Predicting dose differences to swallowing OARs in head and neck (HNC) patients

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INTRODUCTION

- Differences between planned (D_P) and delivered (D_A) dose (Δdose) in HNC patients treated with X-Rays are poorly understood.
- Such differences may be accentuated by proton dosimetry[1].

OBJECTIVES

- **Quantifying and predicting differences between D_P and D_A to swallowing OARs with X-Ray plans, may help to guide and inform adaptive PBT strategies for HNC.**

METHODS

Sample: all patient with HNC, recruited to the VoxTox study (UK CRN ID 13716) – 239 had full datasets.

Treatment protocol: 65Gy/60Gy in 30 fractions, 2/3 dose-level technique [2]. Concomitant weekly cisplatin (133, 55.6%), cetuximab (16, 6.7%).

Treatment platform: TomoTherapy *Hi-ART* system, daily image-guidance (IG), match to high-dose PTV/upper cervical spine, zero action-level.

Dose calculation:

- Manual contouring of: ipsilateral & contralateral parotid glands (IPG & CPG), and submandibular glands (ISMG &CSMG), superior and middle pharyngeal constrictor muscles (SPC & MPC), oral cavity (OC) and supraglottic larynx (SGL) on kVCT planning scans, according to consensus atlas [3] (Figure 1).

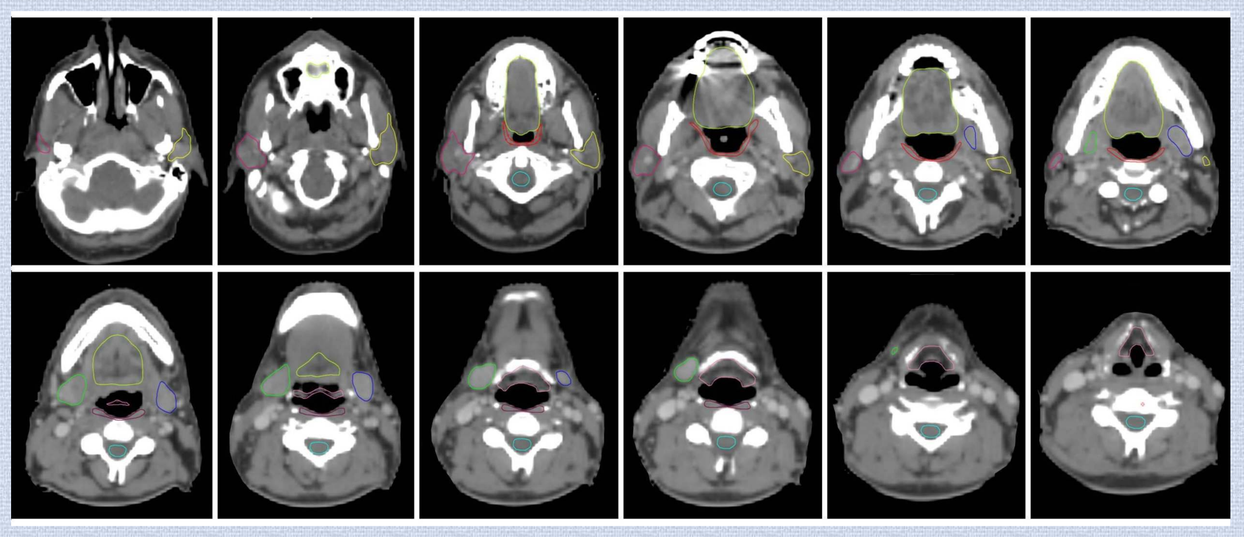

Figure 1: Example atlas of full 'swallowing OAR' structure set contoured on planning CT

- Open-source, intensity-based, deformable image registration software (Elastix), trained and validated according to consensus guideline TG 132 [4], used to propagate kVCT contours to daily MVCTs (Fig 1), and accumulate dose.
- Mean D_P and D_A are reported.

