Abstract

Cancer is a major health concern in our country, and majority of the patients require radiotherapy during the course of treatment. Radiotherapy simulator is a machine that helps in radiotherapy planning, prior to the radiotherapy treatment. It helps to diagnose the physical extent of the tumour and its relation to the surrounding tissues for selecting the size and orientation of the radiotherapy beams. It also helps to plan the treatment and to protect the critical organs adjacent to the tumour to be treated. The capability of a simulator for real-time review and analyses of the images helps in accurate planning and verification in a short time.

Although, radiotherapy simulator is an essential tool for improving the quality of teletherapy, there is acute shortage of such machines in our country due to the high cost of the imported units and the lack of indigenous technology. Bhabha Atomic Research Centre (BARC), Mumbai has recently developed a Digital Radiotherapy Simulator. In this article, important features of this indigenous machine are discussed in brief.

Introduction

Radiation therapy is one of the established modes of cancer treatment. For the safe and effective radiation therapy, it is necessary to ensure that the whole target is exposed to the prescribed dose of radiation while limiting the exposure to surrounding healthy tissues. This necessitates proper planning through delineation of the tumour and identification of the organs at risk for accurate delivery of the planned radiation dose. The performance of radiotherapy depends mostly upon the precision with which the tumour can be located and the accuracy with which the radiation field is applied. Radiotherapy simulation is a process 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. It is performed using a machine called radiotherapy simulator, which is a combination of a diagnostic x-ray machine and an external beam radiation therapy machine. In the conventional form [1], it is similar to an isocentric external beam therapy machine. It can reproduce the geometric movements of (external beam) radiotherapy machines. However, unlike a teletherapy machine that delivers high-energy radiation beams for treatment, a radiotherapy simulator uses diagnostic X-ray beams for imaging, either in radiography or fluoroscopy mode. It has two roles: as a tumour localization tool; and as a treatment plan verification tool adapting the same treatment parameters, patient localization, immobilization etc. in a manner similar to a treatment machine.
Unlike the complex CT-Simulators, which performs virtual simulations, radiotherapy simulators are less expensive, easy to operate and easy to maintain [2]. The conventional design of Radiotherapy Simulator does not pose any restriction on the size of the patient. Moreover, the patient dose can be significantly less in conventional simulator compared to that in CT-Simulators. For moving tumours or tumours close to organs moving due to breathing, fluoroscopy mode of conventional simulators can detect the extent of the movement and help in limiting the exposure to normal tissues. Visualization of actual radiation field on the patient’s skin is another important feature which helps to avoid accidental exposure.

In India, there is wide gap between the demand and availability of radiotherapy facilities [3]. Most of the centres with teletherapy facilities do not have radiotherapy simulator. They generally depend on conventional radiography units for tumour localization. Considering the growing requirement for such machines in our country, BARC has initiated and successfully developed the technology. So far, three machines are operational including one at Tata Memorial Centre, Parel, Mumbai (Fig. 1). This article describes the development in brief.

**Brief Description of the Unit**

Major sub-systems in the radiotherapy simulator are gantry, collimator, x-ray tube, imaging unit, and patient support/positioning system [4]. The schematic layout of the machine is shown in Fig. 2.

**Control Console**

The patient setup is generally performed through the local console mounted on the patient positioning couch. Various machine parameters are displayed on the wall-mounted display inside the simulator room.

Another control console is located at outside the simulator room. After immobilizing the patient on the simulator couch, the operator leaves the room, and operates the machine from this console. The console consists of a desktop computer, a mouse, a physical key switch, and two buttons for activating the X-ray beam. One more desktop computer is used for display and storage of the acquired images.

The user can control all unit motions, viz. gantry, collimator, imaging arm and the couch, through the graphical user interface as shown in Figure 3. The digital readouts of all the motions are displayed on the console. For imaging, the operator can select one of the two modes: fluoroscopy or radiography. In fluoroscopy mode, the live images of any moving organ can be viewed continuously. This mode can also be used while one or more unit motions are active, for determining appropriate beam (for therapy) directions. Static anatomical images can be captured in the radiography mode. For either of these modes, the operator can select the exposure parameters, such as tube voltage, tube current and time.
Auxiliary sub-systems

Anti-Collision Systems

During patient setup, various motions of the machine have to be performed while the patient remains immobilized on the couch. The control software avoids collision between various subsystems viz. the couch and the C-arm. Additionally, to ensure any accidental collision between any subsystem of the machine and the patient, the collimator and the image intensifier are equipped with sensors to detect such instances. Whenever the system detects any collision, the motions stop immediately and the operator is intimated by audible beeps.

Patient Positioning Lasers

Accurate patient positioning is essential for effective treatment simulation. The laser system consists of three linear red diode lasers: two in cross planes and one in sagittal plane. The projections of these lasers mark the isocentre, which serves as the reference for various setup parameters in order to reproduce exact positions on treatment machines.

