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Virtual simulation and treatment verification—merits and demerits: experience at Sindh Institute of Urology and Transplantation (SIUT), Pakistan

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Abstract

Background: The rapid changes in practice of radiotherapy have taken place over the past 5 years in Pakistan. With advent of computed tomography simulator, and multileaf collimators–assisted linear accelerators and electronic portal imaging system, few centres in Pakistan have switched from conventional radiotherapy to modern computer-based technology. Our hospital is first centre in Pakistan which is using virtual simulation since March 2006. We present our experience with list of merits and demerits.

Design: Retrospective study.

Patient collection: Medical records of all patients who received radiotherapy in our centre were reviewed. Parameters included were type of malignancy, type radiotherapy (curative/palliative), simulation and planning process time and the displacement of the beam-axis from the planning isocentre in clinical situations during three-dimensional conformal radiotherapy using electronic portal imaging device (EPID). Data were collected on written proforma. Percentages, frequencies, measures of central tendency and dispersion were calculated using SPSS version 17.0.

Results: A total of 289 patients were treated from March 2006 to November 2008. Transitional cell carcinoma of urinary bladder was most common malignancy seen (42.4%) followed by prostate (28.62%) and renal cell carcinoma (14.14%). Of these 34.26% patients were treated on curative basis. The virtual simulation process could be completed in an average time of 5 min (SD 3.5). Under many cases, the treatment portals could be designed and the patient marked in one session. The displacements were recorded for 43 portals for early prostate cancer using an EPID system. The mean displacement was found 2.44 ± 0.8 mm in x (transverse), y (craniocaudal), and z (anteroposterior) directions during treatment. Standard deviation (SD) was 0.87 (90% CI 2.21–2.66). Average number of portals taken was 10 (6–27) per treatment session.

Conclusion: Computer-based simulation and treatment over conventional methods is appropriate for curative patients, achieving more accurate tumour localisation, sparing normal organs at risk, reduced field sizes and a film free environment; however efforts are required to achieve maximum immobilisation during treatment.

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Keywords

Radiotherapy in Pakistan; virtual simulation; multileaf collimator linear accelerators; electronic portal imaging devices; digitally reconstructed radiographs

INTRODUCTION

Currently there are 22 cancer centres in Pakistan offering radiotherapy services to their patients. Majority of these centres are using conventional methods; tumour localisation by fluoroscopy-assisted simulators getting help from bony landmarks. The most commonly used machine is cobalt-60 or linear accelerator without multileaf collimators on which beam shaping is done by customised blocks.

The radiotherapy planning has changed drastically in recent years. Radiation oncologists now require defining the target volume more precisely, not just in two dimensions, but also in three dimensions, to irradiate the tumour to as high a dose as possible, while saving the normal tissues. To achieve this, radiation oncologists require the help of computed tomography (CT) and magnetic resonance imaging to identify critical structures, computer-based treatment planning system, contouring tools, shaping of fields around target using multileaf collimators, transfer of plan to linear accelerator and for verification of plan needs digitally reconstructed radiographs for online treatment accuracy.

Virtual simulation, a term described by Sherouse et al.[1] to refer to the processes on a computer, using a three-dimensional conformal radiotherapy (3D CRT) patient data set, that allow full simulation and verification of radiotherapy treatment. Virtual simulation comprises two phases; first, CT simulation, which is physical CT scanning (patient required) and second, V-SIM (patient not required, during this oncologists delineate the tumour and field shaping).

Considering the changes that have taken place over the past 5 years, we switched over from conventional fluoroscopic simulator to virtual simulation, using SOMATOM Emotion Duo/Emotion6 CT system and the COHERENCE Dosimeterist by Siemens in March 2006 for tumour localisation, contouring the normal organs and beam shaping. We are presenting merits and demerits we experienced while dealing with virtual simulation.

