Journal of Radiotherapy in Practice

Journal of Radiotherapy in Practice 2003
3, 63–67
© Greenwich Medical Media Ltd. 2003

Original Article

Clinical implementation of intensity modulated radiotherapy: initial experiences

H. A. McNair*, J. Selous-Hodges*, D. Convery†, V. Cosgrove†, J. Balyckyi*, D. P. Dearnaley**, C. Nuttings**

†*Joint Department of Physics and* **Department of Radiotherapy;* ***Academic Unit of Radiotherapy and Oncology, Royal Marsden NHS Trust, Sutton, Surrey, UK*

Abstract

The development of intensity modulated radiotherapy (IMRT) has allowed the delivery of concave dose distributions. Planning studies have demonstrated the potential clinical benefit of IMRT in the treatment of the prostate and pelvic nodes in patients with advanced prostate cancer. As a consequence, IMRT was clinically implemented in the Royal Marsden NHS Trust in September 2000, using Elekta SL*i* series linear accelerators and NOMOS Corvus v3.0 planning system. As a relatively new treatment procedure in the United Kingdom, the clinical implementation involved developing appropriate quality assurance and verification procedures as well as training staff. This paper describes the practicalities of implementing IMRT into the routine workload of the radiotherapy department.

Keywords

IMRT; clinical implementation; prostate cancer

INTRODUCTION

Intensity Modulated Radiotherapy (IMRT) is a further advancement of conformal radiotherapy (CRT) having the capacity to shape radiotherapy dose distributions to concave tumour volumes.[1] This enables the dose to the target volume to be escalated whilst allowing the dose to critical organs, e.g rectum in prostate patients, to be minimised and improve the therapeutic ratio.[2,3] Planning studies carried out at this centre indicated the potential benefit of IMRT in reducing the volume of bowel treated when irradiating pelvic lymph nodes.[4] It was therefore decided to introduce IMRT clinically, at the Royal Marsden NHS Trust and initially treat patients with localised advanced prostate cancer (stage T3 a/b or T2 with PSA >20 ng/ml or Gleeson score ≥8). Previously we had elected not to treat the pelvic lymph nodes, despite the high risk of nodal involvement in these cases, because of the perceived risk of bowel toxicity. A phase 1 study was designed treating the prostate to 70 Gy and escalating the lymph node dose in successive cohorts of patients from 50 Gy to 60 Gy. The end point was set as the absence of small bowel toxicity after dose escalation. Ethical approval was obtained and patient information sheets were developed to assist obtaining informed consent. In September 2000, the first patient was treated with dynamic IMRT using Elekta SL*i* series linear accelerators and NOMOS Corvus v3.0 planning system.

Correspondence to: Helen McNair, Radiotherapy Department, Royal Marsden NHS Trust, Downs Rd, Sutton, Surrey SM2 5PT. E-mail: Helen.McNair@rmh.nthames.nhs.uk
Research radiographer post funded by Cancer Research UK.

https://doi.org/10.1017/S1460396903000037 Published online by Cambridge University Press

PREPARATION

As a new and relatively complex technique, it was decided with discussion between the radiographers, physicists and medical staff to re-examine all parts of the planning process from first principles. This ensured that optimum changes were made, if necessary at each level. Effective communication between these multi-disciplinary teams was essential at this stage.

Preliminary extensive Quality Assurance was carried out on the linear accelerators, which included multileaf collimator (MLC) calibrations, dose per monitor unit checks, MLC field shaping consistency and reproducibility and monitoring output for small field sizes.

TRAINING

A research radiographer was appointed to co-ordinate between research physicists, radiographers and clinicians and to ensure effective communication.

IMRT is a relatively new treatment procedure in the United Kingdom. As there was no information in the public domain to indicate the time demands a course of IMRT treatment would place on a department, it was decided to perform a test-patient treatment with an anthropomorphic phantom, to assess the time, reproducibility and reliability of the treatment delivery. The phantom was taken through the complete treatment process from radiotherapy CT scanning to treatment delivery. As part of staff training, appointment times were allocated in the patient booking system and the phantom was treated. This also allowed radiographers to become familiar with the treatment delivery and verification and highlight any potential problems in a routine clinical environment.

