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A Survey on the Quality Assurance Procedures Used in Intensity Modulated Radiation Therapy (IMRT) at Indian Hospitals

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Abstract

A national survey to obtain information about the Quality Assurance (QA) procedures and methods being followed at Indian radiotherapy centers for intensity modulated radiation therapy (IMRT) was conducted. A questionnaire containing parameters relevant to IMRT QA was evolved to collect the information pertaining to the QA of IMRT delivery system, QA of IMRT treatment planning system, and patient specific IMRT QA. The questionnaire was circulated to 40 hospitals in the country and responses of 31 centers were received. Survey results showed that 71% centers are having adequate machine specific IMRT QA programme, 19% centers have inadequate machine specific IMRT QA programme and 9% centers have irrelevant machine specific IMRT QA programme. No specific answer for question of QA tests of TPS specific to IMRT were received from the user. Almost all the centers have programme of setup verification of the patient by means of EPID/DRR/OBI. However, 91% of centers could not provide any information about the QA methodology of the devices used for setup verification. For patient specific dosimetric QA, almost all the hospitals have the program of pre-treatment dose verification using calibrated ionization chambers of sensitive volumes in the range of 0.01 to 0.65 cc. Dosimetric verification is performed by combining dose from all gantry angles to a single gantry angle. Two dimensional (2D) dosimetry systems such as radiographic and radiochromic films, 2D array of ionization chambers/ semiconductor diodes and EPID are also used in patient specific dosimetry verifications. Majority of the centers (about 48%) accept the plan with 3% dose difference and 3 mm dose to distance agreement criteria with gamma index less than unity. However, a number of other acceptance criteria specific to institution and tumor site are being also followed. This survey reveals that a variety of IMRT QA program is being followed at the Indian hospitals. This study has brought into focus the need to evolve a national protocol for IMRT QA so that treatment outcomes of all the IMRT centers of country can be compared.

Keywords: IMRT QA; Survey; Patient dosimetry; Dose verification; QA protocol

Introduction

Intensity modulated radiation therapy (IMRT) is a complex radiotherapy techniques which allows to deliver radiation dose conforming to complex shaped target volumes and at the same time efficiently spare the surrounding normal/healthy structure. Thus it is the treatment of choice for curative radiotherapy. There are about 280 radiotherapy centre in India out of which about 60 are practicing IMRT. The implementation of IMRT in Indian Hospital is increasing at the rapid rate and in the future more number of centers will be practicing this technique. The IMRT involves a high risk of mistreatment due to its nature of sharp dose gradient at the boundary, complicated treatment planning and delivery procedure. Any small geometrical miss in patient setup as well as in mechanical accuracy of beam delivery can lead to a large deviation of delivered dose from the planed one. Since high geometric and dosimetric accuracy is required for this advanced technique, verification of the delivery of IMRT (Intensity Modulated Radiation Therapy Collaborative Working Group, 2001) dose distributions is a prerequisite for its safe and efficient application (Saarilahtia et al., 2005).

The successful use of IMRT technique is lying with implementation of comprehensive QA programme before and during the IMRT in routine clinical practice. Since starting of the IMRT for clinical practice a number of reports and chapters in a book have been published (Intensity Modulated Radiation Therapy Collaborative Working Group, 2001; Ezzell et al., 2003; Galvin et al., 2004; Bortfeld, et al., 2006; Palta and Mackie, 2003). All these reports emphasize the importance of performing a comprehensive acceptance testing, commissioning and QA programme of IMRT equipment. The need for these types of verification programmes has been demonstrated, during an independent dose evaluation performed by the Radiological Physics Centre (RPC) of institutions wishing to participate in a Radiation Therapy Oncology Group (RTOG) IMRT protocol (Molineu et al., 2005; Ibbott, 2006). Roughly one third of surveyed hospitals fail to meet the acceptance criteria set by RPC. These results clearly demonstrate that institutions vary significantly in their ability to deliver dose distributions that agree with their own treatment plans, and that quality assurance tests play a critical role in IMRT planning and delivery. There is, however, not yet consensus to what extent tests, dealing with issues specific for IMRT, should be performed (Ezzell et al., 2003; Palta and Mackie, 2003; Ahnesjo, et al., 2006; ICRU Report, 2010). IMRT requires verification of a number of parameters related to planning as well as delivery system which is still an ad hoc process at majority of the centers. This is because new systems are continuously becoming available, while also there exist no clear guidelines and criteria for the accuracy required. Furthermore, the variation in complexity and clinical practice of IMRT

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in different centers make it unlikely that a single QA programme would fit the needs for all radiotherapy departments. Many centers have developed their own QA procedures for IMRT, and only recently some more specific suggestions for tolerance limits and action levels for planning and delivery of IMRT have been provided (Palta and Mackie 2003; Stock, et al., 2005; McDermott, et al., 2007; Sanchez-Doblado, et al., 2007).

