Evaluation of the feasibility for proton therapy of gastric cancer - a treatment planning study

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Background
Radiotherapy of GC involves the treatment of large tumour volumes. This in turn requires irradiation of large volumes of normal tissue surrounding the target. For this reason, the normal tissue toxicity is an issue and a treatment limiting factor. The use of scanned-proton beams has the potential to reduce the irradiation of critical normal structures, however scanned-proton beams have also been shown to be prone to uncertainties in tumour sites influenced by anatomical changes.

Aims of this study
The aim of this study was to evaluate the potential of scanned-proton SFUD to reduce the dose and toxicity of the organs at risk (OARs), compared to VMAT in radiotherapy of GC and to study the impact of variations of abdominal tissue density in the dose distributions in VMAT and SFUD plans.

Conclusions
- A better sparing of the OARs was achieved with scanned-proton SFUD plans, compared to the photon VMAT plans. However, the SFUD plans were found to be less robust against the introduced density changes, which highlights the need for robust approaches in SFUD treatments of GC cancers.
- The use of field-specific PTVs and robust optimisation in SFUD planning resulted in plans that were robust against density changes and with improved OAR sparing, compared to the VMAT plans.
- The dose reduction with the robust SFUD plans led to significant NTCP reduction for the left kidney, compared with the VMAT plans.

Materials and Methods Workflow

\textbf{Part I: VMAT vs. PTV-based SFUD plans}

- Clinical VMAT plans (8 GC patients) 1.8 Gy x 25 fractions
- Plan with scanned-proton SFUD (2-fields)
- Recalculate the obtained doses on two modified CT sets with (1) the density of the abdominal air cavities replaced with water; and (2) expanded volumes of air cavities

\textbf{Part II: VMAT vs. robust SFUD plans}

- Clinical VMAT plans (8 GC patients) 1.8 Gy x 25 fractions
- Plan with SFUD on CT sets with the density of the air cavities replaced with water; perform robust optimisation accounting for setup and range uncertainty (SFUD\textsubscript{opt})
- Recalculate the obtained doses with SFUD on the original CT sets (SFUD\textsubscript{opt}).

Results
Similar DVHs were obtained for the PTV with the SFUD and VMAT plans. However, the SFUD plans resulted in lower doses to the OARs compared to the VMAT plans prepared on the original CT sets (Figure 1a). The VMAT plans were robust against the density changes (Figure 1b), while the SFUD plans were more deteriorated (Figure 1c).

The use of field-specific PTV and robust optimisation improved the SFUD plans in terms of target-dose coverage, while maintaining the sparing of the OARs (Figures 2 and 3).

In the assessment of NTCP, a significant reduction of NTCP for the left kidney was obtained with the SFUD plans, compared to the VMAT plans (Figure 4).

![Figure 1. Comparison of the DVHs for: (a) VMAT (full lines) and SFUD (dot-dashed lines), (b) VMAT and (c) SFUD plans prepared on the original CT (full lines), CT with water replacement (dotted lines) and CT with enlarged volumes of air cavities (dash-dotted lines).](image1)

![Figure 2. Dose distributions obtained with (a) VMAT, (b) SFUD\textsubscript{opt} and (c) SFUD\textsubscript{opt} (Source: modified from Mondlane et al. (2018) Anticancer Res, In Press).](image2)

![Figure 3. Median DVHs determined for the CTV and OARs, for all patients with the VMAT (full lines), SFUD\textsubscript{opt} (dot-dashed lines) and SFUD\textsubscript{opt} (dotted lines). (Source: Mondlane et al. (2018) Anticancer Res, In Press).](image3)

![Figure 4. NTCP values calculated for the left kidney with VMAT, SFUD\textsubscript{opt} and SFUD\textsubscript{opt}.](image4)