CHANGES IN WORKING PRACTICE

During these training sessions using the test-patient the following issues were brought to the treatment radiographers attention:

- The monitor units (MU's) used, to deliver the complex intensity patterns, were in the order of 8–9 times greater than those used to treat by conformal radiotherapy. Hence radiographers did not have an instinctive "feel" for the accuracy/appropriateness of the MU settings.
- The radiographers were unable to carry out routine calculation checks since the treatment was inversely planned and the fields were extremely complex, both in the nature of delivery and the variability of the photon fluence within the field.
- Dynamic delivery does not allow a visual light-field check on the patient before leaving the treatment room due to the closed starting leaf positions.
- During the test-patient treatments it was noted that posterior oblique fields could not avoid the c-arms of the Elekta couch regardless of their position due to the maximum extent of the field width. The treatment plan "class solution" beam arrangement was then changed to lateral fields, with two anterior obliques and a posterior field, without detrimentally affecting plan dose distribution. A special solid couch insert with an aperture was made to allow the posterior field to be delivered without build-up while maintaining couch stability.
- Initially, the linac javelin system operating software did not support dynamic IMRT delivery in "clinical" mode. The linac was therefore used in "service" mode to deliver the IMRT fields using software provided by Elekta via the IMRT International Consortium. This meant the MLC station and the linac were not fully interlocked (only gantry, collimator and floor angles were interlocked) and independent checks were required prior to each field delivery and manual reset following any abnormal terminations. User confidence also had to be developed when using this non-standard operating system.

These differences highlighted the changes in working practices that formed the basis for the treatment and verification protocols.

TREATMENT PLANNING

Localisation

The patients were CT scanned using the same protocol as for conformal radiotherapy (CRT);

https://doi.org/10.1017/S1460396903000037 Published online by Cambridge University Press

supine using 5 mm slice thickness at 5 mm intervals with a comfortably full bladder. The immobilisation system, which consisted of ankle stocks, had been evaluated in a previous study at this centre.[5] Anterior and lateral tattoos were placed at the level of symphysis pubis and used to define the field centre (*not* the geometric centre of the treatment volume). This anatomical location was chosen for the tattoos because of the greater stability gained as compared to the more superior geometric centre, hence improving set-up reproducibility.

Planning

Planning was carried out on the NOMOS Corvus v3.0 inverse planning system. The definition of lymph node groups and identification of enlarged and/or suspicious lymph nodes was performed in conjunction with a radiologist. A planning target volume (PTV) margin of 1 cm was added to the prostate gross target volume (GTV) and 5 mm margin to the lymph nodes. The bladder, left and right femoral heads, rectum and small bowel were contoured as organs at risk (OAR).

For the inverse planning process target doses of 70 Gy to the prostate and 50 Gy to the pelvic nodes were assigned and dose constraints were assigned to the OAR (Table 1). To achieve an acceptable plan it was sometimes necessary to marginally adjust the values entered into the planning system. The resulting plan had five fields; posterior, two laterals and two anterior obliques.

Table 1. Assigned doses for target volumes and dose constraints for organs at risk

Structure	Volume	Dose required
Prostate PTV	99%	90% (63 Gy)
	95%	95% (66.5 Gy)
Nodal PTV	99%	90% (45 Gy)
	95%	95% (47.5 Gy)
	50%	100% (50 Gy)
	Dose Constraint	**Volume required**
Rectum	40 Gy	60%
	65 Gy	30%
	70 Gy	15%
	75 Gy	3%
Bladder	50 Gy	50%
	60 Gy	25%
	70 Gy	5%
Bowel	45 Gy	78 cc
	50 Gy	17 cc
	55 Gy	14 cc
	60 Gy	0.5 cc
	65 Gy	0 cc

Pre treatment verification

Once an acceptable plan had been produced the plan was recalculated onto the previously scanned anthropomorphic phantom (Alderson-Rando). The phantom was then loaded with typically 80 thermoluminescent detectors (TLD's) and irradiated. These TLD readings replaced the conventional MU calculation check. During this verification XV Kodak films were attached to the head of the linac to acquire intensity patterns of the delivered fields. Up to five XV films were also loaded in the phantom in the region of the prostate, seminal vesicles and pelvic lymph nodes. The phantom was irradiated with a reduced dose of 0.5 Gy to avoid over irradiating the films and the linac dose rate was reduced from 400 MU/min to 100 MU/min, to ensure the leaves moved at the same speed as with the standard 2 Gy per fraction dose delivery.

