Editors' pick

In vivo dosimetry in brachytherapy: requirements and future directions for research, development, and clinical practice

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What was your motivation for initiating this study?

The paper was initiated after the first physics workshop that was run by the European SocieTy for Radiotherapy and Oncology (ESTRO) that was held in 2017 in Glasgow. One of the tracks considered in-vivo dosimetry methods for external beam radiotherapy and brachytherapy. The participants included clinicians, researchers, large vendors and small dosimetry start-up companies. From the discussion during the workshop it became evident that despite a clear interest in improved development and dissemination of in-vivo dosimetry, the progress was very limited. One of the major obstacles was later referred to as the "chicken and egg" problem. The clinics were not using in-vivo dosimetry due to a lack of dosimeters that exhibited adequate accuracy. On the other hand, the vendors were not prioritising the development of dosimeters due to the lack of usage. The development was therefore mainly driven by local research groups and small start-up companies and very few solutions were tested in clinical trials. There was therefore a lack of common ground to work from and little direction in the efforts.

Professor Frank Verhaegen and Professor Kari Tanderup initiated a working group that comprised experts from different hospitals and universities to look at the issue. The aim of the working group was to draw up recommendations towards a coordinated effort in the development of in-vivo dosimetry solutions that were suitable for clinical implementation. This would clearly improve patient safety. For instance, there are reports of treatment errors that has happened for years in clinics around the world; treatment errors that could have been identified with in-vivo dosimetry.

The task was divided into external radiotherapy and brachytherapy. Our focus has been on brachytherapy.

What were the main challenges during the work?

A main challenge was the diversity of the working group members and the target group. The working group members were of different backgrounds and worked in countries with different legislation that sometimes adopted different terminologies. Additionally, the report would target researchers, manufacturers and end-users, and these readers would probably also use different terminologies. It was therefore important to get feedback from all stakeholders. We included many stakeholders in the advisory committee and organised a meeting (open to the public) that was held one day before the second ESTRO physics workshop, which was held in 2018 in Malaga.

This process led to long discussions about the terminology that should be employed in the document, e.g. terms such as "error" or "in-vivo dosimetry" were extensively discussed. It turned out that there were several different interpretations of the term "in-vivo dosimetry". The first challenging task was therefore to define in-vivo dosimetry and define the scope of the paper in order to have a clear base to work from. In our opinion, these discussions contributed to making the report more broad and applicable to different scenarios.

Additionally, for brachytherapy, the lack of information (because there is no centralised database) about treatment errors and near-misses that were associated with the absence of accurate treatment verification methods made it very difficult to define tolerances and action levels based on clinical evidence.

What are the most important findings of your study?

The first part of the study was a PubMed search on both in-vivo dosimetry studies and reports on novel dosimetry techniques. The in-vivo dosimetry search revealed several reports on large deviations between measured and expected dose. These deviations were often reported to stem from positional uncertainties of the dosimeter and to depend on the time between image acquisition (e.g. planning CT) and treatment delivery. These findings indicated that improvements in imaging and the workflow could improve in-vivo dosimetry. Most of the studies employed time-integrated methods. Studies that use time-resolved methods are now starting to appear more frequently in the literature. The search of novel techniques revealed a large variety of new technologies. All showed promising results in laboratory settings. However, very few were tested clinically. It seems like one of the main hurdles is in getting the technology from bench to bedside.

Another obstacle towards dissemination was identified to be a lack of communication between the equipment that delivered the brachytherapy and the in-vivo dosimetry systems. The in-vivo dosimetry systems are mainly stand-alone systems that have been developed by companies other than the major brachytherapy vendors. The information that is needed for treatment verification, therefore, needs to be extracted and this is not always possible. Afterloaders can scale dwell times (depending on the source activity) and apply other corrections so that the delivered dwell times can be made to differ from the planned dwell times, but this information is not readily available to the user. Therefore, a list of requirements was created that was directed to the brachytherapy vendors regarding the information that is required to be available for extraction. The support from vendors is very important so that in-vivo dosimetry can be integrated into the brachytherapy workflow.

Finally, the working group identified that use of time-resolved dosimetry significantly enhanced the quality of in-vivo dosimetry for brachytherapy. We also identified ways to process the data further so that the feedback to the clinicians could be improved. This data included source tracking, dose reconstruction sensitivity and specificity.

What are the implications of this research?

The aim is that this ESTRO task group report will provide some guidelines for all partners involved in development and dissemination of in-vivo dosimetry for brachytherapy. The list of requirements for vendors clarifies how the industry can support current efforts to develop in-vivo dosimetry systems. A clear definition of feedback level and requirements should also support developers to provide the information that the end user needs in order to find the most suitable system for each application. Regardless of the method, the level of feedback, accuracy and types of errors that can be detected should be specified for each system. We hope this will lead to a more united and coordinated effort and improved usage of in-vivo dosimetry in the daily routine, with increased security for the patients and the capability to record the true delivered dose.

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