Hypothesised predictors of dose differences:

- ***Weight loss:*** pre-RT vs final treatment week (kg and %).
- ***Patient separation:*** lateral neck dimension (LND) - the transverse skin-to-skin distance), and slice surface area (SSA) of this contour was measured at the level of C1 and the thyroid notch on day 1 & 30 MVCTs, and differences noted (ΔLND/SAA) (Fig 2).
- ***Primary disease site.***
- ***T and N staging.***

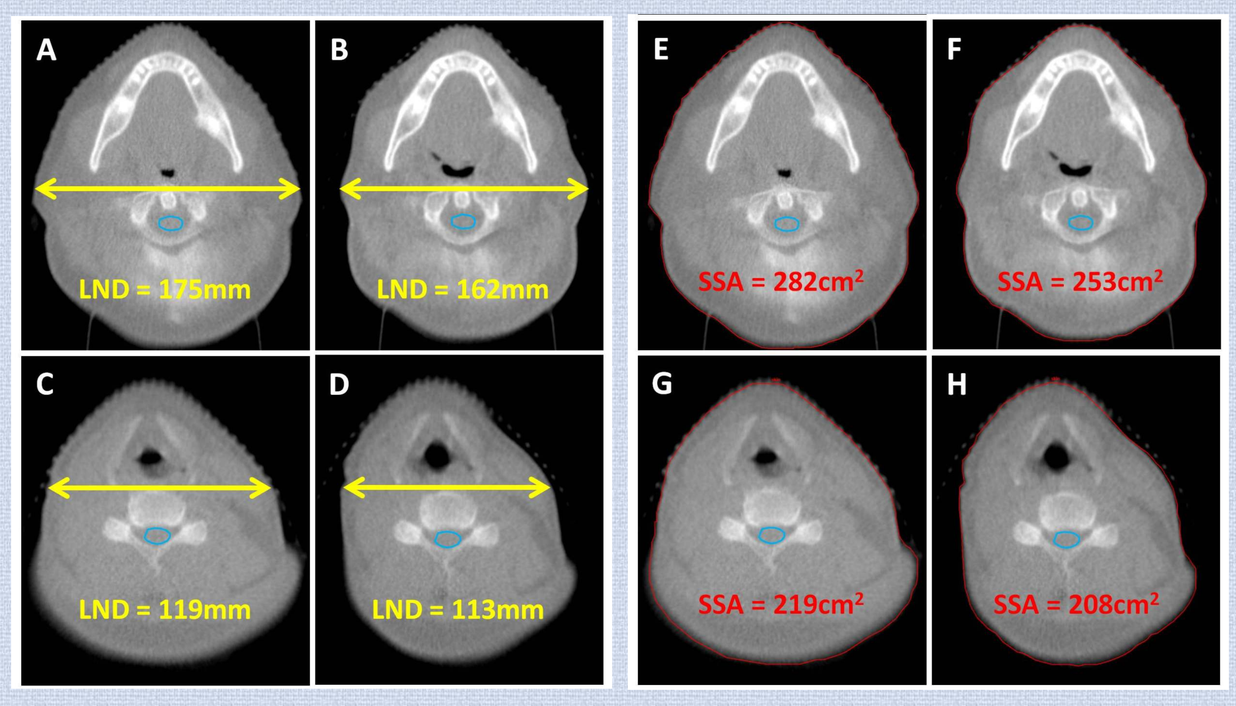

Figure 2: Measuring anatomical change; lateral neck diameter (LND, captions A-D) and slice surface area (SSA, captions E-H), – measured on the IG-MVCT at the C1 vertebra (C1) and thyroid notch (TN) on the first and final treatment day. Captions A&B, and E&F are day 1, captions B&D and F&H are day 30.

RESULTS

Primary disease sites (n = 239):

- 145 oropharynx, 28 hypopharynx/larynx, 32 salivary gland/sinus/skin, 19 oral cavity, 7 nasopharynx, 8 unknown primary.

