Robotics

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Robots in Healthcare

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Radiotherapy Simulator

ABSTRACT

Robots have revolutionised industrial production and are now increasingly being used in other areas like space, research, defence, agriculture, underwater etc. Use of robots in healthcare is slow but for some of the applications robotic devices are now almost indispensable. It is important to note that most of the devices discussed here are remotely-operated, computer-controlled machines designed for specialized medical applications. In some cases, where robots are used, doctors always remain in the loop. Involvement of experts during such applications is important, particularly because every patient is unique, and parameters are expected to be different when someone seeks medical intervention.

KEYWORDS: *Medical robots, Bhabhatron, Radiotherapy, Localized cancer, Brachytherapy, Multi leaf collimator*

Introduction

Human cancer is one of the leading causes of death worldwide and is increasing at an alarming rate. Radiotherapy is an established and cost-effective treatment modality for the management of localized cancers. Since radiation is equally harmful to surrounding healthy tissues/organs and those coming in the path of the radiation beam, utmost care has to be taken to restrict the prescribed radiation exposure only to the affected organ/region. Additionally, it is essential to protect the operator, other hospital staff and the environment from the harmful effects of radiation. This requires specialized devices and some of these are discussed below.

In teletherapy, also termed as external beam radiotherapy, radiation dose is delivered from a distance to the affected region of a patient. For the source of radiation, there are two options: either it can be generated as and when required using devices like x-ray tubes, or using certain radioisotopes which emit radiation continuously. Bhabhatron is an indigenously developed teletherapy machine and uses high-energy gamma radiation emitted by Cobalt-60 radioisotope for the treatment of localized cancers[1]. It has 10 motorized and remotely operated motions for accurate patient positioning and radiation field shaping. A source capsule containing Cobalt-60 radioisotope of activity upto 15kCi is controlled remotely to toggle between the shielded and treatment positions. Since the geometry of the cancer-affected organ/region is highly irregular, a Multi Leaf Collimator (MLC) System has been developed and integrated with Bhabhatron. Thin divergent leaves made of tungsten alloys are grouped into two banks (30 in each) and are driven independently by individual electric motor. A computer program controls the leaves and independently positions each of the leaves to generate required radiation field geometries conforming to the irregular tumour boundaries. The accelerator based imported teletherapy machine is similar except the source of radiation is replaced by a compact linear accelerator emitting high-energy x-rays.

Safe and effective radiation therapy necessitates proper planning through delineation of the tumour and identification of the organs at risk for accurate delivery of the planned radiation dose. Radiotherapy simulation to determine the shape, size and orientation of the high-energy radiation field(s) to which the patient will be exposed later during the radiation therapy treatment is performed prior to the radiation therapy treatment, using a machine called radiotherapy simulator which has mechanical and radiation beam geometry identical to that of a teletherapy machine. In the indigenously developed system[2], there are 18 remotely controlled movements to reproduce the geometric movements of a teletherapy machine. However, unlike a teletherapy machine that delivers high-energy Gamma radiation beams for treatment, a Radiotherapy Simulator uses low-energy X-ray beams for imaging, either in radiography or fluoroscopy mode.

Indigenous Cobalt-60 Teletherapy Machine - Bhabhatron.

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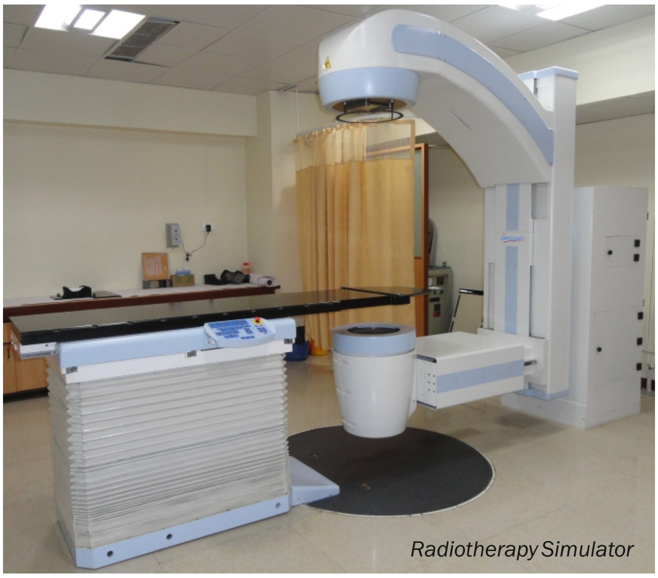


