Journal of Medical Physics

LETTER TO EDITOR
Year : 2019 | **Volume** : 44 | **Issue** : 2 | **Page** : 135--138

External beam radiotherapy with telecobalt machine: Tissue deficiency compensation in head-and-neck region and effect on skin reactions

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How to cite this article:
Ravichandran R, Barman B, Datta G, Kannan R. External beam radiotherapy with telecobalt machine: Tissue deficiency compensation in head-and-neck region and effect on skin reactions.J Med Phys 2019;44:135-138

How to cite this URL:
Ravichandran R, Barman B, Datta G, Kannan R. External beam radiotherapy with telecobalt machine: Tissue deficiency compensation in head-and-neck region and effect on skin reactions. J Med Phys [serial online] 2019 [cited 2019 Dec 6];44:135-138
Available from: http://www.jmp.org.in/text.asp?2019/44/2/135/259925

Full Text

Sir,

This work pertains to revisit of application of cobalt machine as a resource armamentarium for external beam radiation therapy (EBRT) in the era of modern state-of-the-art linear accelerators. The continuation of cobalt isotope machines in the radiotherapy was recommended in earlier reports[1],[2] as a cost-effective tool with an edge over higher sophisticated linear accelerators. International Atomic Energy Agency (IAEA) document[3] refers inclusion of telecobalt equipment for basic radiation oncology facility, for curative treatments. Simple treatments, less power needs, constancy in beam quality, and suitability for treatments of normally encountered type of cancers are some of the important advantages of telecobalt machines, which outweigh some of the blames and shortcomings for Co-60 beams, such as decaying dose rate, repeated source loadings, radiation safety issues, and need for waste disposal. Further, by mock trial experiments in cobalt machine,[4] it was recently highlighted that the personnel dose estimate to radiation therapists does not exceed 267 μGy (at 333 TBq, 9000 Ci) in a rare event of "source drawer stuck." Modern telecobalt machines, such as Bhabhatron (an Indian model), have automatic "shutter closing safety mechanisms" in the event of completion of treatment times; further, these machines are fitted with multileaf collimators (MLCs). EBRT remains the mainstay for radical treatments of head-and-neck malignancies. Because of less interfield separations, telecobalt beam quality, as a megavoltage (MV) photon beam, is sufficient to execute these treatments. Most of the earlier reports in literature mentioning the disadvantage of cobalt-60 teletherapy were pertaining to head-and-neck radiotherapy, mainly relating to skin morbidities.

The recent literature from many centers on head and neck radiotherapy (RT) highlights the use of intensity-modulated treatments with MLCs and linear accelerators. An earlier study,[5] based on analysis of 471 patients treated for head-and-neck malignancies (212 in Co-60, 259 in 6MV Linac), highlighted that local control was better with 6MV patients. However, they indicated that neck control rate was improved for high-risk patients (extracapsular extension, more than two positive nodes, and/or T4 primary), treated by Co-60 with high significance, based on multivariate analysis. Based on secondary analysis of intergroup study, another report[6] analyzed 392 patients in a randomized study in patients treated with high-risk head-and-neck malignancies and also low-risk groups. A total of 157 patients had Co-60, 140 patients had 4 MV treatments, and 95 patients had 6MV treatments. They concluded that (a) beam energy showed no significant impact on acute or late toxicity and (b) no significant difference in local-regional control (75% for Co-60, 79% for 4MV, and 80% for 6MV beam qualities). It was also opined that Overall treatment time (OTT) could be associated with increased risk of recurrence, particularly for high-risk patients. The above results could be viewed in support of continued use of cobalt machines for curative treatments.

For the preservation of build-up of MV photons, at the same time, achieving compensations for tissue deficiency is possible by using metal compensators.[7],[8] In most of the cobalt clinics, for immobilization of patients, thermoplastic molds are used for head-and-neck radiotherapy. It had been observed in practice that many of the centers do not cut the window of the irradiated field, which is likely to spoil the entrance build-up advantage of these MV radiations. A quantitation of magnitude of increase of skin dose[9] highlighted that 1 mm of Orfit thermoplastic material increases the skin dose (at 0.5 mm) with cobalt-60 beam quality, from 57% to 77%. Their work[9] mentioned slight increase in the incidence of skin morbidity in the presence of thermoplastic material on the skin surface but could not show statistical significance with respect to "without mold" patients. In the treatments of head-and-neck cancers with intensity modulated radiotherapy (IMRT),[5] a dosimetric correlation was highlighted between percentage volume of oral cavity receiving higher than 15-50 Gy and acute mucositis. With conformal radiotherapy,[6] it was reported that cumulated doses to the oral cavity <32 Gy were associated with minimal acute mucositis. A dose >39 Gy was associated with a longer duration of mucositis. In the above work, with opposed lateral beam portals with 2 Gy fractions, the onset of mucosal erythema occurred after 1 week (10 Gy), patchy pseudomembranous formation after 2 weeks (20 Gy), and ulceration after 3 weeks (30 Gy). It was opined that more heterogeneous dose distribution might be responsible for oral mucositis. Tissue Compensation(TC) in head and neck RT[10] (in another report), outlined two methods to modulate the radiation beam: (1) aluminum or cerrobend missing tissue compensators or (2) segmented MLC fields obtained from forward planning. With mid sagittal dose distribution recorded by verification film in a wax phantom, it was found that there was no significant difference between the two methods to achieve TC. Their results[11],[12] suggested that there was a systematic trend toward decreased acute and chronic toxicities, better speech and swallowing function, and quality of life in the group of patients treated with tissue deficits compensation to decrease "hot spots" in tissues. The dosimetric aspects and the magnitudes of hot spots without TC were highlighted in EBRT[13] for telecobalt beam, and an increase as high as 18% increase in dose was reported from TLD and ion-chamber measurements.

