign or malignant. Benign lesions include cysts, fibroadenomas and papillomas. Malignant tumours mainly arise from the glandular epithelium (adenocarcinomas) (Cavalli et.al 2009). Mammogram is the most method of screening used in early detection of breast cancer it used to decrease the morality rate by more than 30%, In a simplified model described by Harris et al. 110 for every 1,000 screening mammograms, 80 women (8%) will be recalled for additional diagnostic imaging, 10 (1%) will require tissue diagnosis, and of those undergoing biopsy only 3 (0.3%) will have a malignancy. MRI is used to diagnose breast cancer in young women when density of breast is often limiting factor of breast resolution also used to evaluate the local extend of tumor, CT help in both diagnosis and staging and bony extension assessment, US was used to differentiate the solid and cystic lesion of breast mass. FNAC and core biopsy is used to confirm histological diagnosis, treatment of breast cancer it can categorized in for groups surgery, chemotherapy (advance case response to neo-adjuvant chemo-agent in 80-90%), hormone therapy and radiotherapy.

Radiotherapy is one of the most affect method used to kill breast tumor cell which aims to deliver maximum dose of radiation to the tumor while minimizing dose to the critical structure. The effort of radiotherapy equipment 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 [6] or as mention by ICRU, [7] 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 breast 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 [8]. Patients treated with daily fractions of 2.0-2.66 Gy to a total dose of 40-50 Gy over 3-5 weeks in 15 daily fraction as conventional radiotherapy show an acceptable level of toxicity in prospective studies as stated by (ann berrett 2009). Radiotherapy target volume may include: chest wall, supraclavicular area, posterior axilla in addition to the internal mammary chain which planned as stated by (Barrett et.al 2009). As shown below

Figure 2: Patient immobilized for breast irradiation on a slant board with custom mold to minimize day-to-day positioning errors.

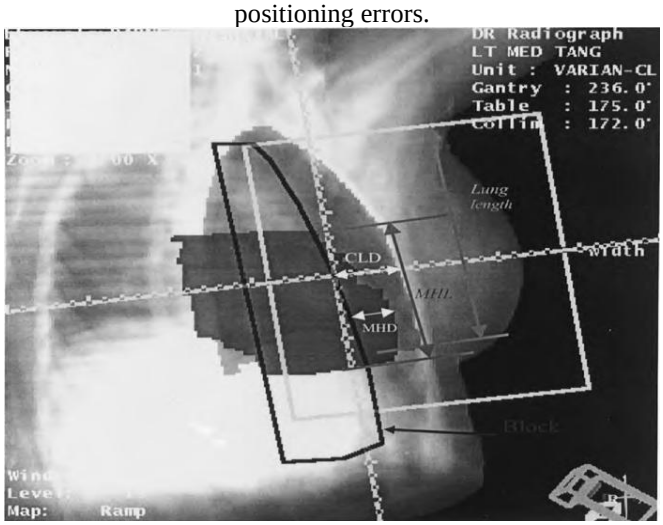

Figure 3: Radiographic parameters using virtual simulator. The contoured heart is shown in black, the lung in gray. The central lung distance (CLD) 2.5cm at the level of the central axis. Lung length is the vertical lung distance included in the radiation port. The maximal heart distance (MHD) 1.5cm, whereas the maximal heart length (MHL) is the maximal length in tangential fields referring to the heart contour in a digitally reconstructed radiograph (DRR). Kong F-M et.al 2002.

This study conducted in radiation and isotopes center in Co-60 unit in women with breast cancer in which the conventional treatment is the most method of treatment in developing countries rather than 3DCRT, IMRT, IGRT and IORT which involved more radiation effect to the patient, Currently, it is practically not possible to obtain a direct measurement of the 3Ddose distribution delivered to a patient. Therefore, the treatment planning has tope based on calculation models. Even if direct measurements were possible. It would still be much more practical and convenient to perform planning based on calculation models.

So the accurate dose calculation is also necessary in order to further improve our understanding of the biological response mechanisms in RT, the biological response of cells to radiation is highly nonlinear, and therefore small errors in the predicted dose may lead to large errors in prediction of the biological response [10].