PATIENTS/METHODS

In our centre, for simulation process, the patient is positioned on the flat-top couch of a CT scanner in the treatment position. Alignment of the patient is made with lateral wall lasers and sagittal laser. A scout view scan is made to determine the region over which axial slices will be scanned. These slices are then made according to the particular protocol for the site to be treated, for example, prostate. The oncologist always remains during scanning process, first identifies a reference slice containing a reference point from the scan study. Then patient is 'marked' where the laser projection illuminates the skin and finally the patient is removed from the couch. Then V-SIM phase is undertaken by oncologist without the presence of patient including target delineation, field borders. Then these plans are shifted to LANTIS for physicist planning. After confirming dose homogeneity, plan is transferred to linear accelerator for treatment. Weekly portals are taken only for curative patients.

For this study, we reviewed medical records of all patients who were simulated on CT SIM in our centre. Parameters included were type of malignancy, type radiotherapy (curative/palliative), simulation and planning process time, the displacement of the beam-axis from the planning isocentre x(right or left), y (craniocaudal) and z (anteroposterior) directions during radiotherapy treatment by portal image taken for each treatment field, using EPID.

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Data were collected on proforma. Percentages, frequencies, measures of central tendency and dispersion were calculated by using SPSS version 17.0.

RESULTS

A total of 289 patients were treated from March 2006 to November 2008. Transitional cell carcinoma of urinary bladder was most common malignancy seen (42.4%) followed by prostate (28.62%) and renal cell carcinoma (14.14%) (Figure 1). Of these 34.26% patients were treated on curative basis, while majority of patients received palliative radiotherapy.

In all patients, non-contrast CT images were acquired. The virtual scanning phase could be completed in an average time of 5 min (SD ± 3.5), after marking isocentre, patient were moved from CT couch. Remaining V-SIM phase including target delineation and field borders were defined by oncologist in absence of the patient. Under all cases, the patient marked in one session; however in few patients, scans were repeated due to setup errors. Palliative patients took longer time because for each treatment site different scout views were made, different isocentres were marked and field borders were defined.

For quality assurance purpose, of all curative patients, 43 patients with early prostate cancer were randomly selected for isocentre displacement in x (right-left), y (craniocaudal), z (anteroposterior) directions using portal image for each treatment field, with average number was 10 (6–27) for each patient during treatment.

The mean displacement in any direction was found 2.44 ± 0.8 mm, standard deviation (SD) was 0.87 (90% CI 2.21–2.66) (Figure 2a–c). These displacements were corrected by either shifting position of patient on treatment couch or doing repeat virtual simulation.

DISCUSSION

As in most developing countries, incidence of cancer is increasing in Pakistan, but due to lack of national population-based cancer registries exact incidence is not known. The first radiotherapy centre in Pakistan started working

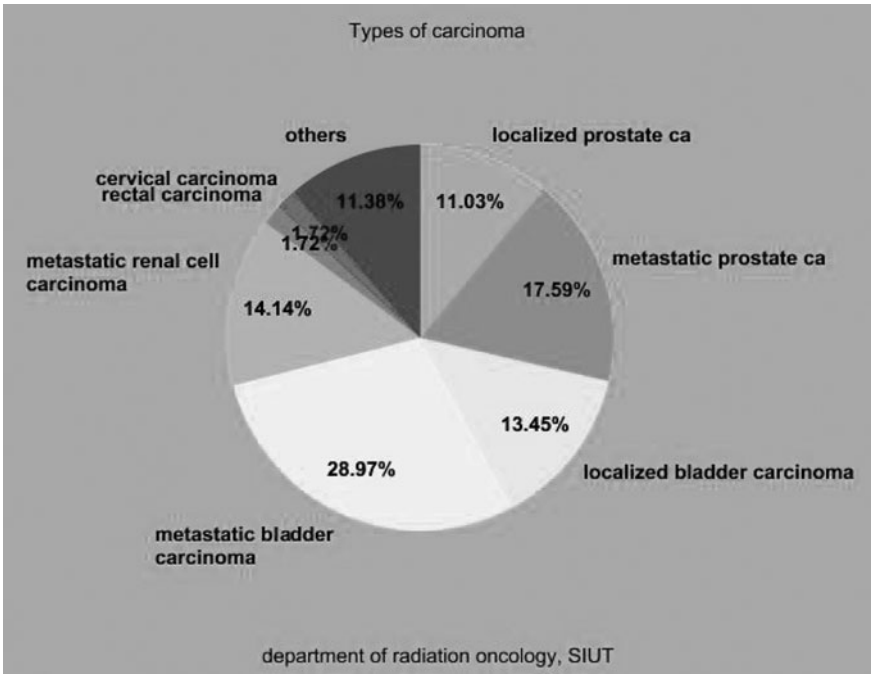

Figure 1. Frequency of malignancies seen at department of radiation oncology, SIUT.

