Statistical analysis for determining initial electron beam parameters in a 6MV Linac: A simulation study

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INTRODUCTION

❖ Purpose

- The purpose of this study was to obtain the initial electron beam parameters of a medical linear accelerator (Linac) with Monte Carlo (MC) simulations using the Geant4 code. The authors employed a statistical method to determine the optimal conditions for the first time.

MATERIALS & METHODS

❖ Monte Carlo simulation

- A 6 MV Varian Clinac iX was simulated using the Geant4 toolkit, ver. 10.03.

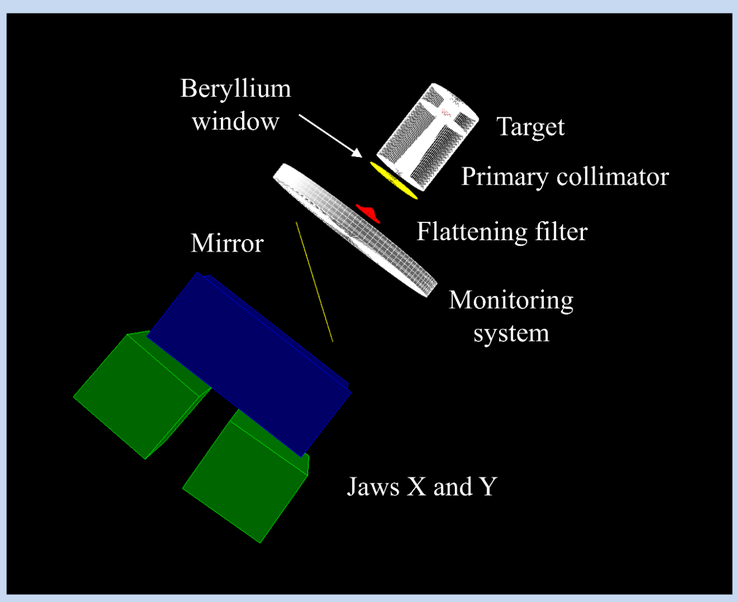

***Fig. 1**. Modeling of Linac head*

❖ Determination of initial electron beam parameters

- This study investigated the relations between the simulated dose distribution and several major initial electron beam parameters; mean energy (E_e), energy spread (ΔE) and radial intensity distribution (FWHM).
- We used the slope of the difference between the measured and the calculated data when we investigated the electron beam parameters to minimize the slope through statistical analysis.
- The acceptance criteria of the slopes were set so that we were able to obtain dose differences below 1% over the regions.

❖ Statistical analysis

- Correlation between the slope values of the dose differences and each electron beam parameter was first investigated with the Spearman's rho analysis.
- For multivariate analyses, the slopes were converted to binomial variables to apply the binomial logistic regression method.
- To determine the best combination, we accepted that a variable was statistically meaningful in multivariate analysis.

RESULTS & DISCUSSION

❖ Statistical analysis

- Although statistical significance in the lateral dose profile were observed in the beam energy through Spearman's rho analysis, this study does not recommend to use values obtained from univariate analysis for the final model.
- Through the multivariate analysis, the best-fit combination of the initial parameters was a model consisted of E_e = 6.4 MeV, ΔE = ±5%, and FWHM = 4 mm. Significance probabilities and odds ratios are given in Table 1.

Table 1. Significance probabilities and odds ratios (OR) of the initial electron beam parameters of the best-fit model providing minimum slope of differences for dose distributions.

		p-value	Odds ratio	95% confidence interval of OR	
				Lower	Upper
PDD	E_e	0.853	1.245	0.123	12.606
	ΔE	0.007	0.861	0.772	0.960
	FWHM	0.531	1.119	0.788	1.588
Profile	E_e	0.018	0.034	0.002	0.556
	ΔE	0.001	0.813	0.721	0.917
	FWHM	0.073	1.449	0.966	2.174

❖ Validation of Linac

- The statistical analyses help to determine the best-fit combination in a 6MV Linac. The calculated dose was good agreement with the experimental dose distributions (Fig.2).

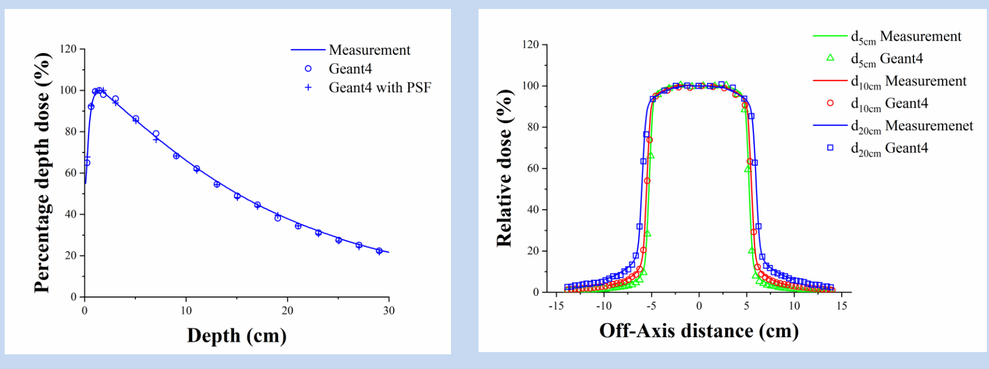

***Fig. 2**. PDD curves (left) at a central axis and lateral dose profiles (right) at depths of 5 g/cm², 10 g/cm² and 20 g/cm² for 10×10 cm² field size were results obtained with the optimal incident electron beam parameters.*

CONCLUSION

- This study has found the optimal initial electron beam parameters for a 6 MV Linac with statistical methods for the first time.
- The Linac model built with Geant4 in this study can be used for further simulations such as radiation therapy planning or more.

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