CASE REPORT
ONCOLOGY

Diseases & Research

Initial Experience in Using Optical Coherence Tomography in Defining Radiation Fields for Head and Neck Basal Cell Carcinoma

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Abstract: Definitive Radiotherapy (RT) brings tissue conservation. Skin cancer RT area delineation can be a challenge especially in basal cell carcinoma (BCC) with morpheaform features. We report our initial experience of 11 consecutive patients imaged with Optical Coherence Tomography (OCT) prior to treatment. The gross tumour volume (GTV) was marked by a radiation oncologist (RO) using a strong light only. OCT was then done by a dermatologist blinded to the RO markings. The difference in areas, if any, were computed and tabulated. Relevant outcomes were recorded. Of the 11 patients there were nine females and two males. Average age was 65 (47–87) years. Patients had initially a total of 13 lesions between them. Of the initial 13 lesions, seven were lesions without previous treatment, five were recurrent post-surgery, one post-cryotherapy. The most common site was the nose (8/13), then lips (2/13). Eyelid, scalp and temple had one each. There were a mix of BCC histologies; infiltrating (4/13), nodular (5/13) morpheaform (3/13) and one was unclassified. The initial RO GTV area on average was 584 (50–2400) mm^2, the average OCT area was 420 (63–2350) mm^2. OCT decreased the size of the GTV with an average change of 164 (-1650 to + 760) mm^2, that is, 28%. The assistance of OCT was not limited to morpheaform lesions. OCT also found three more BCCs, and one lesion thought clinically to be BCC was not. OCT avoided a geographic miss. Three (3/11) were treated with other modalities; two with Moh's surgery, one with Rhenium-188. Eight patients with ten lesions were treated with definitive RT. RT was planned using the OCT area as the correct area. All had clinical complete response (CR) at post-RT follow up. In the five patients having OCT following RT, all had a continuing complete response at an average of 6.8 months post-RT.

Keywords: Skin cancer; Radiotherapy; Survivorship; Optical coherence tomography; Basal cell carcinoma; Australia.

Introduction

The incidence of skin cancer is increasing worldwide[1]. Australia has the highest incidence in the world[2]. Incidence increases with age[3]. The elderly may not be able to have surgery due to comorbidities, others may decline due to the functional and cosmetic impact of tissue loss[4].

Definitive Radiotherapy (RT) brings tissue conservation[5]. To ensure cure and best quality survivorship, it is important to get the dose and volume correct when treating skin cancer. Radiotherapy dosimetry is standard across many guidelines[6–8]. Radiotherapy volumes can be variable amongst clinicians[9]. Skin cancer volume delineation requires knowledge of the depth and area to be treated. Depth can be assessed clinically by a variety of means including palpation, the result of the diagnostic biopsy and various non-invasive imaging modalities[10].

Area assessment is crucial for determining RT volumes such as gross tumour volume (GTV)[11] and the resultant field size that is needed. Area delineation can be a challenge especially in cancers with morpheaform features[12]. Morpheaform change is when tumour cells extend beyond what is observed clinically[13]. See Fig. 1. We report our initial experience of series of consecutive cases of basal cell carcinoma (BCC) imaged with Optical Coherence Tomography (OCT) prior to treatment.

Methods

The medical records of consecutive patients offered OCT for delineation of biopsy proved BCCs with unclear margins clinically

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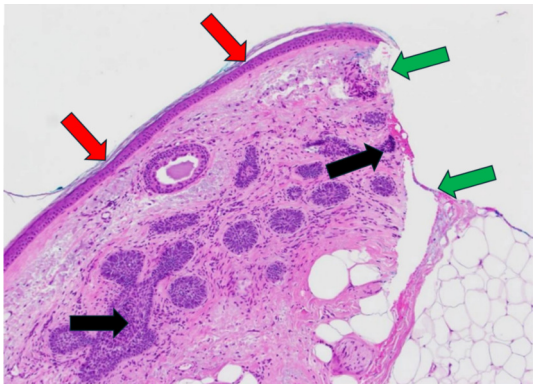

Fig. 1. The problem of morpheaform change.
This is a photo micrograph of a low magnification image of a margin of an excision of a basal cell carcinoma with morpheaform change. The red arrows show the intact epidermis. The black arrows point out where, in the dermis, there are nests of basal cell carcinoma. These nests are progressing underneath the intact epidermis and are involving the margin of the excision, which is indicated by the green arrows. This would need to be called margin positive by the histopathologist. The clinical appearance of the area of skin over this morpheafrom change would have looked like normal skin, except perhaps for obliteration of the skin pores by the advancing edge of the BCC.