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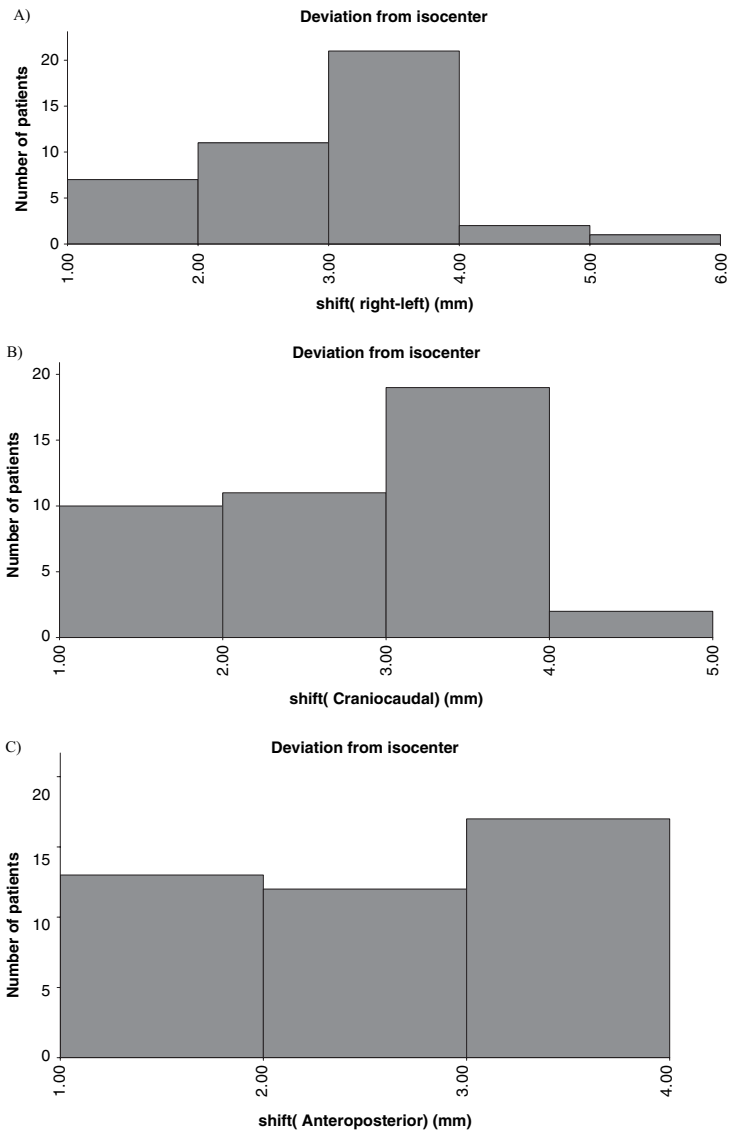

Figure 2. Deviation from isocentre.

in 1950 at Mayo Hospital Lahore.[2] Over last few years the practice of radiotherapy has been revolutionised in Pakistan, with arrival of multi-leaf collimators linear accelerator and computer-based treatment planning system.

Being tertiary care centre for genitourinary cancers, in our study, the bladder carcinoma was predominant followed by prostate and renal cell carcinoma. Similar findings were noticed by a retrospective study conducted in Nishtar Medical College Multan.[3] Underlying causes are smoking, calculi, repeated infections and will be presented somewhere in near future.

