Examination of the best head tilt angle for parotid gland preservation in whole-brain radiotherapy using four-field box technique

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HIGHLIGHTS

- **To determine the best head tilt angle of the brain in the four-field box technique.**
- **Principal component analysis was used.**
- **The parotid gland dose was negatively correlated with the lens dose.**
- **A 14° head tilt angle minimises the parotid gland dose with lens protection.**

INTRODUCTION

In whole-brain (WB) irradiation, the parotid gland is recognised as a major-risk organ [1]; the beam delivery from the left and right sides could not prevent the dose from entering the parotid glands.

In fact, for patients who underwent palliative WB irradiation with the standard prescription of 30 Gy in 10 fractions, Noh et al. reported that 12 (37.5%) and 1 (3.1%) patient received the mean doses of >20 Gy or >25 Gy, respectively [2].

Park et al. proposed a new technique that excluded the parotid gland from radiation fields in the four-field box irradiation using a head-tilting device [3]. This technique would be more practical after determining the optimal head tilt angle to reduce the parotid gland dose.

AIM

To determine the best head tilt angle to reduce the parotid gland dose in the four-field box technique.

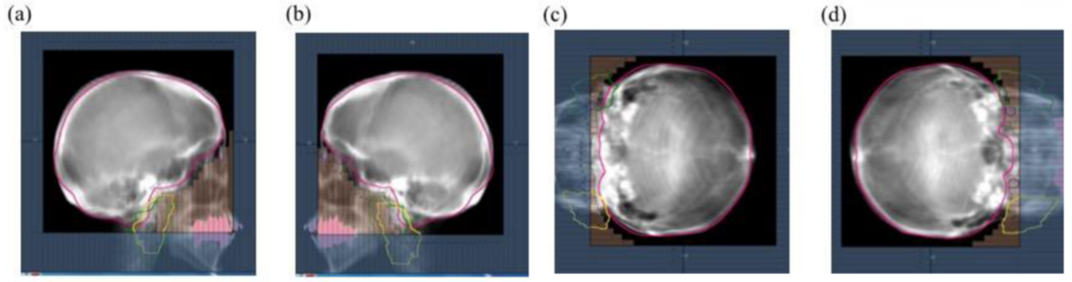
CONCLUSIONS

Since the parotid gland dose is inversely related to the lens dose, the orbitomeatal plane angle required to reduce the maximum lens dose to ≤10 Gy and minimise the parotid gland dose was 14°. If the lens dose was not considered, the parotid gland dose could be reduced by decreasing the orbitomeatal plane angle.

METHOD

Treatment planning

This study was approved by our institutional review board (No. 2020-1-021). First, conventional bilateral beams were set up so that the beamline of the anterior side was parallel to the line connecting the left and right eye sockets. Additionally, a beam from the anterior direction was added with the couch angle of 90°. The beam from the anterior direction was set at a gantry angle where the lens was not included in the irradiation field and the beam from the posterior direction was set on the opposite side. Although a leaf margin of ≥5 mm was basically added to the planning target volume, the multi-leaf collimator was closed up to the position where it did not interfere with the planning target volume in order to reduce the lens dose. The below figure shows representative radiation fields of the four-field box technique.

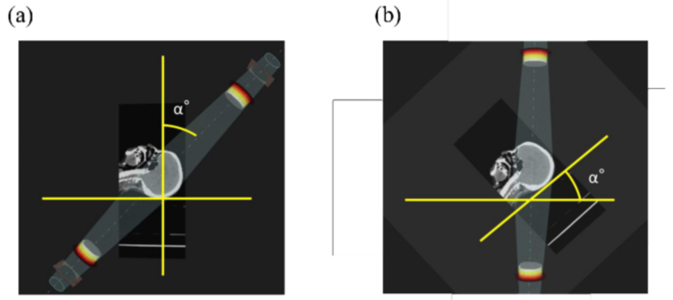


Beams eye view from the (a) left, (b) right, (c) anterior, and (d) posterior directions. Pink, yellow, and purple contours show the planning target volume, parotid gland, and lens, respectively.

Calculation of the head tilt angle

The head-tilting device was not used in the treatment planning CT, and the head tilt angle was set by measuring the gantry angle with the couch angle of 90°.

For example, (a) the gantry angle of α° without the tilting device is equivalent to (b) the gantry angle of 0° with the tilting device of α° as shown in the below figure.



The virtual orbitomeatal plane angle ($OMPA_{virtual}$) was introduced as an indicator that expresses the head tilt angle. It was defined by subtracting the actual OMPA in the direction perpendicular to the couch from the anterior gantry angle (A_{gantry}): $\boldsymbol{OMPA_{virtual} = A_{gantry} - OMPA}$. **(1)**

Principal component analysis

To understand the interrelationship between variables (dosimetric parameters and $OMPA_{virtual}$), principal component analysis (PCA) was performed [4].

What is PCA?

PCA is a multivariate technique widely used in reducing dataset dimensionality to increase the interpretability while preserving as much information as possible. For that, PCA identifies a new set of uncorrelated variables (principal components, PCs) that result from linear combinations of the original ones and that successively maximise the variance.