were studied. All patients consented to the use of their de-identified data. Details such as sex, age, anatomical position of the BCC (s), prior therapy and latest histopathology, if any, were extracted. The initial area size of the lesion was demarcated clinically by the radiation oncologist (RO) using a strong light only. The area was deduced from planning photos and recorded in square millimetres (mm^2). Areas that resembled a rectangle were computed by multiplying the length by the breadth in millimetres (mm). Areas that resembled a circle were computed by using pi, approximated to 3.14, multiplied by the square of the radius in mm. The result in both cases was an area measured in millimetres squared (mm^2). This was the GTV.

OCT was done by a dermatologist with a subspeciality OCT interest who was blinded to the RO markings. The dermatologist provided photographs back to the RO. The areas discovered at OCT were computed in a similar manner and recorded. The difference in areas, if any, were computed and tabulated. Comments were made about the addition of OCT. These results are in Table 1.

For those progressing to definitive RT, RT details such as modality used, dose and fractionation pattern were extracted. The OCT areas were used rather than the original RO GTV for RT treatment planning. For those who had follow up OCT, the response was recorded from the latest OCT. These results are in Table 2.

Statistical Research Methods

Descriptive statistics were employed to summarise patient characteristics and tumour area measurements obtained by the Radiation Oncologist (RO) and by Optical Coherence Tomography (OCT), which was considered the reference standard. Unpaired t test result was done comparing the RO area values with the OCT values. In addition to an area-weighted comparison, a lesion-level analysis was performed whereby each lesion was treated as a discrete observation and categorised as overestimated, underestimated, or accurate. Proportions were calculated, and 95% confidence intervals were derived using the normal approximation to the binomial distribution. All analyses were conducted using Python (v3.12.2).

Results

11 patients who had OCT to delineate their BCCs were discovered. These results are in Table 1. There were nine females and two males. Average age was 65 (47–87) years. They had initially a total of 13 lesions between them. Of the initial 13 lesions,

Table 1. Patient and Tumour Characteristics including area determined by RO versus OCT and treatment given.

No.	Sex/Age	Initial site(s)	Prev Rx	Histo	RO/Area(mm^2)	OCT/Area(mm^2)	Diff in Area(mm^2)	Rx, RT, Mod	Comments
1	F/72	Nose/lip	Surg	Nod Nod	2400/400	750/400	-1650/0	VMAT, SXRT	New BCC found by OCT
2	F/53	Nose	nil	Inf	177	133	-43	VMAT	
3	F/54	Nose	cryo	Inf	79	150	+ 71	VMAT	
4	F/67	Eye/lid	Surg	Uncl	70	63	-7	SXRT	
5	F/74	Nose	Surg	Inf	1000	300	-700	SXRT	A clinical BCC found not to be
6	F/87	Scalp	Surg	Nod	875	600	-275	SXRT	Two new BCCs found by OTC
7	F/64	Nose	Nil	Mor	180	300	+ 120	VMAT	
8	F/56	Nose	Nil	Inf	50	113	+ 63	Mohs	
9	F/47	Nose/Lip	Nil	Mor nod	375 200	79 20	-296 -180	Mohs	
10	M/71	Nose	Nil	Mor	200	200	0	Rh188	
11	M/74	Temple	Surg	Nod	1590	2350	+ 760	VMAT	Geographic miss without OCT
	65 (47–87)	8/13(Noses)			584/(50–2400)	420/(63–2,350)	-164/(-1650 to + 760)		

No., Number; Prev Rx, Previous treatment; Histo, Histology; RO, Radiation Oncologist; OCT, optical coherence tomography; mm^2, millimetres squared; Diff, difference; Rx, treatment; RT, Radiotherapy; Mod, Modality; Gy, Gray; #, fraction; F, female; M, Male; Surg, surgery; VMAT, Volumetric Modulated Arc Therapy; SXRT, Superficial radiotherapy; BCC, basal cell carcinoma; Cryo, cryotherapy; Inf, infiltrative; Mor, morpheaform; Nod, nodular; Ave, average; Tot, total.

Table 2. Characteristics of eight patients with ten lesions treated with definitive RT with five patients having had repeat OCT at least 6 months post-RT.

