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In Vivo Lens Dosimetry in a Case of En Face Electron Adjuvant Radiotherapy for Cutaneous Nasal Bridge Basal Cell Carcinoma: A Case Report

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Abstract

Radiation therapy represents one of the main treatment modalities for basal cell carcinoma (BCC), the most common type of skin cancer. The proximity of organs at risk (OARs) increases the risk of side effects. Treatment planning system (TPS) estimates the absorbed dose, but the real value can be determined only by in vivo dosimetry.

We measured the absorbed dose at the lenses' level in a case who received electron irradiation for a resected BCC with positive microscopic margins, located at the bridge of the nose. The thermoluminescent eye lens dosimeters (TLD) were placed under the lead protections. We compared the measured dose with the values estimated by TPS.

The treatment involved delivering 50 Gy in 25 fractions. A Monaco 5.11 Treatment Planning System (TPS) was used to plan treatment with a 9 MeV electron field and a 10x10 cm applicator at a 100 cm Source-to-Skin Distance (SSD). Customized lead layers and circular lead blocks were used for protection.

The TPS estimated maximum doses of 5.87 Gy for the left lens, and 2.70 Gy for the right lens, respectively. After measuring the doses for the first three fractions by TLD, we calculated that maximum dose for the left lens would get to 0.55 Gy, and to 0.30 Gy for the right lens.

In this case report we show that irradiation for a BCC localised at the bridge of the nose is possible with proper shielding and can be safely delivered, without exposing the patient to long-term side effects.

Keywords: *eye shield, case report, lead protection, electron radiotherapy, basal cell carcinoma*

1. Introduction

BCC is a skin cancer type that appears most often on areas of skin exposed to the sun, such as the face (1). BCC often looks like a brown or glossy black bump and has a rolled border. This type of cancer requires unique treatment planning, a challenge for the medical personnel. The available treatment options are variable and can include cryotherapy, surgical excision,

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radiation therapy (RT), and topical agents, or often a combination of these approaches (2,3).

2. Case Presentation

We present the case of a patient, diagnosed during COVID-19 restrictions with BCC localised at the bridge of the nose region resected with positive R1 margins (Figure 1). The histopathological report described the BCC lesion on an irregular skin flap with a size of 20 x 17 mm. We concluded that the lesion infiltrated the skin to the deep dermis, having a thickness of 3 mm, and also infiltrated the edge of lateral and deep surgical excision.The objective of the study was to measure and compare the calculated doses to the lenses from the TPS with the received dose during the treatment, emphasising patient safety as a core value of radiotherapy.

Figure 1. Clinical presentation – image after surgery

3. Contouring and Planning

A computed tomography (CT) scan used for treatment planning was made in supine position, and for immobilisation, we used a 5-point thermoplastic mask. The mask was removed at the nose bridge region for optimal unobstructed irradiation with electron beams. We obtained CT images of the head, acquired using a Siemens CT Simulator. The slice thickness was 3 mm with coverage of all critical organs from the interest zone (see below). The thermoplastic mask was a Green S-type open EM Head Mask with AccuPerf, with a 3.2 mm thickness, which we heated in a water bath at 70 ℃. The mask material becomes mouldable when thoroughly warm, allowing us to fit it perfectly to the patient's face. Once the mask cools, it becomes rigid and highly durable (4,5).

The patient's outline contour was created by the auto-contouring tools from the TPS, and a radiation oncologist performed the target volume and the organs at risk (OARs) contour tracing. We created clinical target volume (CTV) including the nose bridge region, according to the preoperative description of the lesion and pathology report with the addition of a 1.5 cm margin to the tumour bed (6). We created the planning target volume (PTV) with 0.5 cm margins from the CTV. We considered the following structures as OARs: brain, brain stem, left and right eye, hypophysis, left and right lacrimal gland, left and right lens, optic chiasm, left and right optic nerve, left and right retina, and the spinal cord. As part of the contouring, the physicist had the responsibility to create virtual shielding structures that had the same characteristics as the actual physical ones used during the treatment delivery.

