

MODERN MEDICAL EQUIPMENT

# The Evaluation of Skin Toxicity during Brain Tumor Irradiation Dose Calculation

Oxana A. Pashkovskaya\*; Igor V. Bedny; Olga Yu. Anikeeva, PhD;  
Evgeniy S. Polovnikov, PhD

Federal State Institute "Academician E.N. Meshalkin Novosibirsk State Research Institute of Circulation Pathology", Novosibirsk, Russian Federation

## Abstract

**Background:** Radiotherapy is the keystone in brain tumor treatment, including posterior fossa tumors, and can achieve better patient health-related quality of life. Radiation exposure can be associated with the risk of skin radiation injuries. Accurate tumor and critical structure delineations and precise dose planning may improve the outcomes and decrease radiation complications. **The objective of this study** was to compare the influence of the headrest and treatment couch during dose planning, on the dose distributions and skin injury post irradiation.

**Material and Methods:** Treatment planning calculations were performed for 14 brain tumor patients using the volumetric modulated arc therapy (VMAT) to study the dose distribution and dose-volume histograms (DVH). We compared the following three cases of general patient contours: patient body contour alone, body contour including the headrest, and body contour with headrest, couch and immobilization mask. The same configuration beams were used in all these cases; general patient contours alone were altered.

**Results:** For dose estimations, the skin was delineated as a 2 mm layer beneath the patient's body contour. The comparisons showed that the average dose on the skin, among all the patients included in this study, in the case of body contour alone is 3.3 Gy, whereas in the case of body contour with headrest, it is 6.3 Gy and in the case of body contour with headrest, couch and immobilization mask it is 9.4 Gy.

**Conclusion:** For brain tumors, located in the posterior fossa and near the patient's skin, the skin needed to be included as a critical structure. The skin dose should be considered when evaluating treatment plans, taking into account the bolus effect of the headrest and couch.

**Keywords:** skin toxicity; dose calculation; VMAT; posterior fossa brain tumors.

## Introduction

Radiotherapy has been successfully applied in the field of oncology. The benefits of irradiation could be further improved by encouraging a better understanding of the normal skin reaction post radiation doses. In spite of the currently available advanced radiotherapy facilities, high radiation doses continue to induce dose-dependent skin reactions in the area treated [1, 2]. The severity of the irradiation effects on the skin ranges from mild erythema (red rash) and dry desquamation (itchy, peeling skin) to more severe moist desquamation (open wound) and ulceration [3].

Skin reaction and injuries are dose dependent. The National Cancer Institute (NCI) has established a skin reaction grading system [4], according to which, the severity can range from grades 1 to 4, with 1 being the least severe and 4 including the severest complications [5].

According to the NCI classification, skin reactions for doses up to 10 Gy are usually classified as grade 1. For doses lower than 2 Gy, the conventional rating is no skin reaction. Certain less serious effects like transient erythema and alopecia may occur in doses between 2 and 10 Gy.

Skin reactions that may be observed post doses between 10 and 15 Gy belong to grades 1 and 2 of the NCI classification. Besides erythema and epilation, dry desquamation, telangiectasia and skin weakness are also possible.

The severest skin reaction (NCI grades 3 and 4) may occur at doses above 15 Gy. At these doses, edema, acute ulceration, dermal necrosis, dermal atrophy and/or indurations

\*Corresponding author: Oxana A. Pashkovskaya. Center for Radiosurgery and Radiotherapy of Federal State Institute "Academician E.N. Meshalkin Novosibirsk State Research Institute of Circulation Pathology". Novosibirsk, Russian Federation. E-mail: [oxana.pashkovskaya@gmail.com](mailto:oxana.pashkovskaya@gmail.com)

and late skin breakdown are possible. In such cases surgical intervention may be required [5].

Posterior fossa brain tumors, similar to high grade gliomas, medulloblastomas, ependymomas, are usually subject to radiation therapy in the course of their treatment [6]. The whole brain can be exposed to radiation or it could be focused onto only a specific region of the brain.

