

The Bhabhatron: an Affordable Solution for Radiation Therapy

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Abstract

Radiation therapy as a mode of cancer treatment is well-established. Telecobalt and telecaesium units were used extensively during the early days. Now, medical linacs offer more options for treatment delivery. However, such systems are prohibitively expensive and beyond the reach of majority of the worlds population living in developing and under-developed countries.

In India, there is shortage of cancer treatment facilities, mainly due to the high cost of imported machines. Realizing the need of technology for affordable radiation therapy machines, Bhabha Atomic Research Centre (BARC), the premier nuclear research institute of Government of India, started working towards a sophisticated telecobalt machine. The Bhabhatron is the outcome of the concerted efforts of BARC and Panacea Medical Technologies Pvt. Ltd., India. It is not only less expensive, but also has a number of advanced features. It incorporates many safety and automation features hitherto unavailable in the most advanced telecobalt machine presently available. This paper describes various features available in Bhabhatron-II. The authors hope that this machine has the potential to make safe and affordable radiation therapy accessible to the common people in India as well as many other countries.

1. Introduction

Radiotherapy is one of the established treatment methods of localized cancer. External beam therapy started with kilo-volt systems, and later radioactive isotope based high energy systems were developed. Most of the research and development on these systems occurred during the initial few decades. Although, the telecobalt and telecaesium units were effective and played important roles, there was little effort for further improvements of these designs. In the electronic era, most of the enhancements and developments have come across in linear accelerator based systems. Similar developments have not been found for tele-cobalt machines. The linear accelerator based systems are versatile and offer more options for treatment delivery, but these are very expensive. The lack of resources required for such complex systems is another concern.

In India, it is estimated that, there are more than two million cancer cases at any point of time, and more than one million new cancer cases are detected every year. Additionally, incidences of cancer are expected to rise significantly due to aging population, environmental degradation, changing lifestyle etc. Although, the treatment using cobalt-60 is most cost effective and relevant in a developing country like India, till 2005, all the operating cobalt machines in the country were imported. There are only 422 teletherapy units (282 telecobalt and 140 medical LINACs) available against the modest immediate requirement of at least 1000 machines. Also, the existing facilities are located in urban areas while the vast rural areas remain largely untouched. To meet this shortfall, Bhabha Atomic Research Centre, Trombay, Mumbai has developed a new generation telecobalt unit named Bhabhatron-II [1]. It is

a computer-controlled, isocentric external beam therapy machine with a number of advanced features, viz. full collimator closure, asymmetric collimation, motorized wedge filter, collimator auto setup, battery backup for regular operations during power cuts etc. The important features of this unit are described in brief.



Figure 1: Bhabhatron-II tele-cobalt machine

2. Bhabhatron-II: Brief Description

Bhabhatron-II is an isocentric, external beam radiation therapy system with source to axis distance of 80cm. It houses a Cobalt-60 radioisotope of high activity (15KCi max.). The source capsule is mounted in a pneumatically driven source drawer which toggles the source between shielded (beam-OFF) position and treatment (beam-ON) position. All the motions in the main unit and the treatment table are motorized. The collimator assembly controls the size and orientation of the radiation beam. During patient setup, the area to be exposed can be visualized using a light beam. Two sets of trimmers are provided to reduce the radiation penumbra. Bhabhatron-II is provided with various beam shaping accessories like breast block and shielding blocks. Shielding block protect vital organs in the path or near the radiation field.



Figure 2. Beam shaping accessories; a) Standard shielding blocks, b) Breast block

The counterweight is placed at the rear side (behind the partitioning wall). Large area is now available for the operator, resulting in increased flexibility to ensure proper visual feedback for accurate positioning.

The patient positioning table or couch consists of a turntable mounted eccentrically with the isocentre. The couch has four motorized motions: Isocentric rotation and translations in longitudinal, lateral and vertical directions. The motions are controlled through keypads attached on either side of the couch body. Salient features of the couch are high stability, noise-free motions and high precision.



Figure 3: Couch of Bhabhatron-II

The operator interacts with the system using the mouse and keyboard located at the control console (Figure 4). For normal operation of the machine, highly skilled operator is not required. Inside the treatment room, two keypads are used. Simple, ergonomic, backlit keypads (Figure 5) are located on either side of the patient positioning table for quick patient set-up. Digital readouts on the keypads make the positioning job simpler. Machine parameters (both set values and actual values) and patient specific set-up notes are available on the wall-mounted display monitor inside the treatment room.



