A COMPARATIVE STUDY OF THE PERFORMANCE OF TWO TELECOBALT UNITS, THERATRON-780E AND Bhabhatron-II-TAW, INSTALLED AT SHER-I-KASHMIR INSTITUTE OF MEDICAL SCIENCES, SRINAGAR, J&K.

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Abstract

Cancer is a major health problem all over the world. Like other developing countries, in India, the disease is showing increasing trend. Treatment of malignant tumours (cancers) has always remained a challenge in front of the researchers. Radiotherapy has an important role in the treatment of malignant tumours. Most of the cancer patients need radiotherapy as part of the treatment or as a sole modality. Radiotherapy, however, has not been accessible to all the patients because of the huge investments involved in the procurement of the radiotherapy delivery equipments. Linear accelerators used for clinical purposes in particular are highly costly. Due to the high cost of the latest state of art technology in radiotherapy, there is an acute shortage of radiotherapy facilities in India and other developing countries. To meet the demand of an affordable radiotherapy machine, Bhabha Atomic Research Centre (BARC) made a tele-cobalt machine called Bhabhatron in India. Sher-I-Kashmir Institute of Medical Sciences (SKIMS), procured the latest version of this machine, Bhabhatron-II-TAW in 2012. Since then the machine is in use. Apart from this, there another telecobalt machine, Theratron 780-E was installed at SKIMS in the year 2001, which is Canada made. In this paper a comparative evaluation of the performance of the two machines is presented on the basis of various important parameters that determine the quality of treatment delivered.

Keywords: Key Words:Cobalt-60, Radiotherapy, Bhabhatron-II-TAW, Theratron-780E,
Introduction

The global burden of cancer continues to increase largely because of aging and growth of the world population alongside an increasing adoption of cancer causing behaviours. In this regard, the International Agency for Research on Cancer (IARC), the specialized cancer agency of the World Health Organization, published data on cancer incidence, mortality and prevalence worldwide\textsuperscript{1,2,3}. According to IARC, an estimated 14.1 million new cancer cases and 8.2 million cancer related deaths occurred in 2012, compared with 12.7 million and 7.6 million in 2008 respectively. Further, more than half of all cancers and cancer deaths occurred in less developed regions of the world and these proportions will increase further by 2025\textsuperscript{4,5}.

In India, like other developing countries, cancer is a major health problem. There are about 25 lakh cancer patients in the country. Every year, about eight lakh new cases are detected and more than five lakh patients die due to this dreaded disease. Moreover, the cancer incidence in the country is expected to double in next 15 years\textsuperscript{6,7}. Established methods of treatment for cancer are surgery, chemotherapy and radiotherapy. Being the most cost effective, teletherapy using cobalt-60 is the most relevant method of cancer treatment in a developing country like India. When the finance is limited, tele-cobalt units are preferred over medical linear accelerator because of low cost, low maintenance cost, lower power requirement and less down time\textsuperscript{8}.

On the basis of data pertaining to cancer incidence in India, it is estimated that more than 1000 teletherapy units will be required in the near future\textsuperscript{9}. At present, there are around 499 teletherapy units (231 tele-cobalt units, 253 linear accelerators, 8 Gamma Knife units, 3 Tomotherapy units and 4 Cyber Knife units) in India. Out of the 231 tele-cobalt units, almost all are imported. The imported tele-cobalt units are quite expensive, which is a major hindrance for establishing radiotherapy centres in rural India. It is worth mentioning that in India most of the cancer treatment facilities are located in urban areas, while the vast rural areas remain untouched. Although more than two-third of cancer patients need radiation therapy, only about one-third of them receive it, due to the shortage of teletherapy units and urban-centric distribution of radiotherapy centres. This alarming shortage is due to the lack of affordable tele-cobalt machines. In view of this, Bhabha Atomic Research centre, Mumbai India designed and developed a prototype tele-cobalt unit in the year 2005, which was named Bhabhatron-I\textsuperscript{10,11}. After receiving feedback on the operation of this unit, a modified model, Bhabhatron-II was developed in the year 2006, having a maximum source capacity of 555 TBq of Co-60. Efforts are made to upgrade these tele-cobalt units with advanced technology such as multileaf collimators (MLCs)\textsuperscript{12}.