The dose received by both organ of interest or critical organ around it can affected by many variable such as collimator scatter radiation, thickness of the patient, energy, field size, and any accessories used during the treatment process.
In the method presented by J. R. Cunningham [11], the scatter is computed with the help of a scatter-air ratio (SAR), which is derived from a measured tissue-air ratio (TAR) and its extrapolation to a zero-area beam. Handling of irregular field shapes is typically based on the integration method developed by J. R. Clarkson [8], where the field around the calculation point is divided into a number of angular segments. The dose contribution of each segment is estimated from the scatter function (e.g. SAR), and the contributions are summed up. Later more elaborate semi empirical methods were developed, which derive scatter kernels from measured beam data [12, 13]. Many other method of dose calculation may be used according to such factor that affect radiation delivery, Commonly, the dose distribution calculated for the homogeneous water-equivalent situation is converted into the heterogeneous situation in the same geometry by applying a point-by-point correction factor. Most methods, such as the equivalent path-length method(s) [10] or the Batho power-law method [14], determine the correction factor by a direct ray-tracing from the primary radiation source to the point of interest. More sophisticated techniques, such as the equivalent TAR method [15, 16], use the electron density data from the CT image to determine the correction factors. The use of these correction factors may still lead to deviations up to 10% from the measured dose for certain type of geometries. Kernel-based or convolution/superposition dose calculation methods are based on physical principles of the radiation behavior rather than on direct beam data measurements.

The problems of unnecessary dose may also arise because the outfield tissue may irradiated so the concept of outfield dose assessment was one of the aims of this study, In this realm

several calculations is carried out carefully to determine level of doses out the field limits. EBPT is unavoidably associated with irradiation, at lower doses, of large volumes of normal tissue away from the beam path (Jane et al., 2009; Jeffrey et al., 2010; Johnsson et al., 1997; Keys et al., 1997). According to the latest recommendations of (ICRU) concerning the remaining volume at risk (RVR), the search for means of more accurately determining such doses is of renewed clinical interest. Indeed, according to ICRU Report 83 (ICRU 2010), all normal tissues that could potentially be irradiated should be included in the RVR, and the absorbed dose in the RVR might be useful for estimating risk of later effects such as carcinogenesis. In essence, the out-of-field dose arises from three main sources: (1) leakage from the treatment unit; (2) scatter from the treatment unit head and from beam modifiers such as wedges and blocks; and (3) internal scatter originating in the patient. Different scientists estimated the dose to points in the body outside the primary beam. Therefore a generalized model is developed to calculate this dose with reasonable accuracy better than ±30% (Keys et al., 1999; Keys et al., 2003; Kim et al., 2008).

2. Material

This study was carried out using Varian theraplan plus version 3.8 Co-60 teletherapy machine with average energy 1.25 and percentage depth dose at 10 cm with d_{max} at 0.5 cm depth, tray factor 0,98 , maximum field size is 45*45cm^2 and Treatment Planning System (pinnacle^3) was used for both isodose distribution and calculation.

3. Method

Number of 85patient having breast cancer have been referred to Radiation and Isotopes Center of Khartoum (RICK) for radiation therapy course. After successful investigations as chest x-ray CXR, chest CT, ultrasound, Lab. test, histopathology and bone scan, the patients were decided to receive a radical radiotherapy course i.e. they were in stage I and II without hematologic spread. The radiotherapy planning carried out using conventional simulator, by which the four radiation fields have been determine as well as the radiation field boarders (medial, lateral tangential field anterior supraclavicular and posterior axillary fields) together with the beam entrances as proposed by ann Barret et al, 2009 [16] and as shown in Figure (1). Then the patients' contours (Figure 2) have been taken by using pantograph and the position of target volume and the critical organs (lung, heart, head of humorous and skin) were labeled, the central lung distance was clearly defined and the patient's separation from anterior-posterior and lateral were measured(to calculate both medial and lateral depth from the entrance and exit point, then patient data and his files referred to the physical stage of treatment planning in order to distribute and to calculate the dose to the target volume using pinnacle-3 TPs and the final dose histogram was made, three point was determined at point close to CLD inside the field, and beyond the CLD outside the field (at tangential) and at 1 mm depth (ant) after that the isodose distribution was performed and isodose line passing through these point was measured then the percentage of lung dose was calculated from total GD.

