International Journal of
Radiation Oncology
biology • physics

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Physics Contribution

Radiation Therapy Deficiencies Identified During On-Site Dosimetry Visits by the Imaging and Radiation Oncology Core Houston Quality Assurance Center

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Received Mar 3, 2017, and in revised form Jul 20, 2017. Accepted for publication Aug 11, 2017.

Summary

On-site visits of radiation therapy facilities by IROC Houston include an evaluation of beam calibration, relative dosimetry, mechanical checks, and other programmatic issues. The deficiencies identified over the past 15 years are compiled in this study, highlighting areas where problems are most often found (eg, small field output factors, wedge factors, calibration). These areas should receive particular attention during beam modeling and machine QA by medical

Purpose: To review the dosimetric, mechanical, and programmatic deficiencies most frequently observed during on-site visits of radiation therapy facilities by the Imaging and Radiation Oncology Core Quality Assurance Center in Houston (IROC Houston).

Methods and Materials: The findings of IROC Houston between 2000 and 2014, including 409 institutions and 1020 linear accelerators (linacs), were compiled. On-site evaluations by IROC Houston include verification of absolute calibration (tolerance of ±3%), relative dosimetric review (tolerances of ±2% between treatment planning system [TPS] calculation and measurement), mechanical evaluation (including multileaf collimator and kilovoltage-megavoltage isocenter evaluation against Task Group [TG]-142 tolerances), and general programmatic review (including institutional quality assurance program vs TG-40 and TG-142).

Results: An average of 3.1 deficiencies was identified at each institution visited, a number that has decreased slightly with time. The most common errors are tabulated and include TG-40/TG-142 compliance (82% of institutions were deficient), small field size output factors (59% of institutions had errors ≥3%), and wedge factors (33% of institutions had errors ≥3%). Dosimetric errors of ≥10%, including in beam calibration, were seen at many institutions.

Conclusions: There is substantial room for improvement of both dosimetric and programmatic issues in radiation therapy, which should be a high priority for the medical

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This work was supported by Public Health Service grants CA214526, CA10953 and CA180803 (National Cancer Institute) and Cancer Center Support grant P30CA016672.

Conflict of interest: none.

Int J Radiation Oncol Biol Phys, Vol. 99, No. 5, pp. 1094−1100, 2017

http://dx.doi.org/10.1016/j.ijrobp.2017.08.013

physicists to ensure optimal accuracy is achieved.

physics community. Particularly relevant was suboptimal beam modeling in the TPS and a corresponding failure to detect these errors by not including TPS data in the linac quality assurance process.

Introduction

The mission of the Imaging and Radiation Oncology Core Quality Assurance Center in Houston (IROC Houston), formerly the Radiological Physics Center, is to ensure that institutions deliver high-quality (ie, accurate and consistent) radiation therapy in support of clinical trials. High-quality radiation therapy is critical for clinical trials because it maximizes efficiency by increasing the study's power (1). It is also important in terms of patient outcomes: the Trans Tasman Radiation Oncology Group trial 02.02, for example, was a study of oropharyngeal cancer with or without an antihypoxic agent in which all patients received standard of care radiation therapy. Ultimately the quality of radiation therapy had a greater effect on overall survival than even the hypothesized effect of the pharmaceutical agent at the heart of the study (2). Quality radiation therapy is critically important to patient outcomes and to the advancement of radiation therapy practice.

On-site visits are IROC Houston's most comprehensive tool for evaluating dose delivery. In this program an IROC Houston physicist travels to an institution and performs several days of intensive dosimetric measurements, as well as programmatic review. In particular, such an audit reviews beam calibration, measured relative dosimetry versus that calculated by the treatment planning system (TPS), machine mechanical performance, and programmatic issues such as compliance with the Task Group 142 report (TG-142) (3). Although the exact suite of tests conducted has evolved over the years, these tests are all conducted in a highly consistent manner by IROC Houston physicists with independent dosimetry equipment.

We previously published results from on-site visits focusing specifically on small field dosimetry that indicated frequent errors (4), and more recently relative dosimetric errors associated with Varian accelerators (5). In this work we more broadly review the most common dosimetric and programmatic problems found during the past 15 years of IROC Houston's site visit program. As outlined in the American Association of Physicists in Medicine task group 100 report (6), this information should guide physicists, clinicians, and administration in terms of what aspects of a radiation therapy program are most often deficient (ie, the occurrence of specific failure modes) and therefore likely warrant additional care.

Methods and Materials

Importantly, although some IROC Houston site visits were prompted by suspected dosimetric issues, this was rare because most dosimetric issues can be (and were) resolved remotely using other, less intensive, methods. Rather, site visits were overwhelmingly prompted by routine monitoring of those institutions accruing the most patients to clinical trials: institutions where no dosimetric or programmatic issues were suspected. Reports for site visits occurring from 2000 through 2014 (before which machines begin to resemble current systems less and less, and after which site visits were no longer routinely offered because of budgetary constraints) were abstracted, including 409 institutions with 1020 linear accelerators (linacs). Dosimetric or programmatic deficiencies identified at each visited institution were compiled. Each deficiency that was identified and counted described the type of error, rather than individual instances of the error. For example, if a linac had multiple PDD errors at different depths and for different photon energies, this was only counted as a single "photon PDD" deficiency for that linac. If a linac had calibration errors in multiple electron beams, this was only counted as a single "electron calibration" deficiency for that linac.

The test suite included in an IROC Houston on-site audit has evolved over time (eg, to include multileaf collimator [MLC] [n=45 institutions, 71 linacs] and image guided radiation therapy evaluations [n=32 institutions, 50 linacs], and replacing TG-40 [7] tests and criteria with TG-142 [3] requirements), and some tests are only conducted at a subset of institutions: brachytherapy evaluations were done only at those institutions that had a high-dose-rate or long-half-life low-dose-rate program (n=249). However, all measurements and evaluations conducted during a site visit were made in a consistent manner, with measurements using independent equipment brought by IROC Houston physicists. An institutional deficiency was defined when a dosimetric parameter or programmatic process did not meet established standards. These standards were typically based on published guidelines (eg, TG-142 recommendations for quality assurance [QA] [3], or relative dosimetric accuracy of ±2% based on TG-65 [8]) or achievable levels of accuracy based on decades of auditing experience. All results are presented as the number and percentage of the institutions and machines receiving a recommendation for each test conducted.

During an on-site audit, dosimetric evaluation of all beams of all machines was conducted. The test suite comprises the following:

1. An intercomparison of IROC Houston's and the institution's primary dosimetry system (including thermometer and barometer).
2. Absolute calibration (ie, TG-51 [9]), with a tolerance of ±3% (±5% for brachytherapy source strength).
3. Relative dosimetric measurements (comparing TPS calculations vs IROC Houston measurements), with a