Radiation Planning Index for dose distribution evaluation in stereotactic radiotherapy

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SUMMARY

AIM: The aim of this study was to provide a parameter for treatment plan comparisons in clinical practice.

MATERIALS AND METHODS: 21 patients with brain tumours were selected for analysis. Two alternative treatment plans were calculated for each patient. One of the alternative plans was approved while the second one was rejected by the physician. Alternative plans were compared with the parameter RPI. The computer program RPIWin® was prepared to facilitate the calculation process.

RESULTS: Calculations showed that 80% of approved treatment plans had higher RPI than rejected ones. Only 4 cases of approved treatment plans were characterized by lower RPI values than rejected ones.

CONCLUSION: The experiment demonstrated that the Radiation Planning Index formula takes into account the relation between dose distributions calculated for planning treatment volumes and organs at risk and is a convenient tool for treatment plan comparisons in routine clinical practice.

KEY WORDS: stereotactic radiosurgery, quality index, DVH analysis, dose distribution comparison

BACKGROUND

Conformal radiotherapy is a balance between the prescribed dose delivered to the tumour volume and healthy tissue tolerance [1, 2, 3, 4, 5, 6, 7].

Nowadays the choice of the optimal treatment plan among a number of plans calculated for the same patient in modern radiotherapy is challenging and is based on the experience and knowledge of the physician and radiotherapists.

However, such estimation seems highly subjective, and for this reason we believe that an unambiguous index that ranks the dose distribution will benefit the decision-making process [8, 9, 10, 11].

Numerous indices that characterize the dose distribution in the planning treatment volume (PTV) are widely reported in the literature, e.g. the conformal index, which analyzes the relation between the prescribed dose in PTV, and organs at risk (OAR) [12, 13, 14]. However, most parameters take into consideration only the reference dose value and single PTV. None of the parameters takes into account complicated relations between the dose distribution in the set of PTVs and OAR introduced to the plan.

We believe that the Radiation Planning Index (RPI) is a convenient tool for comparison of treatment plans in routine clinical practice.

AIM

The aim of this study was to introduce the RPI formula and to develop a method for comparison of dose distributions calculated in IMRT technique.

MATERIALS AND METHODS

21 patients with brain tumours treated with stereotactic radiosurgery were selected for

analysis. For each patient 2 alternative treatment plans were calculated by the BrainLab BrainScan treatment planning system. Both treatment plans were presented to the physician. One of the alternative plans was approved for treatment while the second one was rejected.

Each pair of treatment plans contained from 1 to 2 PTV contours and from 3 to 6 OAR. The Radiation Planning Index (RPI) was calculated for each analyzed plan.

For the purpose of this study the following RPI formula (Eq. 1) was proposed as an evaluation tool of the decision-making process.

$$RPI = \sqrt[n+m]{\prod_i^m \left\{ \prod_j^n \left[\left(1 - \frac{w_j \cdot \int_0^{D\max OaR} VjOAR \quad dD_{OaR}}{\int_0^{D\max OaR} VjOAR\ 100\% \quad dD_{Oar}} \right) \cdot \left(\frac{\int_0^{D\max PTV} ViPTV \quad dD_{PTV}}{\int_0^{D\max PTV} ViPTV\ 100\% \quad dD_{PTV}} \right) \cdot (1 - SDev \cdot p_i) \right] \right\}}$$

RPI is the Radiation Planning Index, where n is the number of critical structures (OAR) and m is the number of volumes treated (PTV).

Integral doses in RPI are based on the dose volume histograms (DVHs) (Fig 1.) calculated for each OAR and PTV.

$$\int_0^{D\max OaR} VjOAR \quad dD_{OaR}$$

is the integral dose of the j-th OAR, while

$$\int_0^{D\max OaR} VjOAR\ 100\% \quad dD_{Oar}$$

is the integral dose of the OAR[j] volume, assuming that the whole volume receives the tolerance dose for this critical structure (Fig. 1). Similarly

$$\int_0^{D\max PTV} ViPTV \quad dD_{PTV}$$

is the integral dose of the i-th PTV and

$$\int_0^{D\max PTV} ViPTV\ 100\% \quad dD_{PTV}$$

is the integral dose of the i-th PTV, assuming that the whole volume is homogeneously covered with the prescribed dose value.

SDev determines the standard deviation of the dose distribution in PTV, while p_i is a weight factor of the dose distribution homogeneity for the PTVi. Each OAR is characterized by the importance factor w_j. The importance factor was introduced to RPI to rank organs sensitive to irradiation. Its value is established individually for each patient based on the physician's and dosimetrist's experience, organ's radiosensitivity and patient's history of irradiation.

D max OaR is the maximal dose value, which should not exceed the tolerance dose for the selected anatomical structure.

When

$$w_j * \int_0^{D\max OaR} VjOAR \quad dD_{OAR} = \int_0^{D\max OaR} VjOAR 100\% \quad dD_{OAR}$$

then

$$\left(1 - \frac{w_j * \int_0^{D\max OaR} VjOAR \quad dD_{OAR}}{\int_0^{D\max OaR} VjOAR 100\% \quad dD_{OAR}} \right) = 0$$

It results in $RPI = 0$ because the whole OAR is covered with the maximal tolerance dose. If the integral dose in PTV is much lower than the prescribed reference dose then

$$\frac{\int_0^{D\max PTV} ViPTV}{\int_0^{D\max PTV} ViPTV 100\%} -> 0$$

which results in $RPI -> 0$.

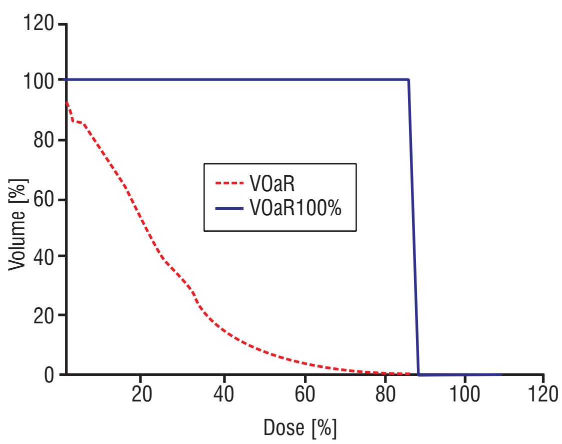

Fig. 1. Dose-volume histogram for OAR represents two dimensional coverage of the irradiated volume. Solid line represents ideal, homogeneous coverage of the irradiated volume with the maximal dose, dashed line is a dose–volume relation assuming realistic, inhomogeneous dose distribution inside OAR.