

The IROC Houston Quality Assurance Program: Potential benefits of 3D dosimetry

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Abstract. The IROC Houston QA Center has provided QA core support for NCI clinical trials by ensuring that radiation doses delivered to trial patients are accurate and comparable between participating institutions. Within its QA program, IROC Houston uses anthropomorphic QA phantoms to credential sites. It is these phantoms that have the highest potential to benefit from the use of 3D dosimeters. Credentialing is performed to verify that institutions that are using advanced technologies to deliver complex treatment plans that conform to targets. This makes it increasingly difficult to assure the intended calculated dose is being delivered correctly using current techniques that are 2D-based. A 3D dosimeter such as PRESAGE® is able to provide a complete 3D measured dosimetry dataset with one treatment plan delivery. In our preliminary studies, the 3D dosimeters in our H&N and spine phantoms were found to be appropriate for remote dosimetry for relative dose measurements. To implement 3D dosimetry in IROC Houston's phantoms, the benefit of this significant change to its current infrastructure would have to be assessed and further work would be needed before bringing 3D dosimeters into the phantom dosimetry program.

1. Introduction

Even with current technologies and safety culture radiation delivery incidents continue to occur and to be reported on. During the past decade, a number of significant radiation therapy errors have been reported [1-3]. There have been several publications indicating that the introduction of advanced technology equipment has permitted errors to occur that might otherwise have been detected [4]. There are also indications that the demands of advanced technologies on department resources have drawn resources from simpler or basic functions [5]. If the basic dosimetry is not correct then it does not matter whether a clinic uses advanced technology or not, the dose delivery will still be inaccurate [6].

Clearly, larger errors have a significant impact on the success of radiation therapy clinical trials. But smaller errors, while having no discernable effect on the treatment of an individual patient, may influence the overall success of treatments of large numbers of patients [7-9] as found in phase III clinical trials. For multi-institutional clinical trials, the radiation treatments need to be comparable among all participating institutions in order to compare treatment arms with minimal uncertainty involved that might blur otherwise distinct differences. Data from Peters *et al* [10] demonstrated the benefit of good radiotherapy data indicating that even if the trial is not a radiation question, the radiotherapy component is still vital to the trial outcome. Thus the need for QA programs to monitor



institutions participating in clinical trials where small deviations in the delivered dose to many patients from individual institutions may impact on the outcome of the trial is needed.

2. The Role of the IROC Houston QA Center (IROC Houston)

The IROC Houston QA Center was established in 1968 as the Radiological Physics Center (RPC) to contribute to the development, conduct, and QA of multi-institutional cooperative group clinical trials as an independent QA center. IROC-Houston currently monitors 1816 institutions (3700 megavoltage therapy machines) that participate in the National Cancer Institute's (NCI's) National Clinical Trial Network (NCTN) multi-institutional clinical trials. IROC Houston promotes six core support components to an effective clinical trial QA program: 1) institution qualification/ QA, 2) review of clinical trial protocols, 3) credentialing of institutions for specific protocols, 4) transfer of radiotherapy data, 5) clinical/technical review of the patient radiotherapy data, and 6) management of radiotherapy data for analysis. These methods within the six components help to ensure that radiotherapy data used for trial outcomes analysis has minimal uncertainty.

IROC Houston primarily focuses on institution qualification, clinical/technical review of patient radiotherapy data and credentialing of institutions. IROC Houston's QA program focuses on ensuring that radiation doses delivered are accurate and comparable between institutions participating in NCTN trials by auditing components of dose delivery from reference calibration to tumor dose calculation.

2.1. Institution qualification and ongoing QA

The qualifications of an institution to participate in clinical trials are initially discerned by the completion of a facility questionnaire (FQ) to understand the institution's current state of practice. As accelerator technology has become more complex and radiation delivery modalities change, demonstration of the expertise of use, appropriate QA program, equipment/resources necessary to deliver the radiotherapy treatment accurately is required. Institution qualification also includes remote verification of machine calibration with TLD/OSLD dosimeters. IROC Houston monitors approximately 14,000 megavoltage photon, electron and proton beams annually.