4. Result Presentation

Table 1: Show the mean± Std. Deviation of dose received by lung, skin, isodose line, SQR with patient age depth from the entrance and exit point, GD and TD.

Variables	*Mean± Std. Deviation*
Patient age (years)	46.2 ± 9.8
Outfield lung isodose (%)	12.2 ± 2.92
Skin dose (cGy) from TD	2914.2 ± 629.1
Equivalent squire for TF	9.5 ± 1.92
Equivalent squire for ASC	12.6 ± 1.57
Depth from medial point (cm)	7.0 ± 1.53
Depth from lateral point (cm)	7.0 ± 2.24
Isodose line (infield) (%)	72.6 ± 8.15
Given dose (cGy)	4379.8 ± 256.2
Dose to lung (infield) (cGy)	3186.2 ± 453.3
Dose to lung (outfield) (cGy)	539.4 ± 147.8

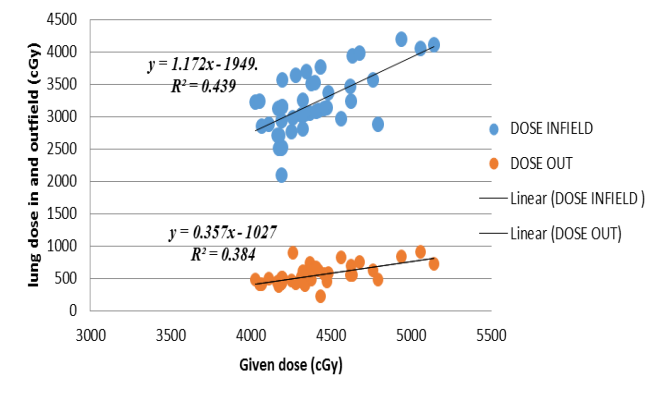

Figure 4: Showing the relationship between the given dose and dose received by lung tissue at both point inside and outside the irradiated field which increase the dose by (1.17cGy) and (0.357cGy) respectively

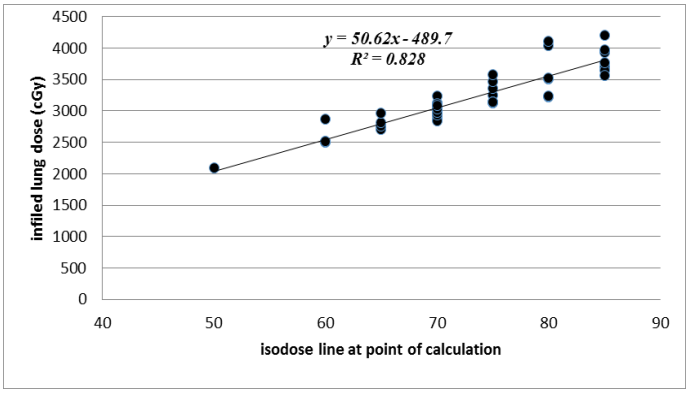

Figure 5: showing the relationship between infield doses received by the lung tissue and isodose line that passed through the point of calculation.

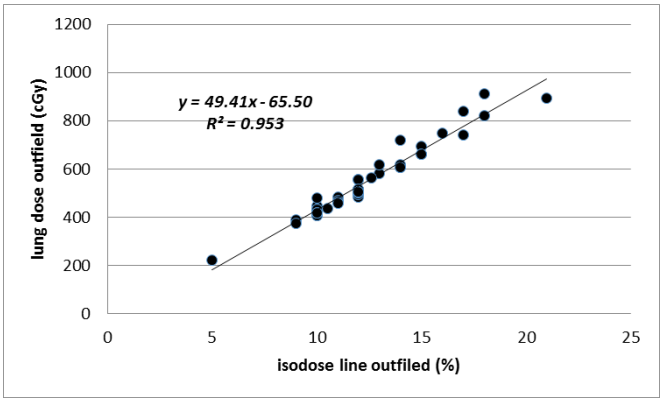

Figure 6: showing the relationship between outfield dose received by the lung tissue and isodose line.