In the present investigation a comparative study of the two machines Bhabhatron -II-TAW and Theratron-780E is presented. This paper gives an insight of various parameters related to these sophisticated radiation generating machines like in-built shielding, operating ease (manual/computerized), jaws (symmetric/asymmetric), rotational freedom for gantry and the break down time etc.

Material and Methods

At SKIMS the department of Radiotherapy is facilitated with two Co-60 units. One machine bearing trade name Bhabhatron-II-TAW, head number 029, source drawer number 34/11-T, source type cobalt-60 and maximum capacity of source head equal to 15000 Ci is supplied by Panacea Medical Technologies Pvt. Ltd and another machine bearing trade name Theratron-780E, head number 105-2455, source drawer number G9-905-113-6, source type cobalt-60 and maximum capacity of source head equal to 12000 Ci is supplied by M/S MDS Nordian, Canada INC.

Both the machines were operated and various important parameters of the machines which affect the quality of treatment delivered to a patient were observed for a period of two years (2013-2014) and studied thereafter. The parameters which were studied include collimator motion, gantry motion, ease of use, down time, security and cost. Moreover a detailed Quality Assurance programme for both the machines was also carried out following the standard protocols.

For radiation safety measurements the detectors used were Ion chamber based Fluke Biomedical System (Model: 451) and Geiger-Muller based Inovision 190 survey meters. Both these survey meters are timely calibrated. For the mechanical tests like isocentre accuracy, SSD verification, Field size
verification and collimator jaw parallelism and orthogonality etc., the tools used were graph paper, mechanical front pointer, iso-align tool etc.

For mechanical tests, a field size of 10x10cm² was marked on a graph paper and the centre of the field was also marked. The graph paper was placed on the treatment table (Couch) at a distance of 80 cm from the source such that the cross wire matches the centre of the field. It was observed that the optical field coincided perfectly with the field marked on the graph paper. Now the table was moved vertically and brought to the extreme positions. A shift was observed in the position of the crosswire with this vertical motion of the field. To see the shift in the position of the crosswire with the rotational motion of the gantry mechanically, a needle with a sharp tip was fixed alongside the table with its tip at the position of the iso-centre. The gantry was rotated through ±180° in case of Bhabhatron-II-TAW and 360° in the case of Theratron-780E. Again a shift was observed in the position of the iso-centre with the rotational motion of the gantry.

Radiation protection involves protection of patients, technical staff handling the radiation generating equipment, other radiation workers, hospital personnel and public. Radiation safety depends on the equipment design/construction, room shielding, staff training, working procedures and practicing of safety rules. The head leakage of both the machines was measured during ON and OFF condition of source following the standard protocol.

Results and Discussion
In order to meet the requirement of cost effectiveness, India developed Bhabhatron-II-TAW to compete with the foreign telecobalt machines. The general features of the two telecobalt units, Theratron-780E and Bhabhatron-II-TAW, installed at Sher-i-Kashmir Institute Of Medical Sciences, Srinagar, J&K, are presented in table 1.

Most of the features are common between Theratron-780E and Bhabhatron-II-TAW. Both the machines use a cobalt-60 radiation source. However, features like source housing capacity, collimator jaw motion, minimum obtainable field size, battery backup, cost and gantry rotation are different. Cobalt-60 radio-isotope is used as the source of gamma radiation. Cobalt-60 emits gamma radiation of average energy 1.25 MeV\(^{19, 20}\). Bhabhatron-II-TAW has a capacity of holding a source of activity 15,000 Ci whereas Theratron-780E can hold a source of activity 12,000 Ci only. In the case of Bhabhatron-II-TAW, the source is safely shielded in the source housing made of lead and tungsten. However there is presence of depleted uranium in the source housing of Theratron-780E.