Due to lack of awareness programmes, palliative radiotherapy burden was high about 65.74% for symptomatic relief of haematuria and painful bone metastasis. We found that virtual simulation for these patients did not aid much to their treatment, because majority of patients presented with more than single painful site, required different position, scout views, markings so spending maximum time on CT simulator. These patients shall be simulated on conventional fluoroscopic simulator. For remaining curative intention radiotherapy in 34.26% virtual simulation was found time saving from 25 to 30 min (SD 4.16) in conventional simulation to 5 min (SD 3.5) on virtual

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simulation (scan phase) with more precision. Because of contrast-induced artefacts non-contrast images were acquired for contouring prostate, bladder, rectum and bones during pelvic simulation. However, for chest and abdomen simulation, non-contrast enhanced images can be less helpful while delineating bowels and viscera.

The displacement of the beam-axis from the planning isocentre in clinical situations during 3D CRT using EPID was found 2.44 ± 0.8 mm in x (left right), y (craniocaudal), and z (anteroposterior). This was found within normal SD, as by Hurkmans et al.[4] using EPIDs, we could adjust patient or field position during treatment. For displacement of beam-axis from planning isocentre more 5 mm, patients were re-simulated. Currently we are not using pelvic thermoplastic sheets; however, but believe every effort shall be done to minimise positional errors. We do believe that each institution should review its own treatment protocol to quantify and reduce set-up errors in clinical practice.

The advantages which we achieved by virtual simulation were

1. By delineating tumour and adjacent nodes and organs at risk, reduced field sizes could be achieved in comparison to conventional simulation. Senan et al.[5] also found that the use of virtual simulation allowed for smaller planning target volumes and field sizes in radical lung cancer.
2. Time saving, scan phase took only 5 min, so the patient can be removed from CT couch after marking and the oncologist can delineate and define field borders without patient. In our experience, conventional simulation takes 25–30 min. Also data by Buchali et al.[6] have reported a study of 23 patients having tangential breast irradiation. The use of virtual simulation resulted in a mean saving of 22 min in the whole treatment planning process compared with physical simulation. Raga et al.[7] have reported that the physician's time involved in the planning process can be significantly reduced using virtual simulation typically from 25 to 5 min per patient (brain and prostate).
3. Could simulate non-coplanar fields. With the help of Room's eye view and beam's eye view, oncologist could get an idea about gantry position with respect to defined field, which is not possible by conventional simulation.
4. Reduced simulation time increased patient comfort, repositioning.
5. Osteolytic lesions are more clearly seen than on conventional simulator.
6. No X-ray film processing was required.

The disadvantages we experienced were

1. Palliative patients (those required more than one treatment fields) took longer time between scanning and treatment.
2. Transfer of verification to treatment unit required extra treatment slot.
3. Small aperture of CT scanner is not suitable for simulating patients with breast carcinoma (tangential fields); however, availability of large bore CT scanner has solved this issue.
4. Data storage.
5. Did not give information on organ motion, while conventional simulator gives idea of organ motion. However, field borders could be visualised on linear accelerator. The same problem was also noticed by Forester et al.[8] Breath holding and gated respiration techniques have been demonstrated to produce four-dimensional data sets that can be used to reduce margins or to minimise dose to normal tissue or organs at risk.[9] Image-guided radiotherapy is being developed to address the interfraction movement of both target volumes and critical normal structures.[10]
6. DRR resolution is not equal to radiographic resolution. For better quality of DRR, more CT slices were acquired as most of recent literature suggests.[10]
7. Contrast-enhanced images affected treatment plans making artefacts.
8. High-radiation dose by CT scanner, also found by different studies.[12] Doses for CT scanners are quoted as CTDIw (CT dose index) with values in the region of 20 mGy.[13] This dose is delivered to regions of normal healthy tissue as well as the tumour volume. Manufacturers

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of CT scanners provide various methods to reduce the total dose to the patient, taking account of the different dimensions of the patient at different levels and modulating the exposure in response to the detector measurements.

We recommend the adoption of virtual simulation in favour of conventional simulation for modern radiation oncology units, considering institutional budget and technical staff. However due to higher number of palliative patients, retention of conventional simulation would seem advantageous, along with virtual simulator.

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