Role of Bhabhatron in Cancer Care in India

K. Jayarajan, D.C. Kar and Manjit Singh

Division of Remote Handling and Robotics, Bhabha Atomic Research Centre, Trombay, Mumbai 400 085, INDIA; E-mail: kjayaraj@barc.gov.in

Abstract

Cancer treatment has been one of the thrust activities of Department of Atomic Energy. Radios isotopes produced from nuclear reactors are being used for cancer treatment. Radiotherapy, using cobalt-60 isotope, is the most cost-effective and the most relevant method of cancer treatment in India. However, there is acute shortage of radiotherapy machines in the country, due the high cost of imported machines. Most of the cancer treatment facilities are located in urban areas, while the vast rural areas remain untouched. In addition, many states and most of the districts in the country do not have any teletherapy machine. As an attempt to reduce these shortcomings, BARC developed a telecobalt machine called Bhabhatron. Source capacity, source to axis distance and maximum field size of Bhabhatron are same as those of the best telecobalt machines in the world. One of the unique features of Bhabhatron is its fully closable collimator, providing improved radiation safety. Computer control of Bhabhatron makes it more user-friendly and safer. However, the major advantage of Bhabhatron is its low cost, making it affordable to many cancer hospitals in the country. Now Bhabhatrons are installed in many cancer hospitals in the country.

Keywords: Bhabhatron, cancer treatment, radiation oncology, radiotherapy, telecobalt, teletherapy

Introduction

Department of Atomic Energy (DAE) has given high priority to health care, especially for cancer treatment. DAE has been funding cancer hospitals for cancer research and setting up of treatment facilities. Radioisotopes, produced in research reactors and power reactors in the country, are being used for diagnosis, treatment and sterilisation of medical products. DAE has also been in developing tools and techniques for treating the killer disease. Bhabhatron, the indigenous telecobalt machine, is one of the successful products developed by Bhabha Atomic Research Centre, Mumbai for cancer treatment.

Cancer is a major health problem in India. 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 died, due to this dreaded disease. Moreover, the cancer incidence in the country is expected to double in next 15 years. Established methods of cancer treatment are radiotherapy, surgery and chemotherapy. A majority of the patients need radiotherapy during the course of treatment. Being the most cost-effective, teletherapy using cobalt-60 is
the most relevant method of cancer treatment in a developing country like India.

There are only about 430 teletherapy machines operating in the country. Many of them are old, needing immediate replacement. Most of the cancer treatment facilities are located in urban areas, while the vast rural areas remain untouched. Many states and most of the districts in the country do not have any teletherapy machine. Although, more than two-third of cancer patients need radiation therapy, only about one-third of them receive the therapy, due to the shortage of therapy units and urban-centric distribution of radiotherapy centres. This alarming shortage is due to the lack of affordable telecobalt machines. Therefore, there is an immediate need to increase the number of teletherapy units to at least three-fold. Bhabhatron was developed to meet the growing demand for affordable high-performance telecobalt machine.

Bhabhatron Models

Bhabhatron-I

The first unit of Bhabhatron was installed at Advanced Centre for Treatment, Research and Education in Cancer (ACTREC), Navi Mumbai. First patient was treated in the machine on June 5, 2005. In addition to treating more than 50 patients daily, the machine was used for blood irradiation and cancer research.

Bhabhatron-II

Based on the operational experience of the first machine, BARC developed Bhabhatron-II, an advanced telecobalt machine. The machine has better performance parameters and improved user interface. Its lower power consumption and battery back-up make it suitable for rural India. Other advanced features include asymmetric collimation, motorized wedge filter and collimator auto setup. First unit of Bhabhatron-II was installed at Indian Red Cross Society Cancer Hospital (IRCS), Nellore, Andhra Pradesh. Honourable President of India, Dr A. P. J. Abdul Kalam dedicated Bhabhatron-II to the service of the nation in 2006.

Parts of Bhabhatron

Bhabhatron houses cobalt-60 source of high activity in a well-shielded containment. For treatment, the source is moved from shielded position to treatment position and the
radiation beam is directed to the cancerous site, after controlling the beam to desired size, shape and differential attenuation. Major components of the machine are radioactive source, source drawer, source head, collimator, gantry, base housing, patient support system and control console.