After careful consideration of different treatment options, brachytherapy, external RT with kV beam, electron beam or photon, available in our clinic or at different institution, we have reached a common decision with the patient, and we have chosen a 3D-CRT en face electron irradiation approach. We argued for an electron beam irradiation technique because it is characterised by a rapid dose falloff at a depth below the skin surface, having little radiation exposure beyond a defined depth (6). Considering the localisation of the tumour we decided to deliver a dose of 50Gy in 25 fractions. In this conventional planning technique, we used an anterior beam, with lead protection of the OARs from these regions and eye shields. The lead protection and the eye shields were virtually simulated according to the ones which were used during the treatment The plan calculation was realised on Monaco 5.11treatment planning system (TPS) with

Monte Carlo calculation algorithm. The used energy was 9 MeV, chosen due to the depth of the target, with a gantry angulation of 345 degrees and a couch rotation of 90 degrees. The applicator size was set to 10 x 10 cm, the SSD was 100 cm, and the plan prescription was in depth of beams at 2.5cm （Figure 2a-c). To protect the critical structures, we placed 2 customised layers of 0.3cm lead protection on the applicator and 2 additional single-layer circular blocks of lead on the eyes (similar in size and shape to TPS-created structure (Figure 2d-*f*).

We measured the equivalent dose with two TLD-Hp(3)-type eye lens dosimeters, which were positioned under the orbital lead protections (7). For treating the PTV, we set the objective that the 80% of the tumoral volume (V80%) of the dose should cover a minimum of 95% of the target volume (8), and the dose for the OARs should be as low as possible (Table 1).