Pt No.	RT/ Mod	Gy//#	Rpt OCT	Clinical FU
1	VMAT/SXRT	60/30	CR 8/12	CR at 12 months
2	VMAT	69/33	CR 8/12	CR at 10 months
3	VMAT	55/25	CR 6/12	CR at eight months
4	SXRT	60/30	CR 6/12	CR at seven months
5	SXRT/SXRT	47.5/19	Nil	CR at two months
6	SXRT	55/25	Nil	CR at one month
7	VMAT	66/33	CR 6/12	CR at six months
11	VMAT	60/30	Nil	CR at one month
Average		59/29	6.8	

No., Number; OCT, optical coherence tomography; RT, Radiotherapy; Mod, Modality; Gy, Gray; #, fraction; Rpt, repeat; VMAT, Volumetric Modulated Arc Therapy; SXRT, Superficial radiotherapy; CR, Complete response; FU, Follow up.

seven were lesions without previous treatment, five were recurrent post-surgery, one post-cryotherapy. The most common site was the nose (8/13), then lips (2/13). Eyelid, scalp and temple had one each. There were a mix of BCC histologies; including infiltrating (4/13), nodular (5/13) morpheaform (3/13) and one was unclassified.

The initial RO area on average was 584 (50–2400) mm^2, the average OCT area was 420 (63–2350) mm^2. Overall the OCT decreased the size of the GTV. OCT brought an average change of minus 164 (-1650 to + 760) mm^2 from RO GTV to a GTV defined by OCT to the 13 lesions, that is, 28%. The assistance of OCT was not limited to those lesions identified by the histopathologists as having morpheaform change. OCT also found three more BCCs. One clinical lesion thought to be BCC was found to be not. OCT avoided a geographic miss (see case 11 case study).

Eight patients (8/11) went on to definitive RT for ten lesions. Table 2 shows the characteristics of these eight patients with ten lesions treated with definitive RT. Three (3/11) were treated with other modalities; two with Moh's surgery and one with Rhenium-188. In the five patients having OCT following RT, all patients had a continuing complete response at an average of 6.8 months post-RT on OCT. The three patients who had not had OCT post-RT as yet had continuing complete responses on clinical grounds at an average of 1.5 months post-treatment.

Statistical Analysis Results

Unpaired t test result was done comparing the RO area values with the OCT values from Table 1. The two-tailed P value equals 0.54 and is not statistically significant. However, the means differ by (584–419) 165 mm^2 with wide 95% confidence intervals of from -375.32 to 704.24 as expected in such a small disparate group.

Of the 13 lesions, 7 (53.8%) were overestimated by the RO (95% CI: 26.7–80.9%), 4 (30.8%) were underestimated (95% CI: 5.7–55.9%), and 2 (15.4%) were delineated accurately (95% CI: -4.2–35.0%). This per-lesion analysis complements the total area-based results, which showed an average GTV reduction of 28% with OCT guidance, by eliminating lesion size as a confounding factor. See Table 3.

Table 3. Per-lesion classification of Radiation Oncologist accuracy in gross tumour volume (GTV) delineation compared to Optical Coherence Tomography (OCT) reference standard, including percentage distribution and 95% confidence intervals (n = 13 lesions).

Classification	Proportion of Lesions (%)	95% Confidence Interval
Overestimated	53.8	26.7–80.9
Underestimated	30.8	5.7–55.9
Accurate	15.4	-4.2–35.0

Lesions were classified by the direction of deviation between the Radiation Oncologist's (RO) estimation of gross tumour volume (GTV) and the OCT–defined reference area. Of the 13 lesions, 7 were overestimated, 4 were underestimated, and 2 were accurately delineated. Confidence intervals were calculated using the normal approximation to the binomial distribution. Negative lower bounds reflect statistical uncertainty due to small sample size. This analysis complements the area-weighted method by providing an equal-weighted, per-lesion view of estimation tendencies, thereby capturing clinician behaviour rather than tumour size bias.

Case presentation

Example of OCT decreasing the area of treatment

Patient one had discoloration and growing thickness of her nasal skin. Biopsy revealed multifocal BCC. She also had a lip BCC that had been treated with surgery and had recurred. These areas of involvement were delineated by the RO and revealed a large area on the nose measuring 2400 mm^2. The lip GTV was 400 mm^2 she was referred for OCT. The OCT image showed that the true area of the nose GTV was 750 mm^2, a change of 1650 mm^2. The lip GTV was the same as the RO area. The OCT had also discovered another lesion unknown to the RO below the medial canthus of the left eye. She was treated with definitive SXRT to lip and medial canthus and VMAT to the nose. Repeat OCT eight months and clinically one year post-RT had continuing CR. See Fig. 2.