2.2 Clinical and technical review of the trial patient radiotherapy data

IROC Houston reviews the treatment plans (external beam and brachytherapy) prepared by participating institutions for patients registered on trials. These patient reviews may be 1) pre-treatment reviews, 2) on-treatment reviews and, 3) post-treatment reviews. Up to a nearly 1000 patient reviews are performed annually by IROC Houston. It is during the post-treatment reviews where the patient case is scored using clinical and dosimetric criteria, as per protocol or as a deviation.

2.3 Credentialing of institutions for specific protocols and treatment modalities

Clinical trials that require the use of advanced technologies such as IMRT, SBRT, IGRT, and proton therapy are considered challenging to implement in a comparable manner for clinical trials, so institutions are required to demonstrate their ability, through a credentialing process, before being permitted to register patients. The mission of IROC Houston is not to restrict participation but to assist institutions in any required remedial actions so that they meet the credentialing criteria and can accrue radiotherapy patients in a comparable manner to other participating institutions. Credentialing requirements include many components, but IROC Houston's primary mechanism is the irradiation of an anthropomorphic end-to-end QA phantom. It is with these QA phantoms that the potential benefits of 3D dosimetry can be realized.

2.3.1. IROC Houston's anthropomorphic end-to-end QA Phantoms

IROC Houston has developed multiple anthropomorphic end-to-end QA phantoms, beginning with the SRS and IMRT heads, to currently having seven different phantom types for photon and proton therapy. The phantoms, while not anatomically exact, are close approximations to the true anatomy of the various disease sites to be used in protocols. The phantoms currently use TLD and 2D planar

radiochromic film to evaluate the dose delivered. These particular dosimeters are limited in their ability to fully evaluate the complex 3D dose distributions delivered using IMRT, IMPT and IGRT. However, in their present form, the phantoms provide a consistent test and criteria to evaluate each institution's ability to deliver a specific radiotherapy treatment ensuring comparability between participating institutions [11-12]. Current phantoms have been used to assess SRS, IMRT, SBRT, VMAT, moving targets, and proton therapy. Since 2000, a total of 5,671 phantoms have been irradiated by participating institutions in North America and elsewhere.

3. 3D dosimetry - Potential Benefits

Today's complex treatment plans are volumetric in design that may contain varying dose gradients depending on the prescription and normal tissue constraints. Independent peer review/verification of these complex treatments is becoming increasingly important in the clinic since these treatments comprise multiple steps, each of which could represent a failure mode resulting in a dose delivery error. Since these complex shaped dose distributions normally are designed to conform to irregularly shaped targets, traditional dosimetry methods, i.e. TLD and planar film measurements may not be sufficiently comprehensive to verify correct delivery [13]. It has been shown that IMRT QA of single IMRT fields may miss catching errors that appear when all fields are combined for the total tumor dose delivery [14]. Studies have shown this method of single planar dosimetry can produce gamma analysis results that are insensitive to the changes in measured and calculated IMRT dose distributions [15]. Volumetric dosimeters have that potential to measure a complete 3D measured dosimetry dataset against which to compare the calculated planned 3D dose distribution.

The IROC-Houston's phantoms are designed to yield only two or three planes of dose information, to compare to the treatment plan calculated data. The failure rate for IROC Houston's IMRT H&N phantom still remains at 10-15% even after 15 years of use [16]. A measured 3D dataset might even capture more errors and possibly provide clues as to the source of the error.

3.1 Preliminary studies

IROC Houston's H&N IMRT and spine phantoms were modified to accept 3D dosimeters to compare against currently used planar film measurements. Studies by Grant *et al* [17] and Lafratta *et al* [18] have shown that PRESSAGE® 3D dosimeters yield equivalent dose profile (figure 1) and gamma analysis (table 1) results as the radiochromic film in the spine and H&N phantoms, respectively.