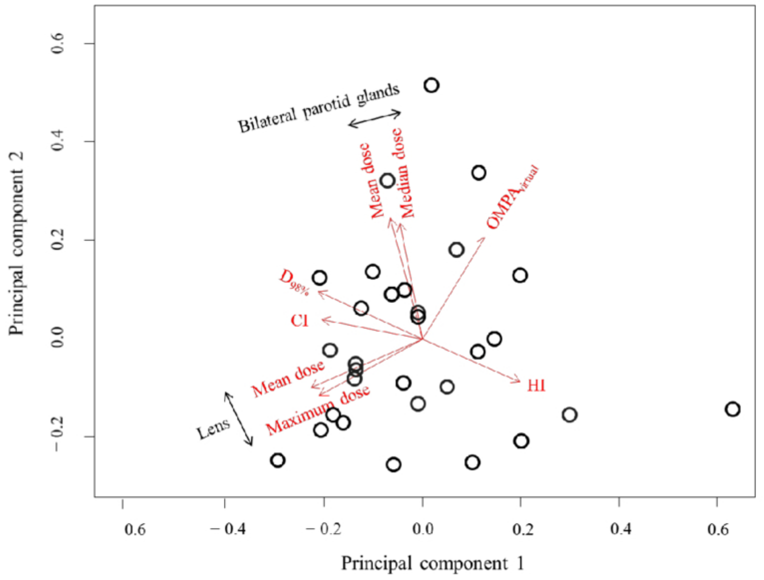
For example, the direction that maximises the data variance from the gravity point of all data shows the first PC (PC1). Next, the direction that maximises the data variance from the gravity point with respect to the direction perpendicular to PC1 is defined as the second PC (PC2). The direction of the maximum variance is repeatedly searched based on the number of dimensions of the original data.

In PCA, the degree to which the PC explains data variation is expressed as a proportion. For example, when PC1 and PC2 proportions are 50% and 20%, respectively, the cumulative proportion is 70%, indicating that 70% of data variation can be explained using PC1 and PC2. In this study, PCs that achieved the cumulative proportion of 70% were used for data retention.

In addition, a biplot expressed each data point corresponding to a treatment plan, and the variable represented by a vector was drawn. In the biplot, positively or negatively correlated variables have the angle of approximately 0° or 180° between vectors, respectively. Conversely, uncorrelated variables have an angle of approximately 90° between vectors.

RESULTS

In PCA, proportions of the PC1 and PC2 variance were 41% and 33%, respectively. The cumulative proportion was 74%. The below figure shows the biplot, where each data point corresponds to a treatment plan. The variable is also represented by a vector, where lateral and vertical axes of the secondary axis represent the weight of variables for the PC1 and PC2, respectively.



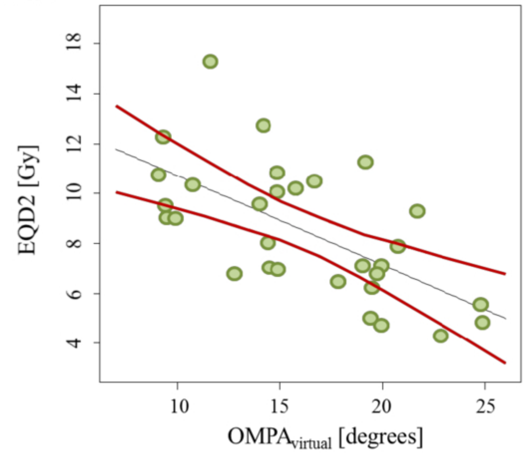
- The angle between vectors of the $OMPA_{virtual}$ and the mean or maximum dose to the lens was approximately 180°, which indicated a negative correlation [r = −0.591 ($p < 0.05$) or −0.627 ($p < 0.05$), respectively].
- The angle between vectors of the $OMPA_{virtual}$ and the mean or median dose to the bilateral parotid glands was small, which indicated a positive correlation [r = 0.475 ($p < 0.05$) or 0.405 ($p < 0.05$), respectively].

→ The parotid gland was negatively correlated with the lens dose.

- The $OMPA_{virtual}$ was not correlated with the $D_{98\%}$, the homogeneity index (HI), or the conformity index (CI) for the PTV [r = −0.118 ($p = 0.535$), 0.012 ($p = 0.951$), or 0.047 ($p = 0.807$), respectively], and the angle between vectors was approximately 90°.

DISCUSSION

The below figure shows relationships between the $OMPA_{virtual}$ and maximum lens dose that converted to the linear–quadratic equivalent doses at 2 Gy per fraction (EQD2). The red line shows a 95% confidence interval.



If the dose constraint of maximum lens dose was set at 10 Gy [5], the $OMPA_{virtual}$ that reduced the maximum lens dose to <10 Gy with a 95% confidence interval was approximately 14°.

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REFERENCES

[1] Fiorentino A, et al. "Whole brain radiotherapy: are parotid glands organs at risk?". *Radiother Oncol.* 2012;103(1):130–1.
[2] Noh OK, et al. Parotid gland as a risk organ in whole brain radiotherapy. *Radiother Oncol* 2011;98:223–6.
[3] Park J, Yea JW. Whole brain radiotherapy using four-field box technique with tilting baseplate for parotid gland sparing. *Radiat Oncol J* 2019;37:22–9.
[4] Jolliffe IT, Cadima J. Principal component analysis: a review and recent developments. *Philos Trans A Math Phys Eng Sci* 2016;374:20150202.
[5] Scoccianti S, et al. Organs at risk in the brain and their dose-constraints in adults and in children: a radiation oncologist's guide for delineation in everyday practice. *Radiother Oncol* 2015;114:230–8.

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