Figure 4. Control console outside the treatment room



Figure 5. Keypads on either side of the couch

2.1 Enhanced Safety: In case of any emergency, the control system pushes the source automatically to the beam-OFF position thus ensuring safety against over-exposure. One of the unique features of Bhabhatron-II is its fully closable collimator. During any emergency, the collimator closes fully to limit unplanned exposure to the patient. Intermeshing leaves as shown in Figure 6.(a), are commonly used in

telecobalt units to define the radiation field size, and it is not possible to close the radiation beam fully using such mechanism. However, Bhabhatron-II uses parallel jaw pairs (Figure 6.(b)) in different planes facilitating full closure of the radiation beam. In addition to physical key, the system allows selective access to operation, machine parameters, and patient/treatment data through password protection. Thus unauthorized exposure as well as access to treatment/patient data is prevented.

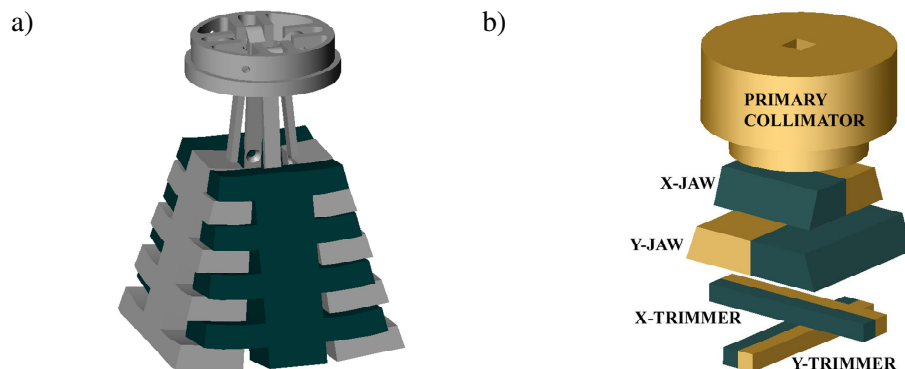


Figure 6. Collimator design: Typical telecobalt unit vs Bhabhatron-II

2.2 Motorized Universal Wedge Filter: Wedge filters are frequently used to provide wedge-shaped dose distributions inside the target. Although, multiple choices are available for generating wedged dose profiles, individual physical wedge filters are typically used in telecobalt units. In addition to the physical wedge filters viz. 15, 30, 45 and 60deg., Bhabhatron-II is equipped with a motorized wedge filter [2] designed to generate maximum wedged field size of $15W \times 20cm^2$, and maximum wedge angle of 60deg. The axes of the physical and motorized wedge filters are perpendicular to each other, facilitating complex dose distributions. In motorized wedge, a wedged beam is combined with the open beam in proper combination to achieve the desired wedged profile. In this way any wedge angle up to the angle of universal wedge filter can be generated. The potential advantages of motorized wedges are often to speed up the patient setup because it is no longer necessary to handle physical wedges. Additionally, motorized wedge filters can generate any arbitrary wedge angle instead of the limited standard angles available with the physical wedge filters.

2.3 Asymmetric Collimation: Telecobalt units typically provide radiation fields symmetric along both the axes. However, in many instances, asymmetric fields can provide improved conformity. For example, physical handling of heavy shielding blocks during breast treatment can be avoided. In Bhabhatron-II, the shielding jaws (for defining the radiation field) corresponding to one axis move independently facilitating asymmetric fields with respect to the radiation beam central axis.

2.4 Collimator Auto Set-up: Typically, for telecobalt units, sets of buttons are provided on or close to the patient positioning table (couch) for setting the radiation field parameters prescribed for any patient. In Bhabhatron-II, the operator can opt for automatic set-up after providing the radiation field details at the control console located outside the treatment room. In auto set-up mode, the computer instructs the control hardware and sets the required field setting automatically. This facilitates fast and accurate patient positioning. Reduction in patient positioning time is very

important, particularly for multi-field treatments. Any saving in treatment setup time is directly related to the number of patients can be treated in a shift/day.

2.5 Battery Backup: The system consumes low power (1.2KW). In remote locations where either electric supply is not available or erratic, it is possible to operate this machine using a low-capacity generator. Additionally, the (rechargeable) battery backup facilitates continuous treatment (~six hours) during power-cuts.

2.6 Remote Monitoring: The telecommunication network has covered almost all the regions of our country. An SMS based communication system is developed for reporting the machine status continuously to the service center. This permits remote diagnosis, and timely corrective actions, ensuring reduced downtime of the machine.