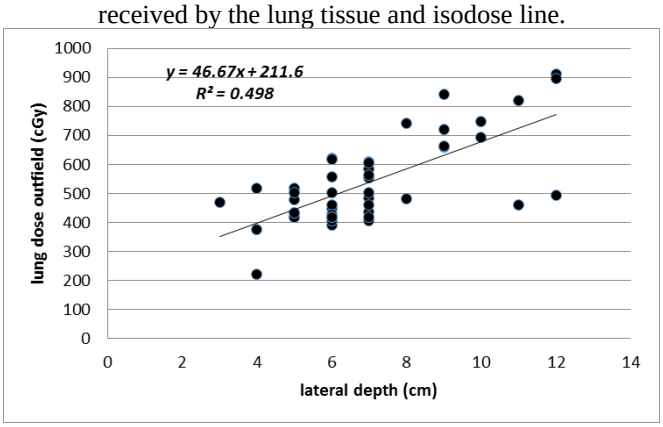

Figure 4: showing the relationship between outfield dose received by the lung tissue and lateral depth from the central point of breast to the entrance point of the lateral tungetial.

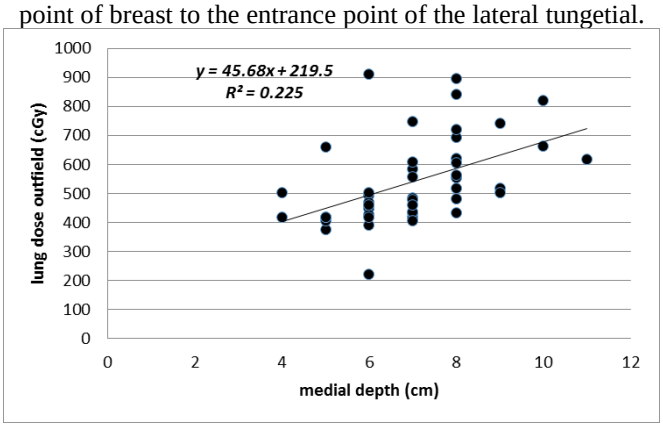

Figure 5: showed the relationship between the outfield lung dose and the medial distance from the medial interance point of medial tangential field

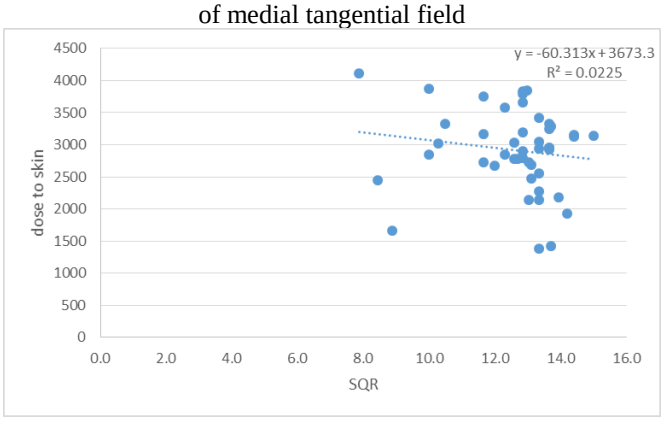

Figure 6: showing the relationship between total dose received by the skin and the Equivalent Square of the field size used during the treatment according to the role of thumb as stated by khan et.al 2003.