Delivered versus planned dose (Figure 3):

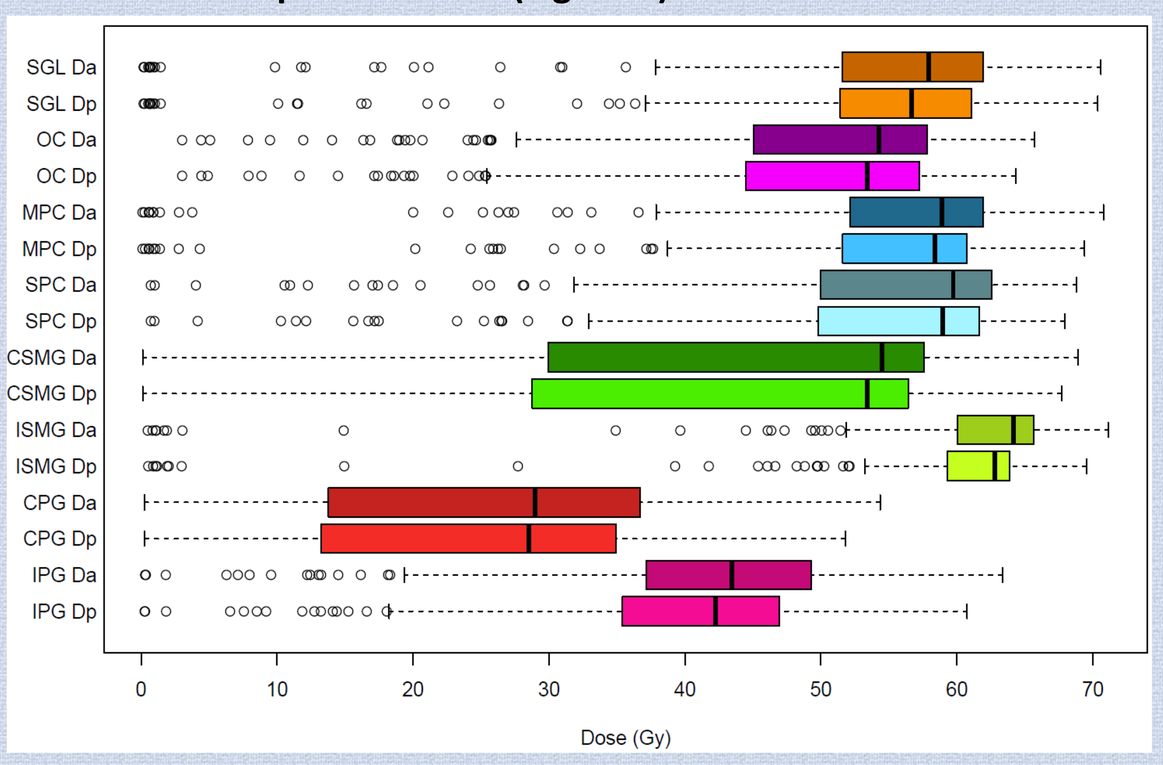

Figure 3: Planned (D_P) versus delivered (D_a) dose for all swallowing OARs. Mean dose differences ($D_A - D_P$, 95% CI): IPG 1.56Gy (1.37-1.74), CPG 0.94Gy (0.77-1.11), ISMG 1.24Gy (1.11-1.36), CSMG 1.17Gy (1.05-1.29), SPC 0.81Gy (0.71-0.91), MPC 0.68Gy (0.55-0.82), OC 0.44Gy (0.30-0.57), SGL 0.98Gy (0.78-1.17)

Hypothesised predictors of dose differences:

(Univariate linear regression models, α = 0.0007 {after Bonferroni correction})

Weight loss:

- $R^2 < 0.1$ for all models (all swallowing OARs)

Patient separation:

- **MPC –** all R^2 0.1 – 0.2, all p<0.0005
- **CSMG vs C1 LND –** R^2 0.14, p<0.0005
- **SGL vs TN SSA –** R^2 0.14, p<0.0005
- **PG's/SPC/OC –** all $R^2 < 0.1$, all p>0.0007

Primary disease site (Figure 4):