**Cobalt-60 Source**

Cobalt-60 isotope of high specific activity is used as gamma source in Bhabhatron. Cobalt-60 emits high-energy gamma rays of 1.17 MeV and 1.33 MeV. In the source capsule, about 40 gm of active pellets are encapsulated in a cylindrical container of 20 mm diameter. Bhabhatron has a capacity to load 15 kCi source.

**Source Drawer**

The source is assembled in a source drawer. The pneumatically driven drawer moves the source between shielded (beam-off) position and treatment (beam-on) position. The cylinder will withdraw the source automatically to beam-off position, in case of any emergency. In beam-off position, the radiation beam can be visualised using a light beam.

**Source Head**

Source head is a heavily shielded container, housing the source drawer. Depleted uranium and lead are used as shielding materials in the source head. Bhabhatron is also available with Tungsten-alloys as shielding material. Low source-to-axis distance of 80 cm is achieved by compact designs of the source head and the collimator.

**Collimator**

The collimator assembly controls the size, shape and orientation of the radiation beam exposed to the patient. One of the unique features of Bhabhatron is its fully closable collimator. During any emergency, the collimator closes fully, protecting the patient.
Fig. 4  Radiation head, shielding, source drawer, source, etc.

Fig. 5  Collimator

from over-exposure. Two sets of trimmers are provided to reduce the penumbra of the beam.

**Beam Shaping and Modifying Devices**

The system has accessories like wedge filters, breast cone and shielding blocks to modify the beam shape or beam attenuation. They are placed on the machine between the collimator and the patient. Shielding blocks protect vital organs in the path or near the radiation field. Wedge filters generate ramped dose distribution of radiation field.

Fig. 6  Shielding blocks

**Gantry, Mainframe and Base**

Gantry holds the source head and counter weight. It can rotate around the patient about a horizontal axis by ±180°, allowing source positioning at any point on a circle of 80 cm radius. The gantry is mounted on the mainframe. Entire unit is mounted on a steel base below floor level. The base supports the mainframe and the couch.
**Patient Support System**

The patient positioning table or couch consists of a turntable mounted eccentrically with the isocentre. The couch has four motorised 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. The couch top is made of lightweight, radio transparent carbon-fibre sheet. Patient restraining straps and universal metal clamps are provided for immobilisation of the patient.

**Controls and Indicators**

Bhabhatron controller is fully computerised. Data of treatment session registered on hard disk can be retrieved for control and analysis. Many safety interlocks are provided to prevent the patient from over exposure to radiation. For example, treatment room door interlock prevents or terminates treatment when the room door is open; gantry fault interlock terminates treatment in case of any error in gantry motion; and source drawer movement interlock prevents treatment when the drawer fails to move in the desired manner. Controls and indicators are installed in mainframe, gantry, door, power panel, operator’s panel, couch and on the wall of the operational room. To provide additional security, access to modification of patient data and treatment data is limited to authorised staff, by password protection.

**Operator’s Panel**

Main interaction between the operator and the machine is through computer monitor, keyboard and mouse. A key switch and an emergency switch are also provided near the operator’s panel.

Control console displays the status of AC power, battery charge level, emergency switch, door closure, correctness of wedge, presence of key and air pressure. Treatment can start, only when all of the above parameters are within the acceptable range. The console also displays collimator opening, collimator orientation, gantry orientation and couch configuration. Source position, whether it is in shielded, transit or exposed position, is also displayed. During treatment, it displays set time, exposed time and remaining time.
Couch Control Panel

Keypads and emergency switches are mounted on either side of the couch. Operator can quickly position the patient on the couch using the keypads. Operator can also control the motions of the gantry and collimator using the keypads. Patient positioning lasers, optical distance indicator, field light and room lights can be controlled using the buttons on the keypads.