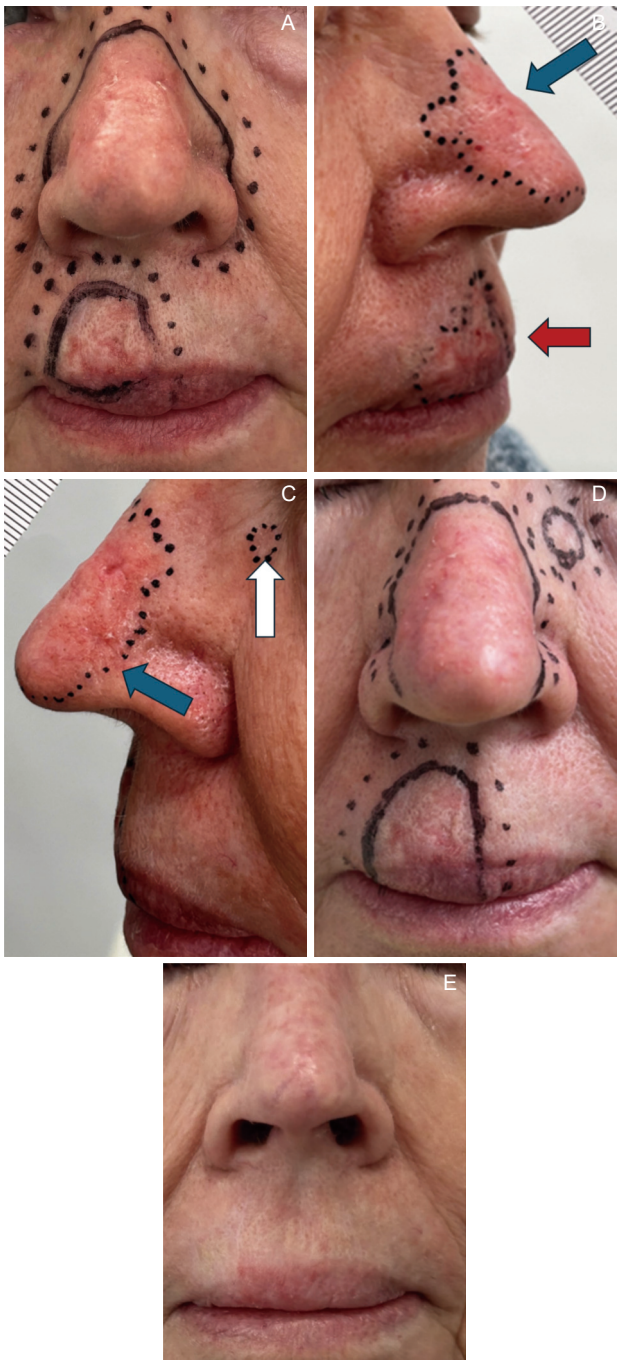

Fig. 2. Example of OCT decreasing the area of treatment from patient one.
A. Patient one: Initial RO clinical mark-up of lesions on the upper right lip and nose. The solid lines show the GTV, the dotted lines show the field edge. The plan was to treat the nose with VMAT and the lip with SXRT.
B. Patient one: Photograph of right anterior projection of OCT, the blue arrow showing the much smaller area delineated as involved by BCC as compared with the RO GTV seen in . Note the red arrow showing the lip OCT which is similar to the RO markup.
C. Patient one: Photograph of left anterior projection of OCT, the blue arrow showing the much smaller area delineated as involved by BCC as compared with the RO GTV seen in . Note the white arrow showing a new area of BCC that was not detected in the RO markup.
D. Patient one: This is the revised RO GTVs and RT field borders based on the OCT. This patient proceeded to treatment based on these areas.
E. Patient one: Anterior photograph taken at last follow up 12 months following definitive RT showing continuing CR in the treated areas. OCT at eight months showed CR.

Example of OCT increasing the area of treatment

Patient seven had a lesion arise almost at the junction of the left nasal ala and the cheek. Biopsy showed morpheaform BCC. The RO GTV was 180 mm^2. The OCT GTV was 300 mm^2, that is, bigger by 120 mm^2. This changed the RT modality used from SXRT to VMAT because of the increased curvature. See Fig. 3.

