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Cobalt radiation therapy treatments with opposed plain fields and beam flattening filter

Abstract

Low LET radiations such as cobalt (1.25 MeV) and 6 MV linac megavoltage gamma/x radiations continue to be a basic facility in a busy radiation therapy department. When the beam profiles in water are carefully scrutinized, linac beams have flattened isodose curves compared to slightly rounded curves in Co-60 beams at all depths. It was speculated that to overcome slight non-uniformity in the edges, as well as slight variations inside the planning target volume (PTV), a beam flattening filter may be preferable to be used along with plain radiotherapy fields. A pilot study of clinical use of beam flattener in cobalt beam is reported.

A flattening filter (FF) was locally made out of dental wax, for 20 x 20cm field, in the 780E Telecobalt machine (M/s MDS Nordian, Canada). Beam profiles with and without FF were measured using water phantom, to confirm the filter efficiency. Both manual and Radiation Field (RFA) methods in water phantom confirmed efficacy of wax filter. This flattened beam was used in the treatments of Uterine Cervix and Oesophagus cancers, (25 patients each) with a measured filter transmission factor **0.805** in treatment plans.

All the patients completed the prescribed dose of 50Gy in 25 fractions for Ca Cervix and 50Gy/25 fractions or 50.4Gy/28 fractions for Ca Oesophagus; at 5 fractions/ week treatment regimens. Case records of these patients retrospectively verified did not reveal any untoward associated morbidity on routine clinical follow ups during treatment or immediate follow up.

As multi-leaf collimated cobalt beam also has built in rounded beam profiles, outcome of this work implemented in clinical applications add to new research knowledge. As cervix, head and neck, oesophagus malignancies form significant percentage of radiation oncology treatments, results of this present work will benefit many conventional treatments. It is strongly recommended that the clinical efficacy of FF Cobalt treatments be investigated in a controlled clinical trial, by random allotments with FF plain fields, with output corrections.

Keywords: cobalt beam, flattening filter, carcinoma cervix, carcinoma oesophagus

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Introduction

Linear accelerators and cobalt isotope machines (megavoltage X and gamma, low LET indirectly ionizing radiations) are widely used in the radiotherapy management of cancer patients. Linacs are preferred because of less safety concerns vis-à-vis cobalt isotope machines, with beam modulation recent innovations. The continued use of telecobalt machines (despite concerns on radiation safety, decaying dose rates, need for re-loading of sources) are recommended for more populated countries[1,2] because of constancy in beam quality, simple operations, need for less infrastructure, simple electrical power requirements, easy maintenance and cost effectiveness. The stray radiation doses which might be received by managing personnel in the exigency of 'source drawer stuck' are very much within acceptable and permissible limits.[3] The basic differences of '6 MV x-ray beam' and Co-60 beam' are a) 'd_{max}' build up depth b) flatness of beam at depths c) sharpness at beam edges d) available dose rate and e) optimum treatment distance for 6MV (100cm) f) less central axis % depth dose for Co-60 because of less SSD(80cm) g) slightly less effective energy (1.17MeV and 1.33MeV 2 photons).

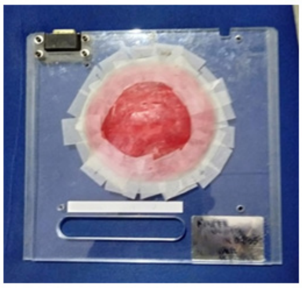
In the linear accelerators, there is a beam flattening filter, which flattens the excess intensity in the middle area, making the beam profile perfectly flat (within ±3%) at 10cm depth. An earlier work[4] demonstrated that presence of a simple beam flattener made up of wax, in the path of the cobalt beam can cut down slightly excess intensity in the central area, and flatten the beam profile, and make it similar to that of a 6MV photon beam profile. These authors advocated that there may be better homogeneity achieved when many flat fields are used in treatments. No clinical application however was made at that context of time. We attempted to continue the same objective, prepare a wax flattener (FF) and used for clinical purpose.