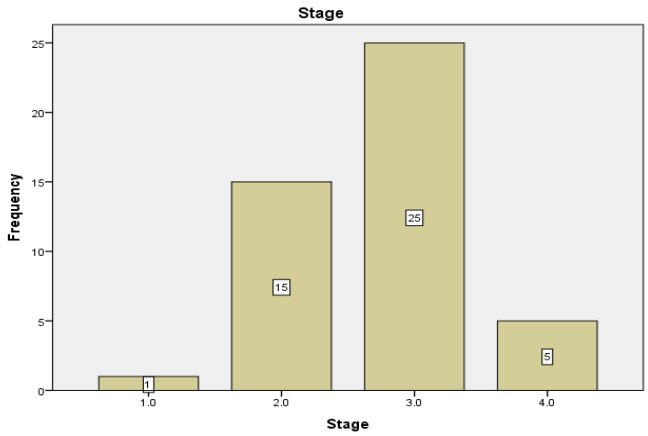

Figure 7: showing the most predominant stage of groub of sample having staging record

5. Discussion and Analysis

This study aims to calculate radiation dose to critical organs (mostly lung tissue at two point inside and outside radiation filed) in External Beam Radiation Therapy (EBRT) for breast cancer which resulted in mean ±Std. deviation of received dose to lung at 2cm depth away from (planning target volume) PTV as outfield point, infield point and skin at 1mm depth equal to 539.4 ± 147.8, 3186.2 ± 453.3 and 2914.197±629.1266 respectively as in table (1).

Many factors may affect outfield dose in radiotherapy, only the first two sources depend on machine design and/or additional beam modifiers placed in the path of the beam ***emami et.al 1991,*** in this study the parameters was include given dose (GD), percentage depth dose (PDD), isodose line at two points, backscatter factors (BSF), Equivalent Square(SQR) and age, which have mean ± Std. deviation of ***4379.8±256.2, 87.8%±2.92%, 12.3% ± 2.9%, 1.03 ± 0.0057, 9.5 ± 1.9*** and ***46.2 ± 9.8*** respectively. Table (1).

Total lung dose calculated outside radiation field at 2cm depth correlate with isodose line passed through this point which showed direct relations between both, as the dose increased by 49.41cGy for every one percent increment of isodose line ***R² = 0.953*** as described in Figure (6), also for infield calculation the dose increased by ***50.62cGy***, ***R² = 0.83*** as in figure (5), and this explained by (khan, 2003) who stated that the percentage depth dose (beyond the depth of maximum dose) increases with beam energy.

From this calculation we noted that the dose is decreased according to the distance from the planning target volume inside the lung which decreased from ***72% to 12%*** isodose line. As stated by *Van Der et.al 1996* the peripheral dose PD has indirect relationship with distance from the field border, also the depth form the both entrance and exit point of tangential named as lateral and medial depths that assumed from external skin of the breast can affect the received doses to both point directly increase outfield lung dose by ***46.67cGy/cm*** increase in this for lateral depth. Also the medial distance from the entrance point to the center of the breast affects the dose directly which increases dose by ***45.68cGy/cm,*** y = ***46.67x + 211.6*** and ***y = 45.68x + 219.5*** as

shown in Figure (4) and (5) respectively. This dose variation at two from medial and lateral entrance point to the center of the field mostly can be explained by the patient contour variation pre-during and post the treatment process.

Given dose to lung has direct relationship with dose received by lung tissue which increases dose by ***1.172cGy/1cGy y=1.172x-1949 (R2=0.439)*** increases in given dose for infield point and by ***0.357cGy/1cGy y=0.357x-1027 (R^2=0.384)*** for outfield point as explained in figure (1).

Figure 7: demonstrate the most frequent stage of 45 patient having staging record which showed that more than half of patient coming with advance stages which affect treatment outcome that mostly be explained be the lake of awareness in Sudanese female patient and lack of early screening of breast cancer.