In another survey (Mijnheer, et al., 2004; Gillis, et al., 2005) it has been demonstrated that each institution applies its own quality assurance (QA) methods. Thus complicating inter-comparisons between institutions. Each users of IMRT has liberty of using any recommendation/methodology to fulfill QA requirements of IMRT. In India, physicists involve in the practice of IMRT and other complex techniques are not having any common protocol or procedure to carry out QA program. Quicker and precise QA methods are preferred in radiotherapy departments considering large patient loads. However there is a need to evolve a national protocol in IMRT so that treatment outcomes of all the IMRT centre of country can be compared. Before evolving such a protocol it is equally important to know the existing procedure of QA in IMRT used at these centers. Keeping this in mind, a national survey on QA procedure/ methods was conducted. This paper describe the results of IMRT QA survey which aim to understand the current QA methodologies, refining them to be as intuitive, efficient, and meaningful as possible; Evolved a unified IMRT QA protocol, based on socio-economic status, experience and relevant clinical end points for Indian scenario.

Materials and Methods

A questionnaire containing parameters relevant to IMRT QA was evolved to collect the information about the exact practice of IMRT QA being followed at the hospitals. As the aim of this survey was to understand and extract the information about the QA methods being used by the hospitals, emphasis was given on descriptive answer over multiple choice type answers. Table 1 show the IMRT QA questionnaire which was evolved for conducting the survey. The questionnaire contains three major part of IMRT QA namely, (i) QA for IMRT delivery system, (ii) QA for IMRT treatment planning system (IMRT-TPS), and (iii) patient specific IMRT QA. Under QA for delivery system, information about detailed machine specific QA which includes details of the machine parameters that are evaluated in the IMRT equipped medical linac and methods and tools for testing these parameters have been included. In the QA for IMRT-TPS, description about the procedure adopted for QA of dosimetric and non-dosimetric parameters used for IMRT planning and their test methods were enquired. Though the section on patient specific QA was further divided: (a) QA for setup verification, and (b) QA specific to the dosimetric methods. But, importance was given to extracting information related to methodologies followed for the dosimetric verification.

Name and address of the hospital: Name of the Medical Physicist:	Phone: Phone:	Fax: Email:
1.	Make and model of Medical linear accelerator	
2.	Photon energy used for IMRT	6MV/15MV/18MV
3.	Make and model of MLC used for IMRT	
4.	Procedure adopted for QA of delivery system (machine specific QA). Describe the parameter, test methods and tools used.) (please write in details , add separate page if needed)	
5.	Make and model of the treatment planning system	
6.	Procedure adopted for QA of treatment planning system used for IMRT/IGRT (TPS specific QA). Describe the parameter such dosimetric and non dosimetric parameters, test methods and tools used.(please write in details, add separate page if needed)	
7.	Make and model of the imaging systems used for IMRT (e.g. CT-Sim, Sim-CT, PET-CT etc)	
8.	Procedure adopted for Patient specific QA about: QA for setup verification 1. QA for set-up verification 2. Dosimetric QA Describe the parameter, test methods and tools used.(please write in details , add separate page if needed)	
9.	Is there any QA related to IMRT/IGRT carried out daily? if yes please describe it.	
10.	Available QA tools, Make and models of dosimetry systems used in QA. (Such as map checks, Imatrix, diode, MOSFET etc)	
11.	Frequency of QA	
	1.TPS specific QA:	Daily/ weekly/ monthly/ others
	2.Machine specific QA:	Daily/ weekly/Monthly/Others
	3.Patient specific QA:	Daily/ weekly/Monthly/Others
12.	Sites and number of IMRT cases treated at your centre.	
13.	Margins for PTV in various cases such as for H&N, Prostate, etc	
14.	Criteria for accepting IMRT plan (e.g. spatial agreement, dose agreement etc)	
15.	Have you ever detected deviation larger than acceptable limit during the QA measurement? (if yes provide details)	
16.	Are you satisfied with IMRT QA procedure?	
17.	Major hurdle in performing IMRT QA	
18.	Any suggestion for improving the IMRT QA procedure in Indian condition	
19.	Any other suggestion/information	

Table 1: Format of IMRT QA survey questionnaire which was circulated to radiotherapy centres in India.