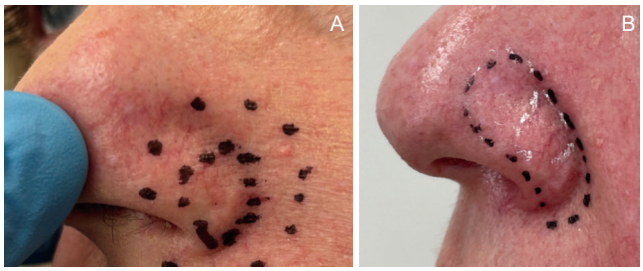

Fig. 3. Example of OCT increasing the area of treatment, from patient seven.
A. Patient seven: This photo shows the original RO markup of a lesion of the left nasal ala. The RO GTV measurement was 180 mm^2.
B. Patient seven: This photo is the OCT GTV which is measured at 300 mm^2. This is an increase of 120 mm^2 from the RO area.

Example of OCT ensuring the correct area was treated

The eleventh patient was referred for RT to a large nodular BCC with diffuse margins on the right face. When the patient was asked where the lesion was, he pointed to his temple. The RO applied a GTV to the temple, but referred for OCT, given the diffuse margins. Later when the photographs arrived from the referrer, it was clear that the planning biopsies had been taken from about 5 centimetres inferior to where the RO decided where the lesion was. If the RO had proceeded without checking the referrer photos or the OCT, this would have resulted in a complete geographic miss. See Fig. 4.

Discussion

We present our initial experience of using OCT to delineate BCCs with clinically unclear margins. Eleven consecutive patients with 13 lesions sent for OCT were initially mapped by one RO with skin cancer experience and then by a dermatologist with OCT expertise and the findings compared. The net change in RT field was overall minus 280 (-1650 to + 760) mm^2.

By adopting a lesion-level classification, we improved the interpretability and generalisability of our findings. This approach mitigates the influence of disproportionately large lesions and reflects clinician-level decision-making patterns. It also enables the use of binomial statistical models and confidence intervals, thereby enhancing the transparency and robustness of our analysis. While the area-based method is appropriate for quantifying radiation exposure, the lesion-based method better represents diagnostic behaviour and may guide future training or quality improvement initiatives.

OCT in general decreased the amount of area that needed to be treated. Eight patients were treated with RT which was planned on the OCT images, the latter being considered the superior image for radiation planning. OCT done at least six months following RT treatment in five patients documented a continuing CR.

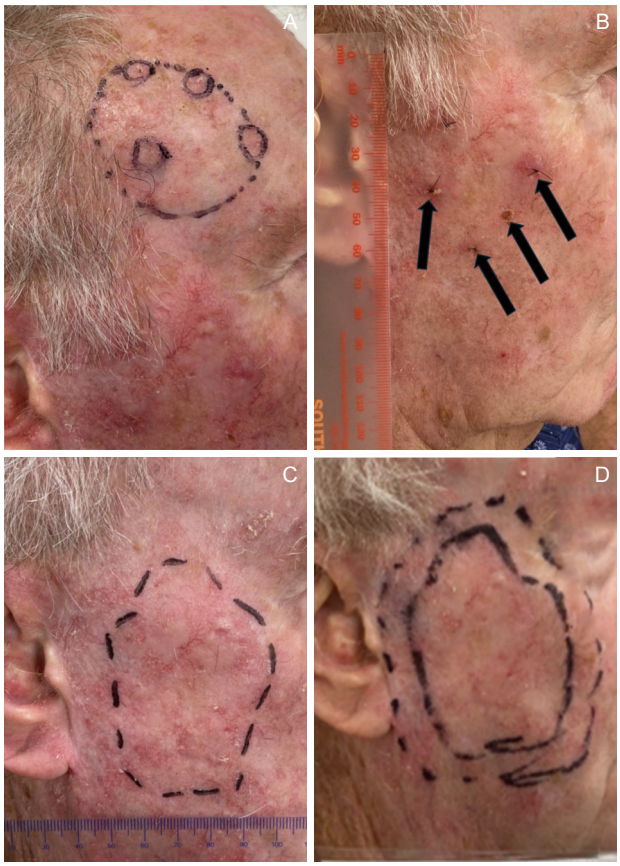

Fig. 4. Example of OCT ensuring the proper area was treated, from patient eleven.
A. Patient eleven: initial assessment RO markup of a lesion of the right face based on patient history before checking referrer's photo or OCT. The RO GTV measurement was 1590 mm^2.
B. Patient eleven: Referrer's photo which arrived after initial assessment. Black arrows indicate positive biopsy site for BCC.
C. Patient eleven: OCT defining of BCC.
D. Final radiation field with inner solid mark being the GTV as defined by the OCT and the outer dashed line being the field edge. The OCT helped to avoid a geographic miss.