Based on the tumor location, size, grade and type of brain cancers, the standard radiation dose of 48-60 Gy is delivered in 1.8 to 3.0 Gy per fraction [7-10]. Treatment delineation is based on MRI after fusion with CT images. New techniques for dose planning such as intensity modulated radiotherapy (IMRT) and VMAT have been provided for better dose conformity and allow limiting the sensitive tissues adjacent to the target. For some patients, the tumor is located close to the patient's skin, especially for those patients who have undergone a prior surgery. In these cases, planning treatment volume (PTV) includes the patient's skin.

Usually, the dose calculation is restricted by patient body contour, although the radiotherapy beams from different angles can spread onto the treatment couch and headrest. Therefore, the actual dose is not restricted by patient body contour, as the couch and headrest definitely alter the dose distributions.

**The objective of this study** was to compare the influence of the headrest and treatment couch during dose planning, on the dose distributions and skin injury post irradiation.

## Material and Methods

The study was performed on 14 patients with brain tumors such as high grade gliomas (10 pts), medulloblastomas (2 pts), ependymomas (2 pts), which had been treated at the Center of Radiosurgery and Radiotherapy of the Meshalkin Research Institute of Circulation Pathology (Novosibirsk, Russia). In all the cases, irradiation had been performed using a stereotactic LINAC (Elekta Axesse, Elekta Instruments AB, Stockholm, Sweden) with thermoplastic masks to immobilize the patients. For patient comfort and additional set-up reproducibility, different headrests were used, to suit the patient's anatomical features.

A pretreatment CT scan was done using the CT scanner (Aquilion LB; Toshiba Medical Systems, Tokyo, Japan) and fusion of the images and delineation of the target and adjacent structures were performed using FocalPro workstation (Elekta Instruments AB). The dose was planned with the ERGO++ stereotactic treatment planning system (TPS) (Elekta Instruments AB). All treatment plans were calculated for 6 MeV energy on the Elekta Axesse LINAC and included VMAT technique. The doses were calculated with a 2-mm grid resolution. Eleven treatment plans (80%) had one noncoplanar arc added for optimal dose distribution.

For each patient, three different contours were created. The first was the normal body contour, which was delineated with automated segmentation techniques in FocalPro. The headrest was included in the usual body contour in the case of the second case studied. For the third case, we manually delineated the headrest, couch and immobilization mask in

addition to body contour.

The skin was delineated as a 2-mm layer beneath the patient's body contour. The head skin (scalp and facial skin) alone was included in the estimations.

Dose distributions were then calculated for the first case without the use of immobilization devices (case 1). Other cases were recalculated with the same beam configurations as for case 1. The DVH were analyzed.

## Results

A total of 14 patients were included in the current study. From the database of brain tumor patients, only those with tumors located in the posterior fossa were selected.

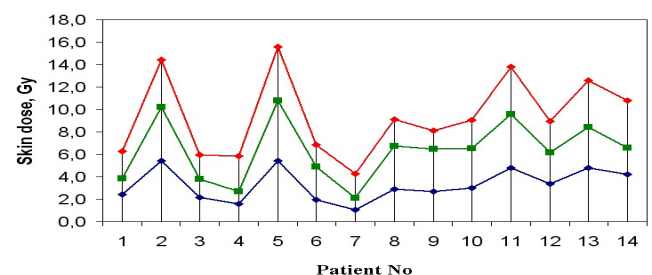
Table 1 presents the patient's clinical characteristics and treatment details such as PTV and total dose. Fig. 1 demonstrates the doses to the skin for the cases studied.

**Table 1.**

*The patient's clinical characteristics and treatment details*

| Patient No. | Sex | Age | Type of tumor   | PTV (cm <sup>3</sup> ) | Total dose, Gy |
|-------------|-----|-----|-----------------|------------------------|----------------|
| 1           | F   | 41  | AA              | 122                    | 48             |
| 2           | M   | 51  | GBM             | 310                    | 60             |
| 3           | M   | 28  | GMB             | 71                     | 54             |
| 4           | M   | 5   | medulloblastoma | 21                     | 53.2           |
| 5           | F   | 51  | AA              | 357                    | 60             |
| 6           | M   | 42  | ependymoma      | 245                    | 54             |
| 7           | F   | 5   | medulloblastoma | 14                     | 53.1           |
| 8           | F   | 33  | AA              | 120                    | 48             |
| 9           | M   | 28  | GBM             | 71                     | 54             |
| 10          | M   | 7   | GBM             | 51                     | 50,4           |
| 11          | F   | 48  | GMB             | 327                    | 60             |
| 12          | M   | 5   | ependymoma      | 108                    | 55,8           |
| 13          | F   | 45  | AA              | 417                    | 60             |
| 14          | F   | 48  | GBM             | 379                    | 60             |