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Information about the make and model of MLC which is used for delivering the IMRT was asked to understand suitable QA methodology related to MLC. Considering the importance of imaging in IMRT, imaging modalities used for IMRT planning in the hospitals were also explored. Question related to acceptance criteria of an IMRT plan for treatment after the pre-treatment dose verification was also included. Information regarding site as well as centre specific IMRT planning such as margin for PTV and acceptance criteria was enquired. It was also enquired whether user has detected any deviation larger than acceptable tolerance during their QA so far. The survey was sent to 40 IMRT practicing hospitals.

Analysis of the machine specific QA were done by scrutiny of the data received from different hospitals. This scrutiny was done by dividing the hospitals in three categories: (a) Centers with Adequate Machine specific IMRT QA program - those hospitals which have programme of machine specific QA relevant to IMRT following standard recommendations/ protocols (b) Centers with Inadequate Machine specific IMRT QA program- If the information provided by the hospitals were not sufficient, and (c) Centers with Irrelevant Machine specific IMRT QA program.

Results and Discussion

Out of 40 radiotherapy centers in India practicing IMRT, 31 centers responded to this survey. Figure 1 shows the pie chart of the information provided by the hospitals related to machine specific QA for IMRT. It can be observed from this chart that 71% centers are having adequate machine specific IMRT QA programme, 19% centers have inadequate machine specific IMRT QA programme and 9% centers have irrelevant machine specific IMRT QA programme. The 9% centers have described QA program relevant to a conventional medical electron linear accelerator with some arbitrary test methods. Regarding the question of QA tests of TPS specific to IMRT, a variety of answer were received from the hospitals. Almost all the hospitals have a different answer for this question. Some of the users have described a few QA tests for TPS listed in IAEA TRS 430 (IAEA Technical Series Report 430, 2004) and some of them refer AAMP Report 62 (Benedick, et al., 1998). As is known to all, neither TRS 430 nor AAPM Report 62 describes comprehensive test procedures for TPS relevant to IMRT and hence it can be concluded from the response of the hospitals that none of them are having adequate QA test program

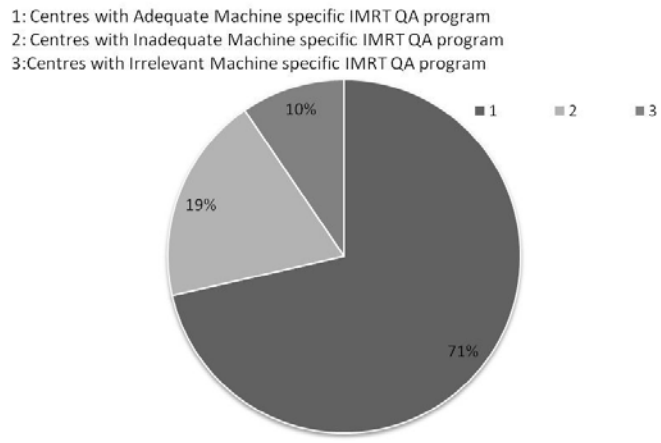

Figure 1: Pie chart of the machine specific QA for IMRT (% of Participated Hospitals). 1: Centres with Adequate Machine specific IMRT QA program 2: Centres with Inadequate Machine specific IMRT QA program 3: Centres with Irrelevant Machine specific IMRT QA program.