Wax tissue compensator kept far away from the skin, and a method to account for divergence of the beam has been advocated for head-and-neck treatments with telecobalt machine.[14] This work however outlined a need for making "plaster of Paris (POP)-positive impression" of head-and-neck region for each patient. Our cancer hospital EBRT statistics (which reflects the trend of head-and-neck cancer incidence in the northeastern parts of India) reported in an earlier communication[15] showed that 50% of patients are from head-and-neck sites. To overcome non-uniform dose distributions for simple parallel opposing lateral field EBRT with telecobalt beam, we introduced aluminum tissue compensators (ATCs) for head-and-neck patients during 2016. An objective evaluation of the skin reactions in the population of these treatments, carried out as a retrospective study (2017–2018) in two groups of

patients 89 in each group (treated with and without ATC), documented some striking results.

Four groups of patients (A, B, C, and D) were studied who had identical treatment plans, viz., (a) up to 45 Gy full field, (b) later, shrinked field to exclude spinal cord, up to a dose of 56 Gy, and (c) at the end a small field to boost dose up to 70 Gy to the active tumor volume. Group A had Orfit thermoplastic molds (Supplied by M/s Meditronix, New Delhi) without portals cut open and without TC; Group B had POP neck immobilization along with TC; Group C had the portals cut open in the thermoplastic mold and without TC; and Group D had Orfit mold with cut treatment portals and TC. Patients treated from 2016 to 2017 were analyzed. In 178 patients (89 in uncompensated [Groups A and C] and 89 in compensated [Groups B and D]), about 43% of patients were in the age group above 60 years. Most of them received chemotherapy with RT (in concurrent or in adjuvant form); about 74% of patients had concurrent chemotherapy (cisplatin, carboplatin, and paclitaxel). About three-fourth of patients in all groups were with advanced disease (Stages III and IV). Group B and Group D patients had build-up preservation because of no intervening materials in the path of the beam and included compensation for tissue deficits.

We found out an important observation that there was no skin morbidity in Group B patients even at 70 Gy, showing efficacy of TC, unlike Group A patients (with uncut Orfit immobilization without TC). Some patients in Group A manifested as high as Grade IV skin reaction [highlighted in [Figure 1]a and [Figure 1]b.{Figure 1}

In Group B (POP immobilization and TC), 83% (24/29) completed RT >60 Gy. In these 24, 11% (3/24) only had interruptions >5 fractions. 24% (7/29) could complete 70 Gy. Group B patients did not face more interruptions due to treatment morbidity. Furthermore, in Group B, there were no skin sequelae (in all 29), and 17% (5/29) had only <Grade I mucositis. More skin morbidity is observed in Group A (Orfit immobilization/no compensation); in Group A, 12 out of 38 (31%) have not completed dose up to 60 Gy (more dropouts). In 26 remaining patients who completed >60 Gy dose, 9/26 (35%) had absented >5 fractions; only 4/38 (11%) of patients 70 Gy planned dose.

With thermoplastic mold cut, with and without TC, the results were bit different than POP immobilization. In Group D, 28% (with TC) completed a dose of 70 Gy compared to only 6% in Group C. In Group D, 90% (54/60) of the patients could complete >60 Gy dose; however, in Group C, only 65% (33/51) could complete >60 Gy. In 54 patients (Group D) who completed >60 Gy, 89% of patients (48/54) completed treatments with minimal interruptions; however, in Group C, only 73% (24/33) of patients completed >60 Gy with minimal interruptions. A careful review of all groups brings out an important observation that in “uncompensated RT” (A and C), 31% and 35% of the patients could not reach a dose up to 60 Gy; in “compensated RT” (B and D), only 17% and 10% of patients did not complete 60 Gy. Grade IV skin and mucosal reactions which occurred in Group C reduced in Group D.