2.7 Security and Data Management: The machine, patient and treatment data are password-protected and accessible to authorized staff only. Since the machine is computer controlled, it is possible to manage the patient and treatment related parameters easily.

3. Telecobalt Source and Disposal of Decayed Source

The Co-60 radioisotope is produced from natural cobalt-59 by the thermal neutron capture reaction in a reactor and fabricated in required geometry for the end users. The source capsule is remotely assembled to the source drawer (part of the Bhabhatron-II unit) inside hot-cell (facility for handling radioactive substances inside shielded room remotely). Subsequently, the source drawer assembly is transported to the installation site, and loaded into the machine. Similarly, the decayed source is brought back along with the drawer to the hot-cell for decommissioning. Sometimes, the decayed source capsule is recycled for further fabrication or securely preserved for long-term interim storage. The block diagram of Cobalt-60 life cycle is shown in figure 7.

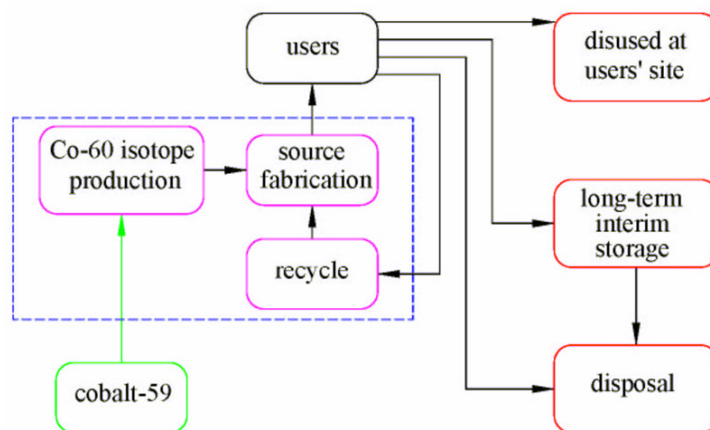


Figure 7: Cobalt-60 life cycle

3. Telecobalt Source Transportation

The strength of the radioactive cobalt-60 source decays with time and after few years, the radiation source needs to be replaced. A transportation flask is a shielded container used to transport the source capsule from the manufacturer's

site to the location of the teletherapy unit (typically a hospital). It is also used to return the decayed sources from hospitals to designated facilities for final disposal. Since, the transportation flask containing the radiation source is to be transported through public domain; utmost care and safety are essential to protect people and the environment from the harmful effects of radiation. As per the safety regulations [3] of IAEA, the integrity and effectiveness of the radiation shielding is must during normal as well as accident conditions of transport.



Figure 8. Teletherapy Source Transportation Flask

The source transportation flask (Figure 8) is designed for this purpose and approved as type B(U) package. It has a sacrificial piped structure to protect the containment from mechanical damage during accident conditions of transport. It also contains thermal shield to protect the shielding against excessive heating during accidental fire.

4. Quality Assurance

Like other radiotherapy systems, the main objective is to deliver prescribed dose to the target while limiting the exposure to the surrounding healthy tissues. Regulatory requirements are quite stringent to protect the patient, staffs and the environment from the harmful effects of radiation. This machine conforms to the requirements as per the International Electrotechnical Commission (IEC) [4,5] applicable to this type of equipments. It also has CE marking conforming to the requirements of the Medical Device Directive 93/42/EEC.

5. Bhabhatron-II Future

Although the present trend is in favour of linear accelerator based systems, Bhabhatron-II is gradually becoming popular due to advanced features at much lower cost. We feel that Bhabhatron-II will play significant role in coming years in improving the cancer care in India as well as other developing countries [6].

6. Developments in Progress

Like all commercially available telecobalt units, this machine also provides rectangular field. But, the collimation systems using multiple leaves (MLC) offer excellent conformity to complex targets. Such systems are typically used for Linear Accelerator based systems. Till now, this feature is not available for any telecobalt machine due to limitations arising from space availability and other operational complexities. The collimator system of Bhabhatron is different from other telecobalt systems. Preliminary studies show that MLC is possible to implement in Bhabhatron. Work has already started in that direction, and it will be a significant development enabling affordable yet high precision radiation therapy.

7. Conclusion

The indigenous development of Cobalt-60 teletherapy machine has the superior features in terms of safety, user-interface and security. Moreover, the cost of Bhabhatron-II is significantly lower than imported machines of similar capacity. The technology is already transferred for its mass production. Bhabhatron-II development is improving the access of cancer patients to treatment facilities and reducing treatment cost not only for Indian but also for the rest of the world.

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