Safety Interlocks and Emergency Stop Buttons

Many safety interlocks are provided to protect the patient and the operators from unwanted exposure to radiation. These include door interlock of the treatment room (to prevent exposure by accidental opening of door), external mains power supply interlock and emergency interlock (due to fault in any of the unit motions). Emergency stop buttons are installed in the base housing, couch, door, control console and on the passage wall inside the room.

Image intensifiers are widely being used in medical imaging due to cost-effectiveness and significantly low patient radiation dose. However, image distortions introduced by an Image Intensifier are unavoidable. Here, the distortions of the raw image are corrected [5] automatically (Fig. 4) through software without any operator intervention. Important features viz. last image hold, MLC (multi leaf collimator) overlay, DICOM (Digital Imaging and COmmunication in Medicine) compatibility, storage and management of acquired images, annotations, image processing and viewing tools, printing etc. are implemented for the convenience of the user.
Wall Mounted Display

A monitor in the treatment room displays important parameters related to the machine. Whenever an authorized user logs into the system, system parameters like FAD; image intensifier distance; gantry rotation angle; collimator rotation angle; and positions of the collimator blades, delineator wires, couch longitudinal, lateral, vertical and isocentric rotation are displayed in the monitor.

Connectivity to Hospital Network

After simulation, the patient details, acquired x-ray images and the parameters finalized for the radiotherapy treatment have to be made accessible to the Hospital network through which other systems like Treatment Planning Systems (TPS), treatment machines (medical LINAC, Telecobalt, brachytherapy etc.) can utilize the simulation details. For interoperability, the simulation results are stored/managed and made accessible conforming to the DICOM Standards which is used in virtually all hospitals worldwide.

Patient Simulation

Radiotherapy Simulation is performed prior to the radiation therapy treatment. The purpose is to localize the extent of the tumour so that the whole of the affected region can be exposed to treatment beams while limiting exposure to the adjacent healthy tissues/ organs. Once the patient lies down on the patient positioning table, the operator positions the suspected region closer to the isocentre by actuating various motions through the keypads. Focus to axis distance (FAD) is set as the same as the treatment machine in which the patient will be treated. Depending on the affected organ/region, the C-arm is rotated to a suitable angle. Imager, collimating jaws, delineating wires, collimator angles are set for relatively larger x-ray fields. Patient positioning lasers, optical distance indicator, in-room wall-mounted display, field light projections etc are used for accurate and repeatable positioning of the patient. The patient is instructed not to move and all the staffs leave the room.

At the remote console, patient and treatment related data are entered by authorized operator. Depending on the location of the suspected region and the size/built of the patient, x-ray parameters like kV, mA and time are set. The operator fires the x-ray in appropriate mode, and the raw image appears on the adjacent monitor almost instantly. After couple of seconds, the distortion-corrected image is displayed on the screen. Based on the instruction by the radiation oncologist, the operator needs to repeat after changing some of the machine/ x-ray parameters for better visualization and delineation of the target region (Fig. 5). Processing of the acquired image can also be performed. For multiple fields (if any), the whole process has to be repeated. In some cases, patient-specific immobilization masks (Fig. 6) using perforated thermoplastic sheets are made to ensure repeatable positioning for each radiation therapy treatment. Finally, the set of parameters recommended by the doctor and corresponding images are stored and/or printed.
Quality Assurances and Regulatory Compliances

Radiotherapy simulator has major influence on the overall performance of the radiation therapy process. Although not used directly for the dose delivery, its role is important in determining the target location, treatment planning and spatial accuracy in dose delivery. As the simulator has many features of therapy machine and diagnostic radiology unit, it has to conform to requirements of both the applications. The unit is tested and conforming to the International Electrotechnical Commission (IEC) Standards [6]. The machine is cleared by Atomic Energy Regulatory Board (AERB) for clinical use.

Performance

One unit has been installed at Tata Memorial Centre (TMC), Parel, Mumbai for thorough performance evaluation in the clinical environment. It is inaugurated in March 2013, remotely from Trombay, by H.E. Mr. Yukiya Amano, Director General, IAEA. 10-15 patients are being simulated on this machine daily. Another unit is being commissioned at Saroj Gupta Cancer Centre & Research Institute, Kolkata for the same purpose.

Technology Transfer

Radiotherapy simulator is an essential tool for improving the performance of the radiotherapy treatment. However, in our country, many cancer hospitals with teletherapy units do not have any radiotherapy simulator. The cost of the indigenous Simulator is significantly less compared to the similar imported units. To make the machine available commercially, the technology is transferred to a M/s. Panacea Medical Technologies Pvt. Ltd., Bangalore.

Conclusion

The technology for our indigenous radiotherapy simulator is developed successfully. So far, three units are operational. Based on the operational feedbacks, suggestions and recommendations by the experts and users, the unit is being continuously improved. This computer-controlled machine is simple and user-friendly. Other features of the machine, such as filmless operations and ease of transfer and storage of digital images can streamline the workflow and improve overall performances of the department. The indigenous machine is less expensive, compared to
imported simulators. Therefore, smaller radiotherapy centres, especially those at remote places, will be able to afford this simulator, leading to better accessibility to the common people of the society.

References