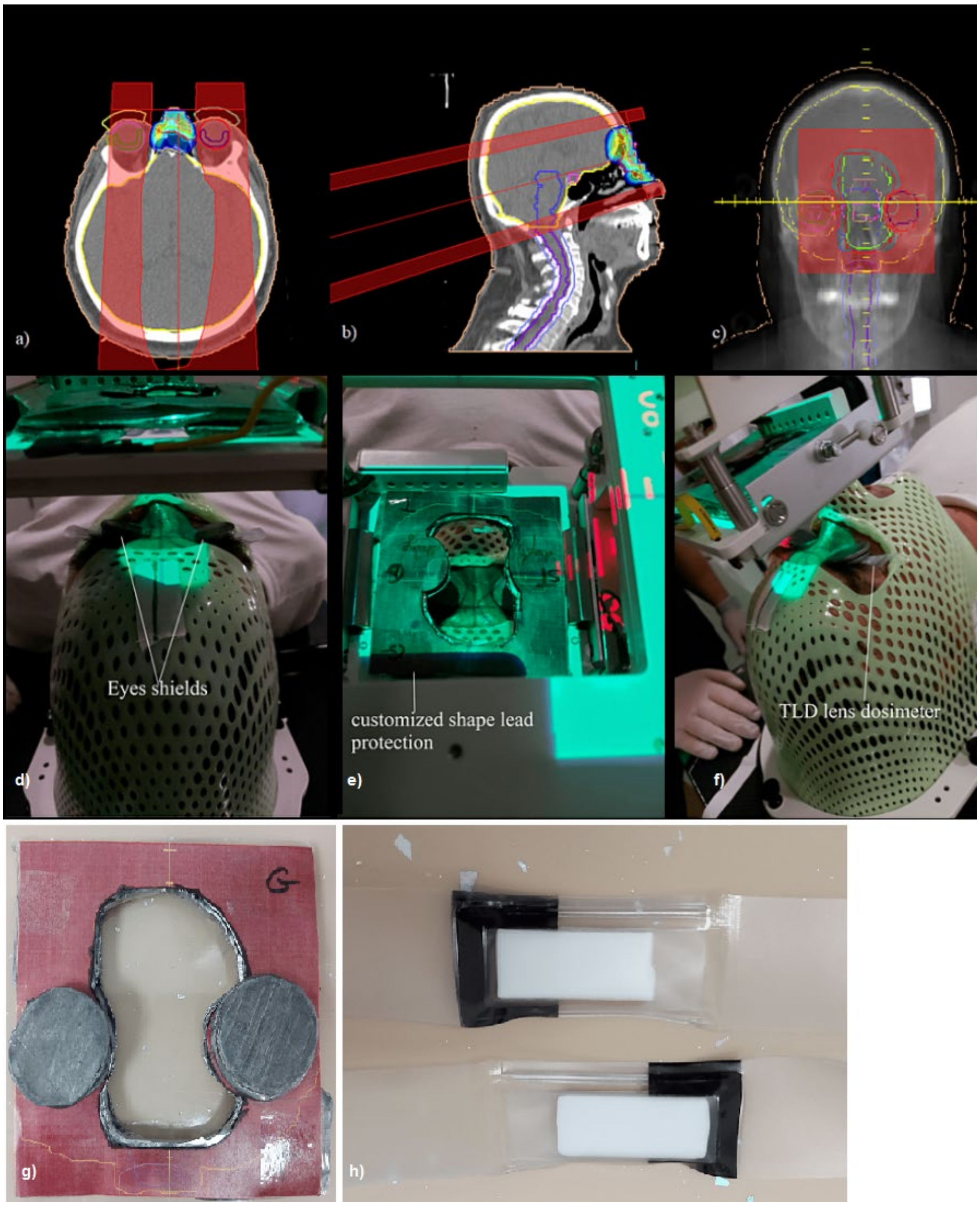

Figure 2. Beam’s Eye view (BEV): a) transversal plane, b) sagittal plane, c) frontal plane imagines, d-f) Patient set-up during the treatment delivery with personalized lead protection for the eyes, g)Customized shape lead protection with circular blocks for eyes h) Termoluminescent dosimeters (TLD) Hp(3)

4. Results

Following the evaluation of the target volume, we obtained PTV 50 Gy coverage of 98.11%. The maximum dose on the plan was 70.74 Gy, which is equivalent to a maximum of 141.48%. We had a volume of 0.74 cm^3 (cc), which received a dose of 60 Gy (120%). For a more accurate evaluation, we developed a treatment plan that involved the delivery dose of 60 Gy. This plan showed no significant improvement in terms of either the coverage of the PTV or the OARs (Table 1).

Table 1: Dose constraint compliance for OARs and dose comparison between the 50 Gy and 60 Gy RT plans in case of a BCC irradiation

Goal or Dose constraints		**60 Gy/30 fr**	**50 Gy/25 fr**
PTV V80		95.50%	98.11%
PTV V85%		92.69%	96.43%
PTV V90%		88.52 %	93.42%
PTV V95%		81.87%	90.05%
Dmax		131.70% (79.027 Gy)	141.4% (70.738 Gy)
Lens Left	Dmax<7Gy	6.561 Gy	5.873 Gy
Lens Right		3.018 Gy	2.701 Gy
Retina Left	Dmax < 45 Gy (50 Gy)	34.016 Gy	30.448 Gy
Retina Right	Dmax < 45 Gy (50 Gy)	23.123 Gy	20.698 Gy
Eye Left Dmax	Dmax < 50 Gy	37.188 Gy	33.287 Gy
Eye Right Dmax	Dmax < 50 Gy	27.679 Gy	24.776 Gy
Optic Nerve Left	Dmax < 55 Gy (3%)	23.123 Gy	20.698 Gy
	54 Gy < 0.01 cc	18.165 Gy	16.165 Gy
Optic Nerve Right	Dmax < 55 Gy (3%)	14.395 Gy	12.885 Gy
	54 Gy < 0.01 cc	10.455 Gy	9.355 Gy
Optic Chiasm	Dmax < 55 Gy (3%)	2.999 Gy	2.684 Gy
	54Gy <0.01 cc	1.902 Gy	1.702 Gy
Brain	Dmax < 68 Gy	67.764 Gy	60.656 Gy
	60 Gy < 1 cc	62.627 Gy	56.058 Gy
Brain stem	Dmax < 54 Gy (59 Gy)	0.882 Gy	0.79 Gy
	54 Gy < 0.1 cc	0.753 Gy	0.674 Gy
Hypophysis Dmax	Dmax < 50 Gy	1.944 Gy	1.74 Gy
Spinal Cord Dmax	Dmax < 45 Gy	0.398 Gy	0.363 Gy