Materials and methods

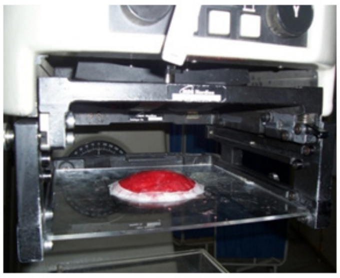
Fabrication of FF

A Theratron-780E Telecobalt machine (M/s MDS Nordian, Canada) was used in this study.

A 20 x 20cm^2 square field isodose pattern in the mid-plane available in 2dimension pattern is traced. Radial lines are drawn to represent field decrement at the position of shadow tray at 48cm from source plane. At 50 % isodose line, a 'chord line' was drawn to achieve final flat isodose pattern. The amount of variable distance is transferred at the position of shadow tray, and a card board negative is obtained, in 2dimensions. By revolving around the centre point, a 'proto-type thermocole flattening filter' 'cut out' is obtained. Using low density dental impression wax (physical density ρ=1 gm/cm^3) a diminished size 'positive FF' is fabricated. This is mounted on a 10mm thick filter tray originally supplied by the manufacturer. The designed FF and how its mounting arrangements during treatments are shown in Figure 1(a,b).



a. Wax FF locally fabricated



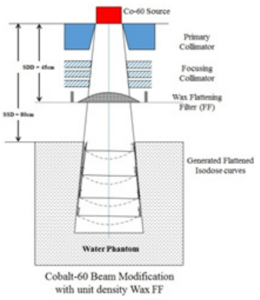
b. FF in position on the machine

Figure 1

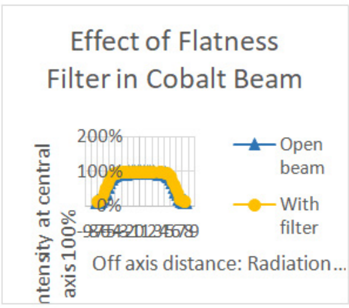
Measurement of beam flatness

Manual & radiation field analyzer methods

As we did not have a radiation field analyzer earlier, at the time of obtaining Ethics clearance, a calibration water phantom with fixed depth ion-chamber position was used to measure the beam profile, with and without FF. The '10cm depth radiation beam profile' at 80cm source-phantom surface distance (80cm SSD), for a 10 x 10cm^2 radiation field size was obtained with a Farmer Type ion chamber(0.6cc) (PTW, Germany). Ionization readings were normalized to central axis by point dose measurements. Beam profile was obtained, by incrementing the treatment table by 5mm till 4cm; and later at 2mm intervals till the intensity falls to 10 % of central axis value. Full beam profile got completed by having mirror image of the profile. Figure 2b shows the measured profiles with and without FF. Also separately measurement at 10cm depth in water was carried out to obtain FF transmission factor. Manual plots were highlighted; but later in the year 2019, RFA method confirmed the validity of earlier manual measurement method.



a. Flattened Cobalt Beam



b. Beam Profile for 10x10 field

Figure 2

Ethics Clearance

As Flattened beam was clinically used for the first time, clearance was obtained from the Institute Research Board and treatments were started during June 2017 (vide document # CCHRC-IRB 2017-18 dated 15-6-2017).

Patients

Plain fields radiation therapy using FF was carried out in treatments randomly, Ca Cervix and Ca Oesophagus patients. Objective of the study was to demonstrate, that introduction of FF in the beam does not have any induced toxicity in the selected cohort of the patients.

Results

The thickness of wax at the central plane was 2.4cm. The obtained profile with inserted, FF demonstrated satisfactory flatness by point dose measurements (Figure 2b) as well as radiation field analyzer measurements. The measured filter transmission is 0.805, about 20% reduction in the original intensity. 24 out of 25 Ca Cx patients (20 patients Stage IIIB and remaining Stage IIB) completed 50 Gy/25 fractions with box-technique, and had additional brachytherapy. One patient had additional 10 Gy by external radiotherapy, because brachytherapy could not be carried out for this patient. In Oesophagus group, 6 patients completed 50 Gy in 25 fractions, remaining 19 of them completed 50.4 Gy in 28 fractions. Scrutiny of case records showed no striking difference clinically recorded with cobalt-60 treatment with FF, compared to normal treatments scenario.