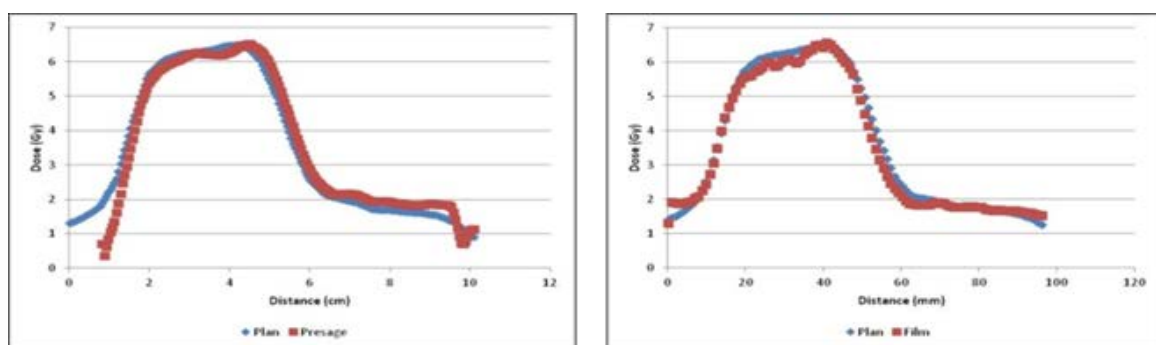


Figure 1. Comparison of dose profiles from PRESAGE® 3D dosimeter and radiochromic film to treatment plan calculated profile.

Table 1. Percentage of passing pixels between PRESAGE® and film in the IMRT H&N phantom

	Constraints	Film	PRESAGE®
Axial Plane	3%/3mm	85%	66%
	5%/3mm	93%	86%
	7%/4mm	99%	93%
Sagittal Plane	3%/3mm	85%	61%
	5%/3mm	90%	82%
	7%/4mm	90%	91%

4. Summary

There exists a definite potential for 3D dosimeters in the IROC Houston QA Center anthropomorphic phantom credentialing program. Results indicate near equivalency in measured data with the 3D dosimeters providing a more comprehensive volumetric assessment. To implement 3D dosimeters in the credentialing phantoms would require a significant change in the current IROC Houston infrastructure. This change needs to be fully evaluated.

5. Acknowledgement

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6. References

- [1] International Atomic Energy Agency. *Safety Reports Series No. 17. Lessons Learned from Accidental Exposures in Radiotherapy* 2000 Vienna: IAEA
- [2] Rogers L “Over 200 hurt or killed by botched radiation” *The Times (London) Online*: <http://www.timesonline.co.uk/tol/news/uk/article711360.ece?token=null&offset=12&page=1>
- [3] WAToday, “Cancer patients 'given excess radiation” <http://www.watoday.com.au/breaking-news-national/cancer-patients-given-excess-radiation-20090131-7u9o.html>
- [4] Patton G A *et al* 2003 *Int. J. Radiat. Oncol. Biol. Phys.* **56** 50-57
- [5] Marks L B *et al* 2007 *Int. J. Radiat. Oncol. Biol. Phys.* **69** 1579-1586
- [6] Hill R *et al* 2014 *Phys. Med. Biol.* **59** R183-231
- [7] Bentzen *et al* 2000 *Eur. J. Cancer* **36** 615-620
- [8] Boyer A and Schultheiss T 1988 *Radiother. Oncol.* **11** 65-71
- [9] Pettersen *et al* 2008 *Radiother. Oncol.* **86** 195-199
- [10] Peters L J *et al* 2010 *J. Clin. Oncol.* **28** 2996-3001
- [11] Ibbott G S *et al* 2006 *Technol. Cancer Res. Treat.* **5** 481-7
- [12] Kry S *et al* 2012 *Int. J. Radiat. Oncol. Biol. Phys.* **84** S128-9
- [13] Schreiner L J 2009 *J. Phys: Conf Ser.* **164** 012001
- [14] McKenzie E M *et al* 2014 *Med. Phys.* **41** 121702
- [15] Kruse J J 2010 *Med. Phys.* **37** 2516-24
- [16] Molineu A *et al* 2013 *Med. Phys.* **40** 022101
- [17] Grant R *et al* 2012 *Med. Phys.* **39** 3724
- [18] Lafratta R *et al* 2014 *Med. Phys.* **41** 350