**BCC – basal cell carcinoma, OAR – organ at risk, RT – radiation therapy, Gy – Gray, measurement unit, Fr – fraction, PTV – Planning target volume*

Evaluating the conformity index (CI) and the homogeneity index (HI) for this setting, we obtained the values HI = 0.37 and CI = 1.01 for the first plan (where we planned to deliver 50 Gy in 25 fractions) and HI = 0.38 and CI = 0.90 for the second plan (where we planned to deliver 60 Gy in 30 fractions).

For evaluation of the treatment plan, we used DVH parameters. (Table 1). Because of better coverage and the novel protection approach we were using; we chose the more conservative approach of 50 Gy/25 fraction (fr). We delivered a total of 253.84 MUs. For in vivo dosimetry we used 2 TLD lens dosimeters, which were placed under the eye shielding (Figure *2d)-f)*). We measured the doses for 3 consecutive days followed by the mathematical interpretation of the results. We obtained absorbed doses for both lenses around 10 times smaller than those calculated through the TPS (Table 2).

Table 2. Dose measurement results and conversion from equivalent dose to absorbed dose (1 mSv= 0.001 Gy)

	Measured Doses			**Estimated Doses (TPS)**
Lens	**mSv/ fr**	**Gy/ fr**	**Total 50 Gy/25 fr**	**Total 50 Gy/25 fr**
Left	12.67	0.01267	0.317	2.701
Right	22.24	0.02224	0.556	5.873

**TPS – Treatment Planning System, mSV – millisievert, Gy – Gray, fr – fraction*

5. Follow-up

We continuously evaluated the patient's condition during the treatment, noting expected adverse events for RT on the skin and good responses to topical treatments for radiation dermatitis. We instructed the patient to perform periodic routine check-ups both at surgical and radiation oncology departments. At the first follow-up (3 months post-RT), late side-effects of RT were hyperpigmentation G1, skin dryness G1, pruritus G1, skin induration G2 and hot flashes G1 in the treated area (Common Terminology Criteria for Adverse Events - CTCAE v5 grading). Imaging via regular CT or magnetic resonance imaging (MRI) imaging with contrast, to monitor the head and neck region for potential regional recurrence, was recommended, this likewise showing patient as disease-free.

6. Discussion

Here, we report a case where we applied a treatment plan to a delicate anatomical region. We applied it with a linear accelerator commissioned to electron beam therapy, a therapy we consider a potentially viable strategy in BBC irradiation to improve treatment compliance and reduce costs. Because of distinct planning limitations owing to the variability of resources facilities equipped with either contact RT, brachytherapy, or 3D-printed bolus solutions available for RT departments, it is challenging to suggest a one-size-fits-all radiotherapeutic guideline for BBC treatment of the nose.

In the planning phase we considered alternative treatment options, with all specialities of the RT staff (physician, physicist, and RT technician) giving input. We took into consideration the use of orthovoltage, brachytherapy, and the application of bolus materials. We considered the possibility of using bolus materials impractical because of the anatomical curvature of the nasal region and the possible variability with daily reproducibility over several fractions.

