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New IAEA end-to-end on-site IMRT audit methodology: Pilot test results

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Introduction
Keeping pace with rapid development of radiotherapy technology during recent years, many cancer centres have transitioned, or are about to do so, from 3-dimensional conformal radiation therapy (3D CRT) to intensity modulated radiation therapy (IMRT) including volumetric modulated arc therapy (VMAT). In view of the complexity of advanced radiotherapy techniques, the IAEA has developed an audit methodology to review the physics aspects of IMRT dose delivery. Pilot test results of the proposed methodology are presented in this report.

Methodology
Procedures were developed for end-to-end, on-site auditing of head and neck (H&N) IMRT treatments using a specially designed anatomical phantom named "Shoulder, Head and Neck, End-to-end"(SHANE) (CIRS, Norfolk, VA). During the audit, the phantom undergoes processes similar to a radiotherapy patient treatment, i.e., it is imaged on a computed tomography (CT) scanner, the irradiation is planned using a treatment planning system (TPS) and the plan is delivered using a linear accelerator. Normally the audit is expected to take two days.

The ultimate goal of the audit is to verify the quality of IMRT treatment from a physics perspective by comparing the calculated and measured doses. The SHANE phantom can accommodate: (1) an ionisation chamber in four different locations to measure the dose at selected points associated with planning target volumes (PTVs) and an organ at risk (OAR), and (2) a film in a coronal plane to measure the dose distribution.

Prior to the on-site visit, the participating centre is required to provide clinically used data of output factors, small beam profiles, and MLC QA tests. In addition, the centre has to prepare an IMRT plan for a virtual H&N patient represented by CT images of the SHANE phantom along with predefined structures. Specific dose constraints are defined for the planning process.

Following the preparatory phase, an on-site visit is scheduled. Initial auditing activities include CT scanning of the phantom, importing the newly acquired CT phantom images into the TPS, transferring of the preliminary H&N plan and structures on these images, and re-optimizing the preliminary plan. The calculated doses at the ionisation chamber positions and in the coronal plane corresponding to the film position are recorded. These activities are followed by measurements of the beam output and subsequent film irradiations in a slab phantom for the film calibration, for checking small field profiles and for MLC QA tests. The local patient-specific QA of the treatment plan is also performed. Next, the SHANE phantom is positioned on the treatment couch using the local treatment position verification protocol and is irradiated according to the plan. The phantom is irradiated four times with an ionisation chamber in four different positions; the film located in the coronal plane is given three fractions. Finally, forms with preliminary results are filled in.

In the following weeks, the auditing organization analyzes the results and sends the audit report to the participating radiotherapy centre with the appropriate comments and recommendations.

The methodology described above has been pilot-tested in three radiotherapy centres in Europe.

Results
Pre-visit evaluation of small beam output factors showed results within 2% between the participants'data and the reference dataset, except for a 2 x 2 cm^2 field where differences of output factors up to 5% occurred. MLC QA results were within 1.0 mm for both the leaf positioning bias and the leaf opening width. The results of ionisation chamber measurements in the SHANE phantom are shown in Figure 1. The measured

to TPS calculated dose ratios range between 0.962 and 1.027. The results pertain to routinely used IMRT treatment modalities in participating centres. Other modalities, commissioned but not used clinically (i.e., Eclipse and Monaco step-and-shoot and dynamic MLC, not shown in the graph), were also included in the study, with the results having a broader range of 0.930-1.082.

For the clinically used techniques, film evaluation results, using a global gamma pass rate with the criteria of 3%/3mm and 20% threshold, ranged from 90.6% to 98.2%. Results for the non-clinically used techniques ranged from 88.6% to 93.0%.

Generally, the participants noted that the treatment planning exercise was demanding; it required considerable time and effort to fulfill the planning constraints.

Conclusion
The pilot-testing of the newly developed end-to-end on-site IMRT audit methodology using the SHANE phantom was successful. Feedback from participants helped to improve the procedures and to clarify the associated instructions. Development of the audit methodology is in its final stage with further tests on-going. Once finalized, the IMRT audit should provide additional support for radiotherapy centres in Member States in the safe use of modern IMRT techniques.

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