In earlier studies, some authors have strongly opined that increase in OTT will be associated with less local control. If we assume an excess of 5 days admissible to complete the stated dose, many patients in Groups A and C [demonstrated in [Figure 2] from our analysis] completed the treatment in increased OTT. Mostly, this delay in completion is attributed to skin morbidity, rest periods, absence, etc., in this non-TC population. A separate study in our work analysed tissue deficit data obtained for 113 patients. Taking 5% excess transmission for 1 cm tissue deficit[16] and applying correction for inverse square law, we quantified the magnitude of excess doses. It was observed that 'without TC', tip of the neck received 10-15% increased dose in 82% of the patients, mid point of the neck plane received 6-10% excess dose in 81% of the patients, and bottom of the neck received 4-10% excess dose in 93% of patients. Similarly, in the chin portion of the head, tip part received 6-13% excess dose in 88% of patients, and bottom portion of the chin received 4-10% in 93% of the cases. The spots of increased radiation doses directly correlate the spots of radiation reactions. It becomes apparent that when the physical dose is more in some regions, it becomes larger fractionation than a prescribed fractionation of 2 Gy/Fraction. Therefore, radio-biologically, there are islands of higher effective dose (as high as 2.32 Gy/Fr), thereby inducing excess morbidity in normal tissues both in skin and mucosa. These patients who are likely to receive higher doses are at risk in developing skin reactions.{Figure 2}

Most of Group B and D patients could complete 60 Gy and above doses, in planned OTT. Due to skin morbidity, when OTT is increased above 42 days, the biologically effective dose (BED) and equivalent total dose (ETD) for the total regimen reduce effectively with likelihood of less local control. When we calculated effect of 60 Gy total dose when OTT is increased from 42 days to 45, 50, 55, 60 days, the effective BED values were 63.6, 61.8, 58.8, 55.8, and 52.8 Gy, respectively; 2 Gy/Fr, 30 fractions ETD were equivalent to 60, 58.5, 56, 53.5, and 51.0 Gy, respectively; when OTT is increased, similarly, a reduction in local control reduces from 100% to 95.8%, 88.8%, 81.8%, 74.8% due to increase in OTT expected (because of ETD decrease). Therefore, we feel that the local control in the Groups B and D are expected to be better; which is planned to be recorded in a separate study.

Two differences are strikingly observed in tissue compensated treatments, viz., no occurrence of excess skin morbidity, as well as reduced mucositis. Another fact which is not reported in this analysis is, about a dentist's opinion during assessment of these patients, that “dental health” was good in tissue compensated treatments, compared to uncompensated, Orfit mold group. On top of these facts, the highest doses up to 70 Gy could be tolerated by these patients, which definitely may increase our local control. Artificial saliva medications could help these patients where there were higher delivered doses to their salivary glands exceeding tolerance. In our tissue-compensated RT patients, it was observed that there was reduced incidence of mucositis. The absence of overlying thermoplastic material would have facilitated retention of “build-up” of cobalt beam till 5 mm subcutaneous tissue.

This report brings out our experience in the introduction of TC treated during 15 months for head-and-neck radiation therapy with telecobalt machine. In India, there are no automated TC methods practiced for head-and-neck radiotherapy patients using computed tomographic scan images. In the existing old cobalt machines, there are no MLCs for modulating the beam intensity and providing TC. By this work, the efficacy of telecobalt machine to address the problems faced in managing head-and-neck cancer patients is brought out.

Head-and-neck cancers are common in India, and in an earlier communication, there was a recommendation to design dedicated short distance cobalt machines.[17] To address the contamination of secondary electrons and low-energy scatter photons, another recommendation of special filtration of the beam also was recommended.[18] In these lines, this report adds that introduction of custom-made compensators is the immediate solution for the ongoing radiotherapy needs of these large number of head-and-neck malignancies, seen at our center. The results of the study may provide a solution for head-and-neck radiotherapy in many institutions in India in general (where the patient number of head-and-neck RT patients is about 30% of total workload) and in Northeastern India in particular (where head-and-neck patient number averages to about 50% of total RT-treated patients).

The present study has brought out that cobalt beam quality is still indicated for curative head-and-neck radiotherapy because uncompensated radiation beam delivery and loss of build-up appear to be main causes of skin and mucosal morbidity. Larger fractionation with nonuniform doses up to 2.35 Gy/fraction to skin gives more radiobiological equivalent dose, explaining skin and mucosal morbidity. The pilot work with POP immobilization along with TC (Group B patients) gave an insight to the physics of RT execution, studied with Orfit mold “portals cut” along with TC, and demonstrated safe delivery in head-and-neck RT with adequate dose delivery, without interruptions. This along with earlier recommendations[1],[19] to have a cobalt machine as basic equipment and to continue its use also has a real message. Further studies on skin dose estimates in these patient irradiation geometries are recommended, to document the geometry effects in head-and-neck RT.

Acknowledgements:

Director, CCHRC is thanked for kind permission. Help from Mr. Biwas, for preparation of jig, department staff for custom made tissue compensators, Mr. Sagar Chakraborty, Medical Records for case records and Mr. Jie Liu, University of Shanghai for Science and Technology, Shanghai, China for help in preparation of scatter plot graphical representation in the script, are acknowledged.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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