**Abbreviations:** F- Female; M- Male; AA - anaplastic astrocytoma; GBM - glioblastoma.

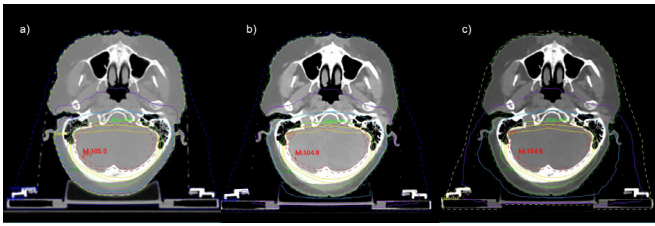


**Figure 1.**

*Doses to the skin for studied case: 1) blue points – only patient's body contour, 2) green points – body contour including headrest, 3) red points – body contour with headrest, couch and immobilization mask.*

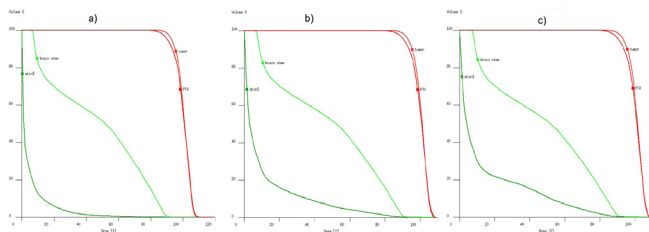
The comparisons showed that the average dose on the skin, among all the patients included in this study, in the case

of body contour alone is 3.3 Gy, whereas in the case of body contour with headrest, it is 6.3 Gy and in the case of body contour with headrest, couch and immobilization mask it is 9.4 Gy (Figure 2 and 3). Figure 3 shows the DVH for the methods studied regarding body contour delineations.



**Figure 2.**

Examples of CT images with planning isodose lines. a) only patient's body contour; b) body contour+headrest, c) body contour + headrest, couch and immobilization mask.



**Figure 3.**

DVH for a) patient's body contour, b) body contour+headrest, c) body contour + headrest, couch and immobilization mask.

## Discussion

Skin dose during radiotherapy is one of the important factors associated with complications in radiation therapy and influences patient's health-related quality of life. Of note, some studies have showed an association between radiation therapy and basal-cell carcinoma induction [11-13]. Until recently, only a few studies have been conducted on the accuracy of skin dose calculation [14, 15]. According to this paper the skin dose load calculation is generally provided within  $\pm 25\%$  accuracy. The use of thermoplastic immobilization masks increases the skin dose [16, 17]. The optimization strategy during planning and multiple tangential beams can increase the skin dose [15]. Court et al. [15] reported an agreement between the skin doses calculated by Eclipse TPS and those measured by micro-MOSFET (metal oxide semiconductor field effect transistors), and the hemispheric phantom dose was within  $\pm 20\%$  for 95% of all the points measured.

In the current paper, the influence of the headrest and treatment couch during dose planning on dose distributions was investigated by including them in the calculation volume. Fig. 1 shows that using the actual body contour for dose calculation is an underestimation of the dose on the patient's body surface. One of the patients was administered a 5.6 Gy dose to the skin, calculated without taking into account the immobilization devices. Moist desquamation was observed as an early side effect of the irradiation. After recalculation

of the treatment plan including the headrest and couch, the ideal planning dose to the skin was found to be 15.6 Gy. Figs. 2 and 3 also demonstrate examples of increasing the dose to the skin for patients with ependymoma, at PTV=245 cm<sup>3</sup> after recalculation. Dose isolines spread to the headrest and couch through the skin, contrary to the case with actual body contour, where they are concentrated just beneath the skin surface. The DVH also indicates the increasing dosage to the skin.

## Conclusion

For patients with tumors located in the posterior fossa and/or near the patient's skin, more accurate skin dose calculation is required. Also, the bolus effect of the headrest and couch should be considered when evaluating the treatment plans.

