Improve the dosimetric outcome in bilateral head and neck cancer (HNC) treatment using Spot-scanning Proton Arc (SPArc) therapy: A feasibility study

Gang Liu, An Qi, Xiaoqiang Li, Di Yan, Craig Stevens, Peyman Kabolizadeh, Xuanfeng Ding
Departments of Radiation Oncology, Beaumont Proton Therapy Center
Oakland University, William Beaumont School of Medicine

Beaumont

OU WB School of MEDICINE

INTRODUCTION

This is the first feasibility study to demonstrate that compared to traditional 3 filed RO-IMPT, utilizing the novel proton therapy technique – the spot-scanning proton arc (SPArc) therapy to treatment bilateral head and neck cancer (HNC) will bring significant clinical benefit, which include dosimetric improvement, delivery efficiency and plan robustness etc.

MATERIALS & METHODS

Ten bilateral HNC patients were retrospectively evaluated. Both SPArc and 3-field robust optimized Intensity Modulated Proton Therapy (RO-IMPT) plans were generated using the same robust optimization parameters (±3.5% range and 3mm setup uncertainties). The prescription dose was 7000cGy[RBE] for CTV_high and 6000cGy[RBE] for CTV_low. Clinically significant dosimetric parameters and potential clinical benefit for parotid glands were extracted and compared. Root-mean-square deviation dose (RMSDs) was used to evaluate the plan robustness. Total treatment delivery time was estimated based on a full gantry rotation with 1 rotation-per-min, 2ms spot switching time, 0.01 minimum spot monitor unit per spot, and energy-layer-switching-time (ELST) from 0.1 to 5 seconds.

RESULTS

The SPArc plan was able to provide equivalent or better robust target coverage while demonstrating significant dosimetric improvements over RO-IMPT in most of OARs sparing(Table1). More specifically SPArc reduced the mean dose of ipsilateral parotid($p<0.001$), contralateral parotid($p<0.001$), and oral cavity($p<0.001$) by 27.1%, 28.1% and 32.6% respectively compared to RO-IMPT. The D1% of brain stem and cord were also reduced by 21.3%($p=0.003$) and 6.2%($p=0.276$) using SPArc, respectively. SPArc reduced the dose uncertainties in cord and ispilateral parotid 119.6cGy[RBE] vs 91.3cGy[RBE] ($p=0.017$), 268.2cGy[RBE] vs 243.6cGy[RBE] ($p=0.027$)) respectively(Fig1). Based on ELST of 0.1s, SPArc was comparable in average total estimated delivery time (284.0s vs 304.5s $p=0.244$). SPArc will decrease the mean probability of salivary flow dysfunction by 8.6% ($p<0.001$)(Fig 2).

Table 1. The average dosimetric characteristic for the ten patients

Structure	Value	SPArc	RO-IMPT	pValue
CTV_high	D95(cGy) [RBE]	7065.0	7094.1	0.001
	D5(cGy) [RBE]	7284.6	7423.2	<0.001
	HI	1.03	1.05	<0.001
CTV_low	D95(cGy) [RBE]	6049.6	6071.7	0.003
	D5(cGy) [RBE]	6331.7	6619.8	<0.001
	HI	1.05	1.09	<0.001
Cord	D1(cGy) [RBE]	2389.6	2548.0	0.276
Brain Stem	D1(cGy) [RBE]	1511.2	1920.5	0.003
Contralateral Parotid	Mean Dose(cGy) [RBE]	1856.3	2582.9	<0.001
Ipsilateral Parotid	Mean Dose(cGy) [RBE]	2679.7	3679.3	<0.001
Oral Cavity	Mean Dose(cGy) [RBE]	2008.3	2978.1	<0.001
External	ID (Gy · L)	123.8	136.5	0.031

Abbreviations: HI (homogeneity index), RBE: relative biological effectiveness, D*x* : the largest dose level percentage covering *x*% volume of a structure, ID: the integral dose.

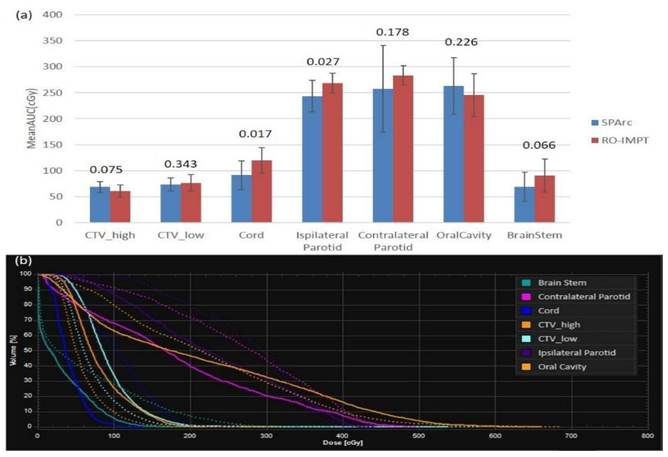

Figure. 1 (a) The average areas under the RVH curve (AUC) for ten patients with p-values on the top of the columns. (b) An example of the root-mean-square dose (RMSD) volume histograms of SPArc (solid line) and RO-IMPT (dashed line) for patient # 3.

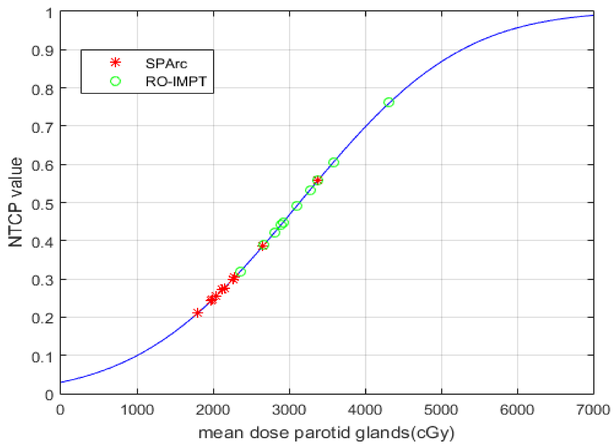

Figure. 2 Normal tissue complication probability (NTCP) model for parotid salivary flow (solid curve). The NTCP value denotes the probability of a reduction in salivary flow to <25% of the pre-treatment flow at ≤ 6 months after radiotherapy.

CONCLUSIONS

SPArc could significantly reduce the dose to OARs (parotids and oral cavity etc.) while providing a similar or better robust target coverage compared with RO-IMPT. SPArc could potentially achieve comparable treatment delivery time with ELST less than 1s.

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A patent related to the proton arc therapy is licensed to Ion Beaumont Application Inc.