Simulation

Orthogonal films were taken in simulator with field sizes chosen to include appropriate anatomy for treatment verification. The films were compared to the Digitally Reconstructed Radiographs (DRRs) in the simulator and used as the gold standard to verify the portal images taken on treatment.

TREATMENT

Isocentre verification

During the first five treatments the treatment radiographers verified the isocentre position with electronic portal imaging (EPI) using Theraview®. The average set-up displacement was calculated using the five portal images and simulator films. Fields were moved if they fell outside a 3 mm tolerance. Any systematic error was also assessed by the radiographers after evaluating the whole set-up and corrected, if necessary. Following any adjustments the patient was imaged until two consecutive in-tolerance images were obtained. Once the set up was approved, the patient was imaged weekly and audited by the clinicians at a weekly meeting.

https://doi.org/10.1017/S1460396903000037 Published online by Cambridge University Press

MLC verification

To verify the MLC configurations and to provide a record of the intensity map delivered during treatment, films were additionally attached to the gantry head. These were compared to the films taken whilst irradiating the phantom. For the first patient, films were taken of all the beams on the first day. A further four sets of films were taken subsequently. These films were assessed initially by physicists, manually on a light box to determine the consistency and reproducibility of the treatment delivery. No inconsistencies in intensity patterns were detected. Subsequently the radiographers reviewed the films. Consequently, the number of beam films were decreased to one film per week, with EPI and film. The EPI is currently being compared with films and once consistency has been established the EPI system will supersede films.

Treatment delivery

The average time taken to treat the patients was 25–30 minutes. This was due to the high number of monitor units, 600–800, required per beam to deliver the complex modulations produced by the planning system.

Since beginning the trial, new Desktop software has been installed on the Elekta Linacs. Since the software does not support dynamic IMRT, the delivery technique has changed to step-and-shoot planned on MDS Nordion Helax TMS planning system. The field arrangement has remained unchanged. The delivery time has decreased to 20–22 minutes and is estimated to decrease by another 5 minutes with the release of new software (personal communication; Elekta).

DISCUSSION

At the time of implementation in this department, IMRT was not clinically used in many departments in the UK. The linacs had also not been designed specifically to deliver IMRT thus confounding the practicalities of clinical implementation. This unique situation resulted in changes in clinical practice, which can be related to the introduction of any new technology into busy radiotherapy departments. Studies conducted on changing environments have concluded that staff contribution to the planning, learning and implementation of a change process lowers resistance and influences employees commitment to change.[6] It has also been recommended that the users of technologies are involved in the implementation and that the system must be acceptable to them for new technologies to be introduced successfully.[7] It is difficult, however, with the limitation of time on a treatment unit to allow time for all staff to be involved in the background work that is necessary in implementing new technology. However, this department has found a lunchtime journal club a useful forum where new techniques and technology can be discussed. The role of the Research Radiographer, to oversee the IMRT project, also facilitated communication between management levels within the organisation which is of importance.[8] IMRT treatments currently require more time than CRT due to the greater number of beams and MU's per beam used. This could potentially impact on many radiotherapy departments in the UK with already stretched workloads and waiting times.[9] The NHS cancer plan is aiming to reduce waiting times for radiotherapy to less than one month from urgent referral to the commencement of treatment.[10] The paradox of introducing new technology while maintaining this service is a challenge and may hinder innovation. To help contend with some of these confounding problems within our department, initially only one patient was treated at any one time, scheduled at the time most difficult to allocate to other patients. Future workload can be reassessed as technology develops, and treatment delivery times decrease. However, the inverse planning and verification does require extra resources. The plan verification in particular is often carried out after standard clinical treatment hours and will also be affected by machine downtime.

It is recommended new treatments be compared to the most common and cost-effective existing treatment approach.[11] The potential benefits of IMRT have been compared to CRT in numerous planning studies but there are a few clinical studies to date.[12] Prospective randomised trials are necessary to fully evaluate the benefits of IMRT, and a multicentre trial in head and neck cancer has just started involving four centres in Europe (Royal Marsden NHS Trust, London; Christie Hospital NHS Trust, Manchester; Netherlands Cancer Institute, Amsterdam; The University Hospital, Ghent).

https://doi.org/10.1017/S1460396903000037 Published online by Cambridge University Press

The application of IMRT to conform doses closely to a target volume while avoiding nearby critical structures has further bearing on patient set-up reproducibility. It is imperative that patient immobilisation is optimised and the possibility of image guided radiotherapy explored in conjunction with IMRT developments.