Discussion

This was a study to clinically utilize a flattened cobalt beam for cancer treatments. It is well known that in cobalt-60 radiation beams, there is a slight un-flattened curvature of isodose curve of beam profile at all depths, and the cross sectional pattern showing fall off dose was well explained.[5] Earlier a one report mentioned about use of specifically designed filters during radiotherapy to account for the dose fall off pattern in intracavitary brachytherapy,[6] with different objective. In linear accelerators, as the intensity profile produced at the target is not uniform, peaking at the central axis. And to get clinically useful large beam, a beam flattening filter is fixed, to provide ±3 % uniform flat beam specified at 10cm depth for a large 20 x 20cm^2 field. For flatness filter free (FFF) beams in linac, about 25% increased dose rate due to bremsstrahlung on thin target transmission, is suppressed using a high density beam flatness filter. Similar forward convex shaped isodose lines appearing cobalt beam due to a) less scatter in beam edges and b) due to solid angle effect of 2cm diameter cobalt source. Further explanation is, scatter components are contributed from both sides of the central axis in the mid plane, but one side scatter missing from the shadow side under the collimated part of the beam. For cobalt-60 beam the intensity variations are slightly more intensity at the centre, with fall in intensity towards penumbral edges. Also, at points slightly away from the central axis, the radial distance from source is more, though the physical depths remain same in the depth plane. So our aim was to make the beam comparable to linac at least from the point of view of flatness and less edge fall off. It is sometimes mentioned that with 6MV linac beams, the penumbra is sharp, compared to cobalt 60 beam. But for broad field sizes this argument may not be favorable, in the interest of edge infiltrations of the tumor.

Flat field has clinical importance, because when multiple fields try to give combined contributions, due to rounded isodose pattern in cobalt beam, there are higher in homogeneity in the treated volume, and some tumor clonogens will receive doses different by about 5-10%. This might be overcome, if we have a flattened beam as a hypothetical model. A 2.4cm central thickness of wax reduces the beam intensity (10-12% because, for cobalt beam a transmission loss of 5.5 % per cm of unit density material). Further, as we used a thick original shadow tray, providing additional 10% attenuation, effectively the overall transmission factor became 0.805. By accounting for density effect, we plan to have a thin Aluminum flatness filter (ρ_{Al} =2.70gm/cm^3) instead of wax FF. If there is annular clear space below filter mount, then we can overcome the 10% loss of intensity.

Present study is carried out that except for beam attenuation by FF, the beam quality remains unaltered, so that clinical use of this

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will be possible if no extra toxicity/morbidity is encountered in these pilot patients. Therefore, this communication becomes important, that later our department can address possible local control differences due to better homogeneity in the treated volume, with special relevance to cobalt treatments. Referring this, we are suggesting to undertake two arm randomized clinical trial in Ca Cervix and Ca Oesophagus patients so that slight improvement in homogeneity of tumor dose in any way help in local control. It is also made clear that when point dose calculations are made with central axis depth dose, this results in reduced volume dose in the off axis at more depths because about 90% isodose curve only might be delivered. This effect also could be overcome, by a flat cobalt beam.

We recently completed a short term study in compensating tissue deficits in head and neck radiation therapy,[7,8] with a main objective of reducing skin and mucosal reactions due to islands of excess doses, and to encourage clinical utility of simple cobalt machines. Here, the flatness effect is achieved indirectly, because we accounted for homogeneity through a grid cross section. In the same lines, if this flattened radiation beam could overcome any possible deficiency because of rounded iso-dose pattern of cobalt beam, homogeneous dose delivery to planning target volume (PTV) could be made better. Therefore, there is no radiobiological difference between cobalt and 6MV beam. We can optimally make clinical use of available telecobalt machines for radical radiotherapy, which is simplest of radiotherapy with more than six decades of applications and addition of this concept appears to make efficacy of cobalt-60 beam applications in radical radiotherapy.

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Conflicts of interest

There is no conflicts of interests with any agency related to this manuscript. No financial assistance is received from any other sources.

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