3rd ESTRO Physics Workshop: Science in Development

Plan quality assessment: dose distribution and robustness metrics track

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The topics of plan complexity and robustness were discussed in depth at this workshop. To ease understanding of the outcomes, we have split this report into two sections, one on each topic.

In summary, the agreed outcomes of the working group discussion regarding both topics were:

1) performance of a multicentre survey is needed: we would like to survey the photon and proton communities regarding their current practices to examine plan robustness (both optimisation and evaluation) and complexity;

2) a paper should be written on the current status of plan complexity and robustness optimisation and evaluation (perhaps with a systematic review of the literature);

3) an editorial is required that encapsulates what plan complexity and robustness should encompass in future.

Plan complexity

Technology for planning and delivery of radiotherapy treatment has progressed in various ways, and these improved technologies bring with them increased complexity of treatment plans. Since the introduction of intensity-modulated radiotherapy (IMRT), new delivery techniques have been clinically implemented, such as volumetric modulated arc therapy (VMAT), and specific technology has been introduced that aims further to improve conformality of the 3D-dose distribution. In addition, commercial systems of proton therapy enable several centres to exploit the physical features of proton therapy. Increased conformality of the 3D-dose distribution is often synonymous with increased modulation of many machine parameters and increased demand on the treatment planning system. The degree of this modulation and computational demand is termed the plan's complexity. Treatment plans with similar dose distribution may differ greatly in complexity, and the degree of plan complexity may affect the accuracy of dose calculation and treatment delivery (1-8). Understanding and handling of these issues is crucial to offering correct treatment, especially in terms of dosimetry audits, clinical trials and for big-data analysis (9-11). In order to investigate plan complexity, several complexity metrics have been proposed (1-8). To date, some complexity indices have provided similar information and can be considered equivalent: however, indices that focused on different plan parameters yielded different results and it was unclear which complexity index should be used (12).
The aim of the proposed multi-institutional survey is to investigate the clinical use of plan complexity metrics, and how such use can improve dose calculation and treatment delivery accuracy. We aim to use the results to suggest a shared and standardised road map for the clinical optimisation and evaluation of plan complexity.

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Robustness

Until a few years ago, the only way that was used to guarantee reliable target coverage and sparing of organs at risk (OARs) was the definition of an adequate margin around the clinical target volume (CTV) and OARs to obtain the planning target volume (PTV) and organ-at-risk volume (PRV). Several formulae have been proposed in the literature for the definition of PTV margins (Stroom et al., 1999; van Herk et al., 2000) and OARs (McKenzie et al., 2002, Stroom and Heijmen, 2006).

However, there are several limitations that affect the PTV definition: it relies on the so-called static dose cloud approximation and it does not guarantee optimal management when the PTV extends into air. Moreover, whether or not the CTV receives the prescribed dose depends on the specific dose distribution rather than geometric margin concepts. In reality, dose distributions are neither perfectly conformal to the PTV nor equally conformal on all sides of the CTV. Non-conformity results in an inherent dosimetric margin (Gordon and Siebers, 2008). In those regions where the prescription isodose line extends beyond the CTV anyway, less or no margin needs to be added to account for setup uncertainty. In addition to conformity, the required margin also depends on the steepness of the dose fall-off near the target. A naturally shallow fall-off may require a smaller margin than a steep fall-off. As Stroom et al underlined, the PRV concept has even more limitations, and it seems necessary to develop alternative ways to include geometric uncertainties of OARs in treatment planning (Stroom and Heijmen, 2006). All these concerns about the use of PTV and PRV are even more important in proton therapy.

It has been shown that robust optimisation can potentially solve the PTV/PRV limitations and improve the CTV coverage and sparing of ORAs (Unkelbach et al., 2007; Liu et al., 2013; Zhang et al., 2018) both for photon and proton treatments. Robust optimization takes into account the dose-shape modifications induced by set-up errors (plus range error for protons) within the patient-specific anatomy and dose-distribution characteristics (field directions, penumbra, dose gradient, etc.). Furthermore, PTV expansion in air is no longer needed because only the CTV variations are taken into consideration.

However, behind the phrases 'robust optimisation' and 'robust analysis' are different methodologies/metrics and there is no agreement on which to implement or how to use them (Unkelbach et al., 2018; Korevaar et al., 2019; Yock et al., 2019; McGowan et al., 2015; Malyapa et al., 2016). Given the potential of these new tools and their current availability in treatment planning systems, it is important that the scientific community discusses and shares what methods are most appropriate for both robust optimisation and analysis.

Hence the proposal of a multicentre survey: we need to be able to understand first how centres use these new tools (if they do) in order to be able to discuss the best way to use these tools in the future, particularly in the light of historical clinical data based on PTV and nominal OAR doses (Marks et al., 2010)

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Group discussion

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