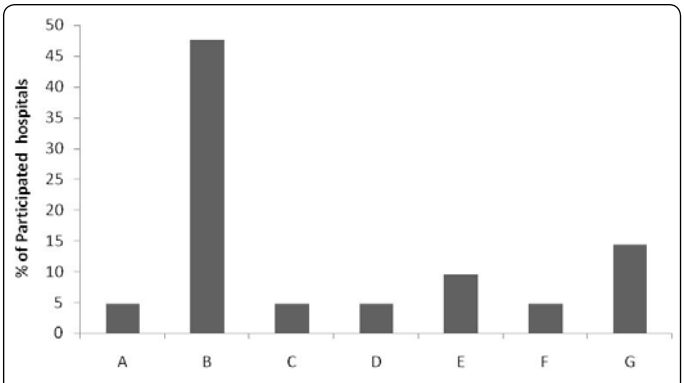

Figure 2: Bar diagram of the acceptance criteria of IMRT plans followed by the hospitals for pre-treatment dose verification; A: 5% dose difference and 3 mm DTA; B: 3% dose difference and 3mm DTA ; C: 3% dose difference and 3mm DTA (Large field); 2% dose difference and 2mm DTA (Small field); D: 4% dose difference and 3mm DTA (Low dose low gradient) , 3% dose difference and 3mm (High dose low gradient) 5-7% dose difference and 4mm DTA (Low dose high gradient) 3- 5% dose difference and 4mm DTA (High dose high gradient); E: 2% dose difference and 2 mm DTA ; F: 3% dose difference and 3 mm DTA/ 5% dose difference and 5 mm DTA (in some specific cases); G: inadequate information.

for TPS specific to IMRT. This kind of response from the users may be probably due to not enough availability of a comprehensive QA protocol for treatment planning system specific to IMRT. Therefore the hospital practising IMRT are in need of a suitable QA protocol for treatment planning system specific to IMRT.

Almost all the centers have reported that they have specific programme of setup verification of the patient by means of EPID/DRR/ OBI. However, 91% of centers could not provide any information about the QA methodology of the devices used for setup verification. This observation indicates that 91% of the centers may not have understood the question properly because the periodic performance evaluations of these devices are also recommended by the manufacturer. For patient specific dosimetric QA, almost all the hospitals have the program of pre-treatment dose verification using calibrated ionization chambers of sensitive volumes in the range of 0.01 cc to 0.65 cc. In this case the measurement of absorbed dose is carried out at a point which is selected in a region of low dose gradient. Two dimensional (2D) dosimetry systems such as radiographic and radiochromic films, 2D array of ionization chambers/ semiconductor diodes and EPID are also used in patient specific dosimetry verifications. However, it is not clear from the survey data that whether both of these methods are used simultaneously for a patient or either of the devices is used. As per the information submitted by user, dosimetric verification is performed by combining dose from all angles to a single gantry angle. However, it is not well known whether this type of verification is reflecting the dose delivered to the patient by all gantry angles. Hence, a thorough study needs to be carried out to demonstrate the similarities/ differences in the dose if the verification is carried out at a single gantry angle composite plan in place of multiple angle treatment plans.

Figure 2 Shows the bar diagram of the acceptance criteria of IMRT plans followed by the hospitals for pre-treatment dose verification. It can be observed here that institution specific treatment plan acceptance criteria after pre-treatment dose verification are followed at the hospitals practicing IMRT. Majority of the centers (about 48%) accept the plan with 3% dose difference and 3 mm dose to distance agreement (DTA) criteria with gamma index less than unity. About 10% centers accept the IMRT treatment plan with 2% dose difference

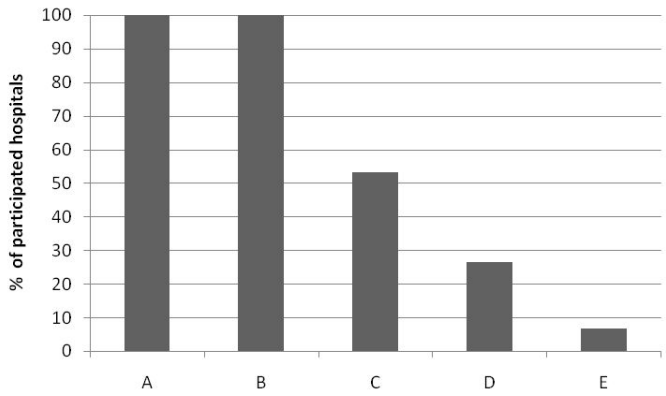

Figure 3: Bar diagram of IMRT treatment sites practiced at Indian hospitals (% centre of hospitals responded to the survey); A: Head and Neck, B: Pelvic Region (Abdomen, Cervix, Prostate), C: Thorax, D: Breast and, E: Lung.

and 2 mm DTA. The varying acceptance criteria, namely (i) 5% dose difference and 3 mm DTA, (ii) 3% dose difference and 3 mm DTA (large field)/ 2% dose difference and 2 mm DTA (small field), (iii) 4% dose difference and 3 mm DTA (low dose low gradient)/ 3% dose difference and 3 mm DTA (high dose low gradient)/ 5-7% dose difference and 4 mm DTA (low dose high gradient)/ 3- 5% dose difference and 4 mm DTA (high dose high gradient), (iv) 3% dose difference and 3 mm DTA/ 5% dose difference and 5 mm DTA (in some specific cases) are followed at 20% (each of the criteria followed at 5% of the centers) of the centers while 14% of the centers provided inadequate data to understand their acceptance criteria for pre-treatment verification.