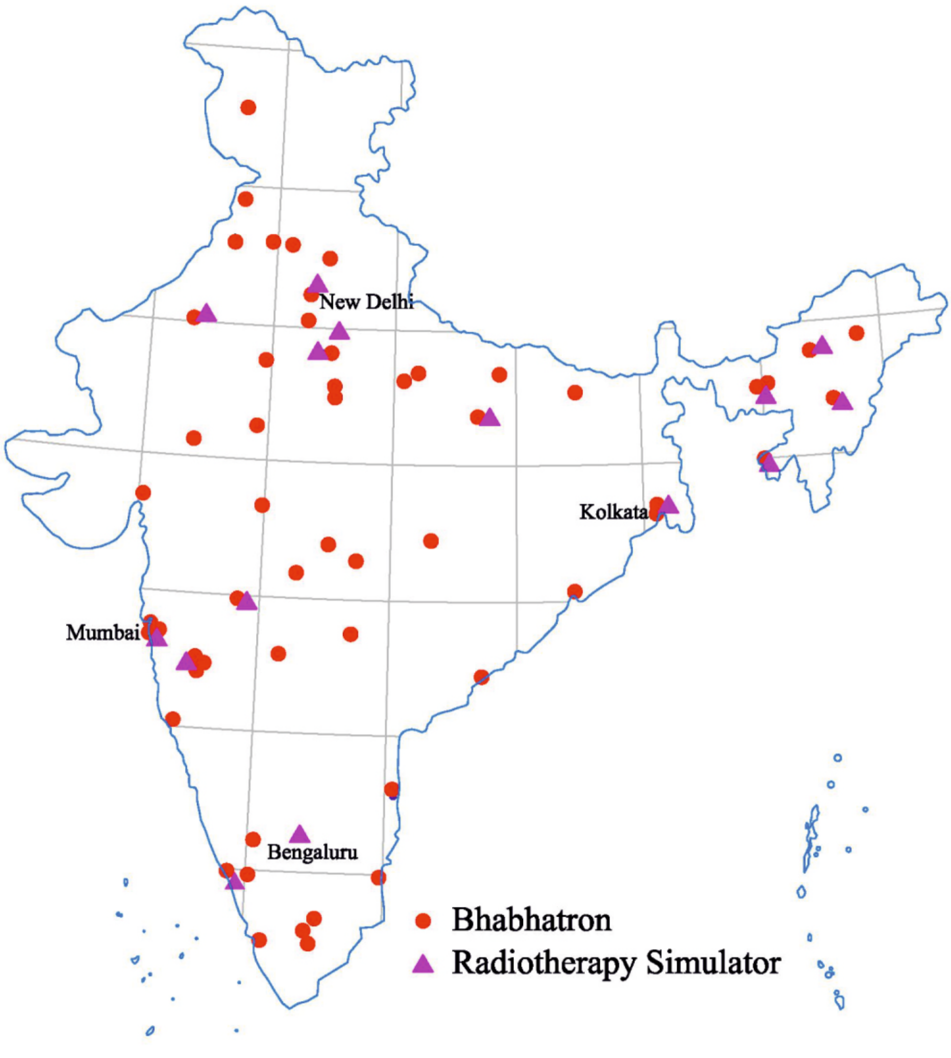
Radiotherapy Simulator

Both the machines, namely Bhabhatron and the Radiotherapy Simulator are designed to conform to the requirements of the International Electrotechnical Commission Standards. Additionally, these are approved by Atomic Energy Regulatory Board (AERB) for clinical use. The technologies have been transferred to industries for commercialization. More than 70 units of Bhabhatron and more than 20 units of Radiotherapy Simulator are in operation in various Cancer Hospitals in India and abroad.