Collimator
The collimator assembly controls the size, shape and orientation of the radiation beam incident on the patient. In case of Theratron-780E the minimum field size that can be achieved by closing down the collimators is 4x4, whereas the minimum field size that can be achieved in case of Bhabhatron-II-TAW is 0x0 and is only limited by geometric penumbra which depends upon the source size. It means that the collimators can be completely closed down in the case of any emergency and hence the patients and staff can be protected from the risk of any over exposure of radiation. Another very significant advantage of Bhabhatron-II-TAW over Theratron-780E is the asymmetric motion of one pair of collimators. Whereas both pairs of collimators move symmetrically in Theratron-780E, it is possible to move Y1 and Y2 jaws asymmetrically in Bhabhatron-II-TAW. Breast cone can be virtually created by help of asymmetric collimation by bringing one jaw to midline. This mimics breast cone for tangential treatments in Bhabhatron-II-TAW. This also helps in avoiding electron contamination in the beam and unwanted dose to skin and superficial tissue. It therefore gives the radiotherapy technologist freedom from muscular work and higher throughput.

Collimator rotation, however, is limited to ±90° only in the case of Bhabhatron-II-TAW whereas in the case of Theratron-780E the collimators can be rotated through ±180°. This is an advantage of Theratron-780E over Bhabhatron-II-TAW as a collimator rotation of ±90° only in the case of Bhabhatron-II-TAW restricts the use of a physical wedge in limited directions only.

Beam shaping and modifying devices
Accessories like wedge filters and shielding blocks are used to modify the shape and differential attenuation of the beam as per the requirements of a particular case. In both the machines there is a provision of putting these devices in the path of the beam manually. However in Bhabhatron-II-TAW, motorized wedges are provided. Motorized wedge offers several advantages over traditional physical wedges. The handling of cumbersome physical wedges and associated safety concerns are eliminated. More
number of wedge angles are possible with motorized wedge and field size limitations are much less stringent with motorized wedge than with the traditional physical wedges. In case of motorized wedge a physical wedge installed in treatment head is programmed to be partially in the beam and be partially in the retracted position from the beam, bringing about different wedge profile. Wedged beam profiles can be modelled similar to a physical wedge and follow a well defined equation to facilitate modelling of arbitrary wedge angles. With such mechanism it becomes possible to have several wedge beam profiles for better conformity of dose to tumour volume.

**Gantry**

Gantry holds the source head and counter weight. In case of Theratron-780E, the gantry can rotate around the patient about a horizontal axis by ± 360°, allowing source positioning at any point on a circle of 80cm radius. However, in the case of Bhabhatron-II-TAW the gantry can rotate by ± 180° only. This is a disadvantage of Bhabhatron-II-TAW as the rotation therapy becomes very tedious with this machine.

**Down Time**

The average downtime of Bhabhatron-II-TAW for the period of two years (2013-2014) was noted to be 20 days in a year while as the average down time for Theratron-780E for the same time period was noted to be only 3.5 days in a year.

**Control Panel**

In Bhabhatron-II-TAW, the data pertaining to a particular patient, including patient's name, age, sex, diagnosis, collimator settings, gantry settings, treatment time etc. can be registered on a hard disk and retrieved any time for control and analysis. This saves a lot of time and effort and thus is a salient feature of Bhabhatron-II-TAW. In the case of Theratron-780E, the storage of patient information is not possible and also the information regarding collimator openings, couch configuration, elapsed time and remaining time is not displayed.

**Wall Mounted Display**

A unit parameter display in the treatment room displays the configurations of the gantry, collimator and couch. Such a unit is provided with Bhabhatron-II-TAW Only. However in the case of Theratron-780E, all these parameters are displayed on the machine itself.

**Couch**

Theratron-780E has a couch made of mild steel. The table top is provided with a nylon mesh which produces a negligible build up for under couch treatments. Bhabhatron-II-TAW, on the other hand, is provided with a couch made of carbon fibre material. During our study we observed that this material provides sufficient build up for under couch treatments as most of the patients who were treated on Bhabhatron-II-TAW with under couch treatments developed grade-II skin reactions.