## References

1. Valentin J. Avoidance of radiation injuries from medical interventional procedures. *Ann ICRP* 2000; 30(2):7-67.
2. Maddock-Jennings W, Wilkinson JM, Shillington D. Novel approaches to radiation-induced skin: a literature review. *Complement Ther Clin Pract* 2005; 11(4):224-31.
3. Bolderston A, Lloyd NS, Wong RK, Holden L, Robb-Blenderman L. The prevention and management of acute skin reactions to radiation therapy: a systematic review and practice guideline. *Support Care Cancer* 2006; 14(8):802-17.
4. Cancer Therapy Evaluation Program. Common Terminology Criteria for Adverse Events, v3.0 (CTCAE). Publish Date: August 9, 2006. [http://ctep.cancer.gov/protocolDevelopment/electronic\\_applications/docs/ctcae3.pdf](http://ctep.cancer.gov/protocolDevelopment/electronic_applications/docs/ctcae3.pdf)
5. IAEA Radiation protection of patients (RPOP). Skin injuries: Occurrence and Evolution. [https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/5\\_InterventionalCardiology/skin-injuries.htm](https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/5_InterventionalCardiology/skin-injuries.htm)
6. Laperriere N, Zuraw L, Cairncross G. Radiotherapy for newly diagnosed malignant glioma in adults: a systematic review. *Radiother Oncol* 2002; 64(3):259-73.
7. National Comprehensive Cancer Network (NCCN) Clinical Practice Guidelines in Oncology™. *Central Nervous System Cancers* (V.2.2013). Retrieved May 6, 2013 from [http://www.nccn.org/professionals/physician\\_gls/pdf/cns.pdf](http://www.nccn.org/professionals/physician_gls/pdf/cns.pdf).
8. Stupp R, Tonn JC, Brada M, Pentheroudakis G; ESMO Guidelines Working Group. High-grade malignant glioma: ESMO Clinical Practice Guidelines for diagnosis, treatment and follow-up. *Ann Oncol* 2010; 21 Suppl 5: v190-3.
9. Clarke J, Butowski N, Chang S. Recent advances in therapy for glioblastoma. *Arch Neurol* 2010; 67(3):279-83.
10. Quick A, Patel D, Hadziahmetovic M, Chakravarti A, Mehta M. Current therapeutic paradigms in glioblastoma. *Rev Recent Clin Trials* 2010; 5(1):14-27.
11. Shore RE. Overview of radiation-induced skin cancer in humans. *Int J Radiat Biol* 1990; 57: 809-27.
12. Karagas MR, McDonald JA, Greenberg ER, Stukel TA, Weiss JE, Baron JA, et al. Risk of basal cell and squamous cell skin cancers after ionizing radiation therapy. For The Skin Cancer Prevention Study Group. *J Natl Cancer Inst* 1996; 88(24): 1848-53.
13. Licher MD, Karagas MR, Mott LA, Spencer SK, Stukel

TA, Greenberg ER. Therapeutic ionizing radiation and the incidence of basal cell carcinoma and squamous cell carcinoma. The New Hampshire Skin Cancer Study Group. *Arch Dermatol* 2000; 136 (8):1007-11.

14. Chung H, Jin H, Dempsey JF, Liu C, Palta J, Suh TS, Kim S. Evaluation of surface and build-up region dose for intensity-modulated radiation therapy in head and neck cancer. *Med Phys* 2005; 32(8):2682–9.

15. Court LE, Tishler RB, Xiang H, Allen AM, Makrigrigorgos

M, Chin L. Experimental evaluation of the accuracy of skin dose calculation for a commercial treatment planning system. *J Appl Clin Med Phys* 2008; 9(1):29-35.

16. Lee N, Chuang C, Quivey JM, Phillips TL, Akazawa P, Verhey LJ, et al. Skin toxicity due to intensity-modulated radiotherapy for head-and-neck carcinoma. *Int J Radiat Oncol Biol Phys* 2002; 53(3):630–7.

17. Hadley SW, Kelly, R, Lam K. Effects of immobilization mask material on surface dose. *J Appl Clin Med Phys* 2005; 6(1):1–7.

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