Cyberknife®[3], originally developed by the Stanford University, USA, is a robotic teletherapy device in which a compact linear accelerator is mounted on an articulated robotic arm for precise delivery of high-energy x-ray beams concentrating to the tumour from wide range of positions and angles. Image-guided operations, coupled with robotic precision help in delivering very high dose to the tumour while limiting exposure to adjacent healthy tissues make it particularly suitable for the treatment of brain tumours.

Another mode of treatment for localized cancers using ionizing radiation is Brachytherapy which involves placement of miniature sealed radioisotope inside or in close proximity of the affected tissues/organ. In high dose rate remote after loading brachytherapy, the tiny capsule containing Iridium-192 or other radioisotope is remotely driven to the preset locations inside the organ through guiding tubes placed inside the body before the treatment. One such device has been developed by Board of Research in Isotope Technology (BRIT), an independent unit of Department of Atomic Energy (DAE).

In the Robot Assisted Neurosurgical Suite[4] developed by BARC, a compact parallel mechanism based six degrees of freedom robot can be programmed to access small deep rooted tumors and extract samples for biopsy. Image guided navigation of this high-precision mechanism provides tool position in real time during the procedure.



Installations

Use of robot for surgery was first started with replacement of hip joint. In the Robodoc surgical system[5] developed jointly by the University of California and IBM, the robot was programmed to drill hole into the femoral shaft for precise fitting between the bone and the artificial implant for improved performance of the joint. Subsequently, robots were used in many other healthcare applications, but the most significant is in minimally invasive surgical applications.

Minimally invasive surgery allows surgeons to perform surgery through small incisions instead of large abdominal cuts. There are significant benefits to the patient in terms of reduced post-operative complications and quicker return to normal physical activities. However, the laparoscopic tools have limited dexterity restricting the procedure to relatively simple operations. Also, these operations are quite demanding for the surgeons. Robot-assisted devices like *da Vinci* Surgical System[6] developed by Intuitive Surgical Inc., USA, allows a surgeon to perform surgical operations using miniature robotic arms (in master-slave mode), sitting comfortably at a remote location. Technologically, these are similar to the servo-manipulator systems used in DAE for nuclear (Hot-Cell) applications. Improved 3D view of the surgical site, force reflection, tremor-filtration etc. can drastically improve the surgical performance.

Brain-Computer Interfaces (BCI) are demonstrated to operate robotic devices for assisting persons with neurodegenerative disorders. The electroencephalography (EEG) signal from non-invasive BCIs are decoded to assign specific tasks for a robotic device enabling the disabled person to interact with their environment, communicate, and reduce dependence. These systems are still in the development stage and have potential to significantly improve the lives of many people with physical disabilities.

During the Covid-19 pandemic, when the proximity of the caregivers was risky, machines were perceived to be safer alternatives. Numerous robotic devices with wide range of sophistications were developed for applications like managing patient admissions, acquisition and monitoring of vital parameters of patients, drawing samples for pathological investigations, delivery of food and medicine, sanitization etc. Probably, a few of these will continue to be used in the post-pandemic era.

Apart from the devices discussed above, there are numerous robotic systems being used indirectly, namely in biological research, pathological investigations etc.

Conclusion

The use of Robotic and other automated devices is increasing rapidly in healthcare applications. Such tools are not to replace the humans but to extend human skills and improve performance. These systems are evolved to protect humans, to reach to locations which are otherwise unreachable, to improve performance and in some cases to perform tasks which are otherwise not feasible. There was an era when human used to be cautioned to stay away from robots/machines. But now, particularly in some healthcare applications, robotic touch is for the benefits of humans.

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