In parallel with patient immobilisation is the requirement for accurate treatment verification. In our department the radiographers evaluate the set-up accuracy from the portal images. This not only results in a more efficient set-up verification and correction process, but also utilises the resource and experience of the radiographers'.[13] The verification of IMRT adds to the treatment time since extra verification fields have to be created, as it is currently difficult to use the modulated treatment fields. However, work is in progress to subtract the modulations from the images, allowing the anatomy to be visualised and hence enable verification.[14] Acquiring the modulations is also time consuming using the camera based EPI system. With the future implementation of an amorphous silicon (aSi) EPI system the images will be taken instantaneously.

Dynamic IMRT delivery has also been associated with increased leaf motor problems.[15] Provision must be made for back-up treatments to maintain continuous treatment in-case of machine breakdown.

CONCLUSION

The initial implementation of dynamic IMRT provided the radiotherapy department with experience in planning, verification and treatment delivery. Consequently, the subsequent move to step-and-shoot IMRT with the new dedicated linac operating software was straightforward. The experience gained has enabled the application of IMRT to other sites, in, for example, head and neck tumours. The clinical introduction of IMRT could lead in the future to decreased treatment margins and dose escalation. These developments must be run in parallel with careful patient immobilisation and verification to ensure accurate and safe treatment delivery.

References

1. Nutting C, Dearnaley DP. Intensity Modulated Radiation Therapy: a clinical review. BJR 2000; 73: 459–469.
2. Zelefsky MJ, Fuks Z, Hunt M et al. High dose intensity modulated radiation therapy for prostate cancer; early toxicity and biochemical outcome in 772 patients. Int J Radiat Oncol Biol Phys 2002; 53(5): 111–116.
3. Fiorino C, Broggi S, Corletto D, Cattaneo GM, Calandrino R. Conformal irradiation of concave-shaped PTVs in the treatment of prostate cancer by simple 1D intensity-modulated beams. Radiother and Oncol 2000; 55: 49–58.
4. Nutting CM, Convery DJ, Cosgrove VP et al. Reduction of small and large bowel irradiation using optimized intensity-modulated pelvic radiotherapy technique in patients with prostate cancer. Int J Radiat Oncol Biol Phys 2000; 48: 649–656.
5. Nutting C, Khoo V, Walker V, McNair H, Beardmore C, Norman A, Dearnaley DP. A randomized study of the use of a customised immobilisation system in the treatment of prostate cancer with conformal radiotherapy. Radiother and Oncol 2000; 54(1): 1–9.
6. Waddell D, Sohal A. Resistance: a constructive tool for change management. Management Decision 1998; 38(8): 543–548.
7. Blacker F, Brown C. Evaluation and the impact of information technologies on people in organizations. Human Relations 1985; 38(3): 213–231.
8. Rabey G. Motivation is response. Industrial and Commercial Training 2001; 33(1): 26–39.
9. Royal College of Radiologists. Equipment, workload and staffing for radiotherapy in the UK 1992–1997. London. Royal College of Radiologists, 1998.
10. Department of Health. The NHS Cancer Plan. Leeds. NHS Executive, 2000.
11. Hutton J, Maynard A. A Nice Challenge for Health Economics. Health Econ 2000; 9: 89–93.
12. IMRT Collaborative Working Group. Intensity Modulated Radiotherapy: Current Status and Issues of Interest. Int J Radiat Oncol Biol Phys 2001; 51(4): 880–914.
13. Suter B, Shoulders B, Maclean M, Balyckyi J. Machine verification radiographs: an opportunity for role extension. Radiography 2000; 6: 245–251.
14. Fielding AL, Evans PM, Clark CH. The use of electronic portal imaging to verify patient position during intensity modulated radiotherapy delivered by the dynamic MLC technique. Int J Radiat Oncol Biol Phys 2002. Accepted for publication.
15. LoSasso T, Chui C, Ling C. Comprehensive quality assurance for the delivery of intensity modulated radiotherapy with a multileaf collimator used in the dynamic mode. Med Phys 2001; 28(11): 2209–2219.

https://doi.org/10.1017/S1460396903000037 Published online by Cambridge University Press