Field Light and Optical Distance Indicator

Field light is used to visualise the collimated radiation field in the beam-off position of the source. The Field light system consists of an external projector employing a quartz halogen bulb and a concave mirror to direct a light beam along the passage of the source drawer. Optical distance indicator (ODI) displays the distance between the source and the patient’s skin. The scale of the ODI is projected on the patient’s skin.

Patient Positioning Lasers

Patient Positioning Lasers are used for accurate patient positioning. Two cross lasers and one sagittal laser are mounted on the wall of the treatment room. The intersection of these three laser beams represents the isocentre, which is the key reference of the machine.

CCTV Camera System

Using two CCTV cameras mounted in the treatment room, operator at the control console can continuously monitor the patient, during treatment.

Wall Mounted Display

A unit parameter display in the treatment room displays the configurations of the gantry, collimator and couch.

Other Controls and Indicators

Many emergency switches are provided at main frame, couch, door and operator’s panel, to terminate treatment in case of any emergency. A mandatory T-rod is provided for withdrawing the source manually to the fully shielded position, in the unlikely event of the failure of automatic source return system. Status lights to indicate the source position are provided on the gantry and access door.

Important Features

Important features of Bhabhatron are listed below. Many of them are unique to Bhabhatron.
1. High Capacity: Bhabhatron is designed to house 15 kilo curie cobalt-60 source.

2. Motorised Motions: All the motions of the main unit and treatment couch are motorised to reduce the patient setup time.

3. Computer Control: The computer continuously monitors all the vital system parameters. It terminates treatment, if any parameter exceeds the acceptable limits. Patient and treatment database are maintained.

4. Improved Radiation Safety: During power failure or other emergency conditions, the source automatically gets withdrawn to beam-off position. In addition, the collimator closes fully to reduce unwanted exposure to the patient.

5. Enhanced Security: Through password protection, access to operation of the machine, machine parameters, patient data and treatment data are limited only to authorised staff.

6. Battery Backup: The machine consumes only 1.5 kW power. A battery backup for six hours of continuous operation is provided to make it suitable for rural Indian conditions.

7. User Friendly: All vital parameters are displayed in the computer screen. The operator can interact with the machine, using mouse and keyboard. Two ergonomic backlit keypads on the patient couch enable faster patient setup. Machine parameters and patient specific notes are displayed on a wall-mounted display in treatment room.

8. More space of operator: Heavy counter weight of the gantry is located on the rear side of the machine, behind a wall to enhance safety. It also provides more space for the operator to setup the machine.

9. Motorized Universal Wedge Filter: Wedge filters are used to provide wedge-shaped dose distributions inside the target. In motorized wedge, a wedged beam is combined with the open beam in proper combination to achieve the desired wedged profile. Additionally, motorized wedge filters can generate any wedge angle, unlike the limited standard angles available with the physical wedge filters.

10. Asymmetric Collimation: The beam defining shielding jaws can move independently to generate asymmetric fields with respect to the radiation beam central axis.

11. Collimator Auto Set-up: Collimator openings and orientation can automatically setup for fast and accurate patient positioning.

12. Battery Backup: As the system consumes low power (1.2 kW), it is possible to operate this machine with a low-capacity generator, when power is not available. Additionally, a rechargeable battery backup is provided to enable treatment during power-cuts.

13. Remote Monitoring: An SMS based communication system provided in the machine reports the machine status periodically to the service center. This enables remote diagnosis and timely corrective actions, and reduces downtime of the machine.

14. Security and Data Management: The machine, patient and treatment data are
Donation to Vietnam

India has donated one Bhabhatron-II to Vietnam through the Programme of Action for Cancer Therapy (PACT) of IAEA. BARC has recently commissioned the machine at Can Tho Oncology Hospital in Vietnam.

Conclusion

Bhabhatrons are installed in many cancer hospitals in the country. Compared to any imported telecobalt machines, the indigenous machine is cheaper and superior in features. Bhabhatron can play a major role in meeting the growing demand of good quality and affordable machines. Hospitals across our vast country, including smaller hospitals located in semi-urban areas, would be able to afford and run these units. The development is expected to result in reduction in cancer treatment cost and wide spread of treatment facilities in India and other developing countries.

References