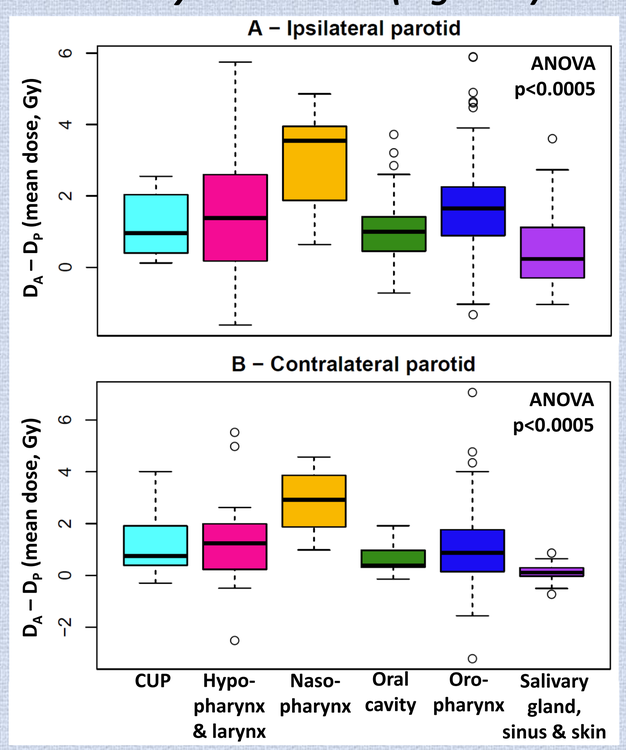

Figure 4: Box-plots of dose differences ($D_A - D_P$, Gy) to IPG (A) and CPG (B), by site of primary disease

T and N stage (Figure 5):

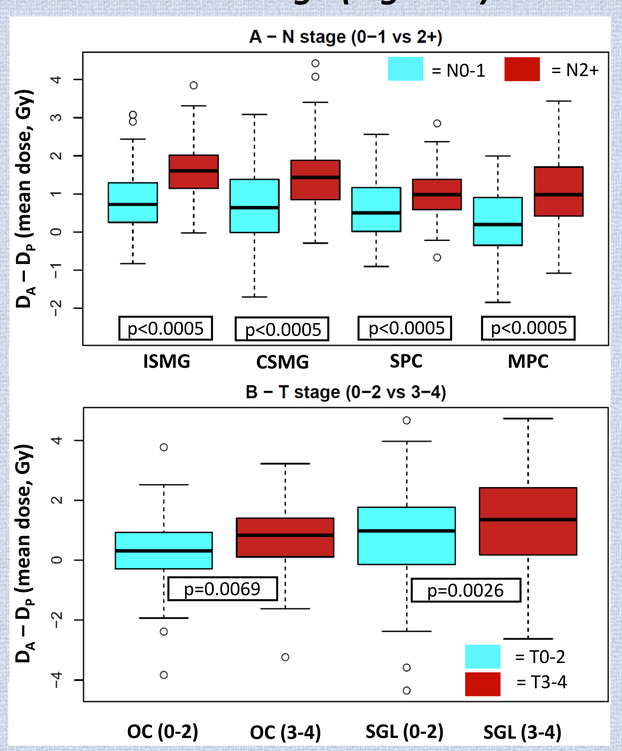

Figure 5: Box-plots of dose differences ($D_A - D_P$, Gy) to swallowing OARs by Nodal (A) and T-stage (B).

CONCLUSIONS

- **Delivered dose was higher than planned for all structures.**
- **Weight loss and anatomical change have minimal impact on dose differences.**
- **Nasopharynx patients see significantly higher D_A (compared to D_P) to both parotid glands.**
- **Higher N-stage predicts higher D_A to all structures, higher T-stage predicts higher D_A to oral cavity, and supraglottic larynx.**

References:

1. Muller BS et al. *Phys Med,* 2015.
2. Thomson D et al. *Clin Oncol (RCR),* 2014.
3. Brouwer CL et al. *Radiother Oncol,* 2015.
4. Brock KK et al. *Med Phys,* 2017.

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