It has been documented that the COVID-19 pandemic increased anxiety among cancer patients with high levels of distress calling for a multidisciplinary perspective. Likewise, patients' mobility and perception of risk has been affected during the pandemic (12). Taking these into account we could not consider the option of brachytherapy and orthovoltage (available at distant medical facilities) because of poor accessibility and logistical reasons, the patient having informed us of these limitations beforehand. Thus, we consider direct electron beam irradiation an optimal compromise for this patient.

In the setting of adjuvant RT for an R1 resection of BCC, the administered dose should approach 60 Gy/30 fr (8). In the multidisciplinary meeting, because of anatomical particularities of the target volume, we reached a compromise to deliver a dose of 50 Gy in 25 fractions. Upon slice-by-slice review of the RT plan we noted that the hot spots reaching ≥ 60 Gy were in the positive margin region (towards the eyes) in corroboration with the postoperative pathological report. Hypofractionation schemes have also been proposed but due to lack of experience with higher dose per fraction with electron RT the choice was made to continue with a traditional 2Gy/fr approach.

Among the techniques we have in our department, we considered the most optimal to be electron beam therapy, even when taking into account its limitations compared to other irradiation methods. Limitations of our technique include the uncertainty of beam homogeneity after entry because of the lack of flat surfaces, creation of hot spots and daily reproducibility variations. We tried to address these shortcomings by making sure that no thermoplastic mask material was interposed between the skin and the beam, as well as by using double lead shielding on both the applicator and on the eyes. As a technique, we consider our solution a straightforward and treatment which requires additional verification of compliance for each step according to guideline recommendations, by the physicist and the attending physician (6,9,10). We guaranteed our set-up reproducibility by a detailed description of immobilisation devices used, mapped photographs for RT technologists and participation of the entire treatment team every second and third fraction. In a similar study to ours Wang et al (11) conducted a study in which they measured the dose of the eye by using a 3D-printed bolus eye shield, concluded with similar results with ours. The difference between the two studies was the fact that the wax bolus permitted to have a simulation CT scan of the surface, while the lead protection used in our approach would lead to significant artifacts.

7. Conclusions

To our knowledge, this report is among the first to describe en face adjuvant electron radiotherapy treatment in which lead protection was used for shielding the eyes. With the aforementioned impediments, we consider that the treatment has been safely delivered under strict dosimetric supervision and represents a cost-effective alternative for cases where other options are logistically inopportune for the patient, made even more difficult by local COVID-19 restrictions. With the possibility of a relatively easy reproducibility of our approach and the accumulated experience, we feel confident about potentially escalating doses, applying hypofractionated schedules, and including a larger number of patients in the form a prospective registry of en face electron radiotherapy.

Abbreviations:

BCC – basal cell carcinoma
Gy – Gray, measurement unit
TPS – treatment planning system
SSD – Source - surface distance
RT – radiation therapy
CT – computed tomography
OAR – organ at risk
CTV – clinical target volume
PTV – Planning target volume
3D-CRT – 3D conformational radiation therapy
CI – Conformity index
HI – Heterogeneity index
DVH – dose volume histogram
MU – Monitor Unit
Fr – fraction

Statements:

Authors' contributions: Conceptualization: GS, KV, DP; Investigation and Validation: GS, KV; Writing- Original Draft preparation: GS, DP; Writing - Review & Editing: GS, DP, ZB; Visualization: GS, DP; Project Administration: GS, DP; Supervision: ZB, DP; Final approval of manuscript: GS, DP, KV, ZB.

Consent for publication: As first author, I confirm that the manuscript has been read and approved by all authors and that the order of authors listed in the manuscript has been approved by all of us.

Conflict of interests: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be a potential conflict of interest.

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Statement of Ethics: This study was approved by the TopMed Clinic ethics committee (84/26.09.2023)

Informed consent for publication: An informed consent was obtained from the patient for publication of this case report and any accompanying images.

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