References

[1] Symonds et.al 2012, Textbook of Radiotherapy, 7th edition, 2012, 2012 Elsevier Ltd. 432, 456.
[2] Gill, J.K.; Maskarinec, G.; Wilkens, L.R.; Pike, M.C.; Henderson, B.E.; Kolonel, L.N.; Gill, J.K.; Maskarinec, G.; Wilkens, L.R.; Pike, M.C.; *et al.* Nonsteroidal anti-inflammatory drugs and breast cancer risk: The multiethnic cohort. *Am. J. Epidemiol.* **2007**, *166*, 1150-1158.
[3] Hortobagyi, G.N.; de la Garza Salazar, J.; Pritchard, K.; Amadori, D.; Haidinger, R.; Hudis, C.A.; Khaled, H.; Liu, M.C.; Martin, M.; Namer, M.; *et al.* The global breast cancer burden: Variations in epidemiology and survival. *Clin. Breast Cancer* **2005**, *6*, 391-401.
[4] VanDer Giessen,W.H Coen ,1993 , Calculation and measurement of the dose to points outside the primary beam for CO-60 gamma radiation , International Journal of Radiation Oncology * Biology * Physics ,Volume 27, Issue 3, Pages 717–724.
[5] VanDer. Giessen PH, 1996, A simple and generally applicable method to estimate the peripheral dose in radiation teletherapy with high energy X-rays or gamma radiation, International journal of radiation oncology, physics and biology, Volume 35, Pages 1059–1068
[6] Zhu X R. (2000), Entrance dose measurements for invivo diode dosimetry: Comparison of correction factors for two types of commercial silicon diode detectors, Journal of applied clinical medical physics, Vol. 1 (3), P: 100-107.
[7] ICRU (1976). Determination of absorbed dose in a patient irradiated by beams of x-ray or gamma rays in radiotherapy procedures. ICRU report 24, Bethesda, Maryland.
[8] Creutzberg CL, van Putten WL, Warlam-Rodenhuis CC, (2004); Postoperative Radiation Therapy in Endometrial Carcinoma Trial. Outcome of high-risk stage IC, grade3, compared with stage I endometrial carcinoma patients. J. Clin. Oncol, 22, P: 1234-1241.
[9] Creutzberg CL, van Putten WL, Koper PC. (2001). Portec Study Group. The Postoperative Radiation Therapy in Endometrial Carcinoma Trial. The morbidity of treatment for patients with Stage I endometrial cancer: Results from a randomized trial. Int J Radiat Oncol Biol Phys, 51, P: 1246-1255.
[10] W. J. Meredith and G. J. Neary. The production of isodose curves and the calculation of energy absorption from standard depth dose data. Br. J. Radiol., 17:126–130, 1944.
[11] J. R. Cunningham. Scatter-air ratios. Phys. Med. Biol., 17:42–51, 1972.
[12] J. R. Clarkson. A note on depth doses in fields of irregular shape. Br. J. Radiol., 14:265–268, 1941.
[13] P. Storchi and E. Woudstra. Calculation of the absorbed dose distribution due to irregularly shaped photon beams using pencil beam kernels derived from basic beam data. Phys. Med. Biol., 41:637–656, 1996.
[14] P. R. M. Storchi, L. J. van Battum, and E. Woudstra. Calculation of a pencil beam kernel from measured photon beam data. Phys. Med. Biol., 44:2917–2928, 1999.
[15] H. F. Batho. Lung corrections in cobalt 60 beam therapy. J. Can. Assoc. Radiol., 15:79–83, 1964. 82
[16] Greene FL, Page DL, Fleming ID et al., eds. Breast. In: AJCC Cancer Staging Manual, 6th edn. New York: Springer, 2002: 223–40
[17] Singletary SE, Allred C, Ashley P et al. Revision of the American Joint Committee on Cancer staging system for breast cancer. J Clin Oncol 2002; 17: 3628–36.
[18] R. Mohan, C. Chui, and L. Lidofsky. Differential pencil beam dose computation model for photons. Med. Phys., 13:64–73, 1986.
[19] From Going JJ, Moffat DF. Escaping from flatland: clinical and biological aspects of human mammary duct anatomy in three dimensions. *J Pathol* 2004;203: 538–544. Reprinted by permission of Wiley-Liss, Inc., a subsidiary of John Wiley & Sons, Inc.
[20] Gar-Alnabi et.al 2014, Estimation of Dose Received by Sensitive Organs in External Radiation Therapy of Cervical Carcinoma, ijsr, Volume 3 Issue 6, June 2014, 1694- 1698
[21] B. Mohamed A et.al, 2012, a multi-plane source model for out-of-field head scatter dose calculations in external beam photon therapy, Journal of physics in medicine and biology, vol 57.
[22] Jane De et.al, Practical Radiotherapy Planning, 2008, 4rd Edition, Arnod Publisher, Lodon.

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