Figure 3 presents the bar diagram of different types of cases treated by IMRT techniques at Indian hospitals. This diagram reveals head and neck and pelvic region (abdomen, cervix, prostate) cases are treated at all the centers participated in the survey. Tumors of thorax region are treated by IMRT at about 53% of the centers. About 27% centers use IMRT for the breast while 7% centers use IMRT for lung cases. It can be observed from this survey that head and neck and pelvic region cases are most preferred site for IMRT in India. However, breast as well as lung cases, which are considered most complex site for the IMRT, are also treated at Indian hospitals. Considering the wide variety of cancer cases treated by IMRT in India, it is highly recommended that IMRT centers of the country should have a proper IMRT QA programme in place and external QA audit should also be initiated to ensure safety and efficacy of this treatment technique. Evolving a unified but simple to execute QA programme to deal with all types of treatment sites will be a very important development in this direction.

In response to the question about margins for Planning Target Volume (PTV) in various cancer cases, majority of centers responded quoting margins in head and neck and Pelvic region cases only. A few centers also provided the information for PTV margins in some other cancer cases also. Most of the centers use 0.5 cm PTV margin in head and neck cases and 0.5 - 1.0 cm PTV margin in the pelvic region during IMRT planning. Very few centers reported PTV margin of 0.6 cm in head and neck and up to 1.5 cm in pelvic region of IMRT planning.

About 67% user reported that they have not detected any deviation more than acceptable limit during their dosimetric QA so far. However, about 33% users reported that they have observed deviations more than acceptable limits. These centers have indicated that erroneous measurement techniques are the reasons of this deviation from the acceptable limits. One of the hospital also informed that the deviation was due to some problem with the TPS which was later rectified.

Users have reported that they perform IMRT machine specific QA periodically (monthly and quarterly) as well as after major repair on treatment delivery devices and after upgradation of software on TPS. The patient specific IMRT QA is carried out before starting the treatment of a patient.

Against our query on hurdles in implementing the adequate IMRT QA programme, majority of the users have quoted their busy clinical schedule and limited availability of the equipment for QA as major hurdles in these aspects. Accordingly, they need a QA programme and test procedures which should be simple and quick to perform. Users have also suggested for a unified QA protocol in the country so that treatment outcome of different centers can be compared. Maximum preference of patient specific dosimetric QA and least preference of the TPS QA are the important observations of this survey.

In this survey a number of centers have reported QA program for delivery system and planning system similar to a conventional treatment modality which uses conventional static fields for dose delivery. Quality assurance procedures for a linear accelerator and multileaf collimator designed for conventional static fields will not be sufficient to address issues pertinent to the accuracy and precision of dose delivery by IMRT. IMRT fields are composed of many irregular, small, off-centre, and abutting field segments throughout the target volume, each delivering only a few MU. Therefore, emphasis should be placed on beam stability for small MU, leaf position accuracy with gantry rotation, Leaf speed, leaf transmission etc. IMRT delivery system is complex enough, there is requirement that tolerance limit of QA test parameter need to be stringent than a conventional medical linear accelerator. IMRT and other advance techniques need stricter performance tolerance of linear accelerator for precise dose delivery. The types of treatments delivered with the machine should have a role in determining the QA program that is appropriate for that treatment machine (Klein, et al., 2009). It is worth mentioning here that separate tolerance limit has been assigned for different QA parameters for a treatment machine capable of delivering IMRT or other advance treatment modalities in AAPM Task Group 142 report along with conventional treatment machines. On the basis of this survey we are working to evolve a exclusive common QA programme for planning system and delivery system involved in the IMRT along with patient specific IMRT QA. This common QA programme can be adopted by all the IMRT practicing centers in the country.

Conclusions

A national survey on IMRT QA by means of a properly designed questionnaire was carried out at 40 radiotherapy centers in India. The survey reveals that majority of Indian hospitals have adequate machine specific IMRT QA programme but highly inadequate QA programme for the treatment planning systems. Pre-treatment dose verification is carried out at almost all the centers but measurement techniques and plan acceptance criteria are institution specific. Thus, a variety of IMRT QA program in totality is being followed at the Indian hospitals. There is a need to evolve a national protocol for IMRT QA so that treatment outcomes of all the IMRT centers of country can be compared.

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