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Validation of Lexicographic Optimisation-Based Planning for Brain Metastasis Radiosurgery with Coplanar Arcs

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Abstract
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Paolo Caricato [1], Sara Trivellato [2], Roberto Pellegrini [3], Martina Camilla Daniotti [2], Valeria Faccenda [2], Denis Panizza [2], Gianluca Montanari [4], Stefano Arcangeli [5], Elena De Ponti [2]

1. Physics, University of Milan, Milan, ITA 2. Medical Physics, ASST Monza, Monza, ITA 3. Particle Therapy, Elekta, Agrate Brianza, ITA 4. Physics, ASST Monza, Monza, ITA 5. Radiation Oncology, ASST Monza, Monza, ITA

Corresponding author: Paolo Caricato, paolo.caricato93@gmail.com

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Abstract

Objectives:

In this study, a not yet commercially available fully-automated lexicographic optimization planning system, called mCycle (Elekta AB, Stockholm), was validated for intracranial stereotactic radiosurgery (SRS).

Methods:

Twenty-five single-lesion SRS treatment plans (21 Gy/1 fraction) delivered between November 2019 and July 2022 were retrospectively selected. mCycle automated planning (Monaco v. 5.59.13) asks for an a-priori assigned priority list, a so-called Wish List (WL) to define the sequential lexicographic optimization. The WL represents a dialogue between the radiation oncologist and the planner, setting hard constraints and following objectives that must be translated into one or more cost functions associated with the contoured structures. Their definition is part of the so-called tuning process, a multi-step iterative method on a subset of patients (tuning set) that goes on until the optimized plans satisfy the defined clinical protocol without affecting plan delivery accuracy. A tuning set of 4 patients was necessary to achieve a robust WL. While in manual plans (MP) the arc setup is freely chosen by the planner, in mCycle plans (mCP) the choice was to tune the WL on the automatic use of 2 coplanar arcs of 140°. The only planner's manual interaction is the choice of the start angle to reduce the involved brain volume. A collimator rotation was set at 0° and 90° for counter-clockwise and clockwise arcs, respectively. After fluence lexicographic optimization, a Monte Carlo calculation is performed with a 1 mm-dose grid and 0.5%-statistical uncertainty. A target coverage as high as possible was requested, with at least 80% of the prescription dose covering 99% of the PTV. The tuned WL was used to automatically re-optimize the remaining 21 plans (testing set). MP and mCP were compared in terms of target coverage, dose-volume constraints, and monitor units (MUs). Statistical significance was assessed by performing the Wilcoxon-Mann-Whitney test with Bonferroni correction for multiple tests (alpha=0.05). Plan delivery accuracy was verified by pre-treatment QA and gamma analysis.

Results:

The median GTV and PTV were 0.8 [0.1-2.5] cm3 and 2.3 [0.7-6.4] cm3, respectively. The WL tuning and the 21 mCP re-planning took only 3 and 5 working days, respectively. The overall planning and calculation time was significantly reduced from about one working day for one MP to about 2 hours for one mCP. A statistically significant increase in target coverage was registered ($p< 0.01$). The median D98% of GTV and PTV for MP were 20.5 [20.1-21.6] Gy and 18.2 [17.1-19.9] Gy, and 21.1 [21.0-21.5] Gy and 19.0 [18.6-19.4] Gy for mCP, respectively. A significant improvement in PTV Paddick's conformity index has been registered: 0.4 [0.0-0.6] for MP and 0.5 [0.3-0.6] for mCP with a $p=0.02$. The brain V12Gy was 7.2 [3.3-9.2] cm3 and 7.6 [3.4-11.1] cm3 for MP and mCP, respectively ($p>0.05$). Other organs at risk were never significantly interested by clinically relevant doses. The brain constraint was violated in only one mCP that has been clinically discussed: the GTV registered the highest value and the radiation oncologist would ask for further optimization to fulfill the violated constraint by accepting a lower target coverage. These results were obtained with a lower median number of MU (MP 2458 [1889-3890]; mCP 2355 [2086-3032]). This difference was not statistically significant ($p>0.05$) and plans registered a comparable local gamma analysis (2%/2mm).

Conclusion(s):

The novel mCycle autoplanning produced high-quality clinically acceptable radiosurgery plans with coplanar arcs, significantly reducing the planning workload. While the OAR sparing was comparable between MP and mCP, the target coverage was significantly increased, reducing the MU number and preserving the

plan delivery accuracy. The validation showed the mCycle capability to generate high-quality deliverable plans according to institutional-specific planning protocols but the present WL could be further optimized to achieve the clinical requests without any manual intervention.