**Quality Assurance**

Before using a machine for patient treatment, it is mandatory to ensure consistency and accuracy in dose delivery as prescribed by the radiation oncologist together with minimal dose to the normal tissue and minimal exposure to the occupational workers. This objective is achieved by carrying out a thorough quality assurance programme of the machine before using it for patient treatment. Parameters which are verified during the quality assurance programme include radiation leakage at various locations in different conditions; accuracy of various beam parameters and components; and functionality of safety interlocks and other sub-systems. A detailed quality assurance programme was carried out for both Bhabhatron-II-TAW and Theratron-780E and the parameters which were observed are listed in table 2.

Table 2 suggests that all the important parameters measured for both the machines are well within the tolerance limits. However the head leakage for Bhabhatron-II-TAW is much less than Theratron-780E. Apart from the parameters listed in table 2, other

<table>
<thead>
<tr>
<th>Feature</th>
<th>Theratron-780E</th>
<th>Bhabhatron-II-TAW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity</td>
<td>12 kli curie Co-60</td>
<td>15 kli curie Co-60</td>
</tr>
<tr>
<td>Collimator jaw motion</td>
<td>Symmetric</td>
<td>X jaws Symmetric</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Y jaws Asymmetric</td>
</tr>
<tr>
<td>Collimator rotation</td>
<td>±180°</td>
<td>± 90°</td>
</tr>
<tr>
<td>Minimum possible field size</td>
<td>±4 ±4</td>
<td>0±0</td>
</tr>
<tr>
<td>Maximum possible field size</td>
<td>±35±35</td>
<td>±35±35</td>
</tr>
<tr>
<td>Gantry Rotation</td>
<td>±360°</td>
<td>±180°</td>
</tr>
<tr>
<td>Machine and Couch motion</td>
<td>Motorised</td>
<td>Motorised</td>
</tr>
<tr>
<td>Battery Backup</td>
<td>Not Available</td>
<td>Available ( 9 hours )</td>
</tr>
<tr>
<td>Ease of use</td>
<td>User friendly</td>
<td>User friendly</td>
</tr>
<tr>
<td>Security</td>
<td>There is no provision of password protection on control panel</td>
<td>Through password protection on computer driven control panel, access to operation of the machine, machine Parameters, patient data and treatment data are limited only to authorised staff.</td>
</tr>
<tr>
<td>Cost</td>
<td>Relatively costly</td>
<td>Relatively cheap</td>
</tr>
<tr>
<td>Machine down time</td>
<td>Comparatively less (1 day out of every 104 days)</td>
<td>Comparatively more (1 day out of every 18 days)</td>
</tr>
</tbody>
</table>

Table 1: Various features of Bhabhatron-II-TAW and Theratron-780E.
parameters and safety interlocks were also checked and were found safe and working. The OFF condition leakage was measured at 5 cm and 1 metre from the surface of the machine head. The ON condition leakage was measured in the patient plane, the centre of which is at a distance of 1 metre from the source and the average value of leakage was 0.011% of RMM for Theratron-780E and 0.006% of RMM for Bhabhatron-II-TAW. In both the cases the leakage was found to be within the tolerance limit of 0.1% of RMM (Roentgen per minute at 1 meter distance) of the loaded source.

**Conclusion**

From our systematic comparative study of Theratron-780E and Bhabhatron-II-TAW, it is concluded that Bhabhatron-II-TAW has superior features compared to Theratron-780E in terms of security, battery backup, asymmetrical motion of jaws, minimum possible field size and cost. There are however some limitations of Bhabhatron-II-TAW as well. The electron contamination due to the carbon fibre material of couch during undercouch treatments is very high, rotation therapy is cumbersome and above all the downtime is more.

**References:**


**Table 2: Comparison of QA Parameters of Bhabhatron-II-TAW and Theratron-780E.**