OCT led to less tissue being irradiated which is in agreement with the ALARA principle (which stands for "as low as reasonably achievable"). This principle is a guiding principle of radiation safety[14].

OCT had other advantages. OCT added confidence to the RO and patient in treating the correct area. In two cases, new BCCs were found that were unsuspected by the RO and the patient. These were treated concurrently while still small. OCT also showed that one clinical BCC was benign. This shows that OCT has more benefits than just delineating RT fields. Follow up OCT was done at least six months after radiotherapy. This is because the radiotherapy does cause change in the skin which can cause a false positive with OCT if done too soon after RT. Five out of five patients treated with radiotherapy then followed up at six months with repeat OCT showed continuing in-field CR.

RT treatment volumes are the product of depth and area. OCT can also be used to assess depth. Depth can be judged clinically by palpation and referring to the diagnostic biopsy result, assuming that the biopsy was taken in the thickest part and also goes right through the tumour to subcutaneous fat to include the full extent of the tumour depth. Non-invasive imaging modalities that can help assess depth include dermoscopy, reflectance confocal microscopy (RCM), high-frequency ultrasound (HFUS) and optical coherence tomography (OCT)[11]. Our study looked more at area than depth as with the RT modalities used, namely VMAT and SXRT, we were confident that coverage at depth could be easily achieved. Indeed, experienced OCT users say that OCT has reliable depth perception to 1mm but not beyond (Sinz, personal communication). While this study primarily focused on defining the lateral margins of skin cancers using OCT, it is essential to consider the complementary role of HFUS, particularly in the 20–30 MHz range, for full three-dimensional lesion evaluation and measurements.

Moreover, it offers greater resolution at depths of 4–5 mm, allowing for accurate visualisation of tumour depth and vertical extent, which is particularly relevant for infiltrative or deeply invasive subtypes. This may be useful for planning the punch biopsy locations. Several studies have demonstrated that HFUS can reliably assess tumour thickness and detect subclinical extensions not visible to the naked eye or via dermoscopy. Wortsman et al.[15] showed that HFUS had a sensitivity of 94.1% and specificity of 85.7% in detecting the lateral and deep margins of BCCs compared with histopathology. Similarly, Crisan et al.[16] found that combining HFUS with clinical evaluation significantly improved treatment planning in skin cancers, particularly for surgical and radiation-based interventions. Future prospective studies exploring a dual-modality imaging protocol may substantiate its utility in standard RT planning workflows, potentially improving outcomes in skin cancer care while preserving tissue integrity.

OCT utilizes light interferometry. A prospective study[17] of 553 patients with basal cell carcinoma (BCC) compared OCT alone with punch biopsy. 75% of 299 lesions in the OCT group had a correct diagnosis when compared to 72% in the punch biopsy group. No significant difference was noted in treatment cost, post-treatment cost, or total mean cost between the groups and concluded that OCT was just as good as biopsy for diagnosis but with no need for tissue removal. In this sense it is a good combination with RT which is also tissue conserving. OCT may soon play a larger role in skin cancer delineation. Representative OCT images of are included in Fig. 5 for future users to familiarise themselves with this imaging modality.

Using OCT to define radiation fields for head and neck BCC fits into an evolving paradigm of personalising treatment and of being able to selectively kill tumour cells amongst normal cells. Two other examples are using Tumour Treating Fields (TTFields) for Glioblastoma (GBM). TTFields combined with temozolomide is the recommended standard of care for eligible patients. It works by delivering alternating electric fields to the tumour, disrupting critical cellular processes that lead to cancer cell death and tumour progression yet sparing intermixed normal cells[18]. Another example is oncolytic viral therapy (OVT). OVT is emerging as a promising subset of immunotherapy, which theoretically can target tumour cells while sparing surrounding healthy cells by harnessing the replication machinery of viruses with tropism for tumour cells, resulting in direct oncolysis, and by transforming immunologically "cold" tumour into areas that elicit the host's immune response[19].

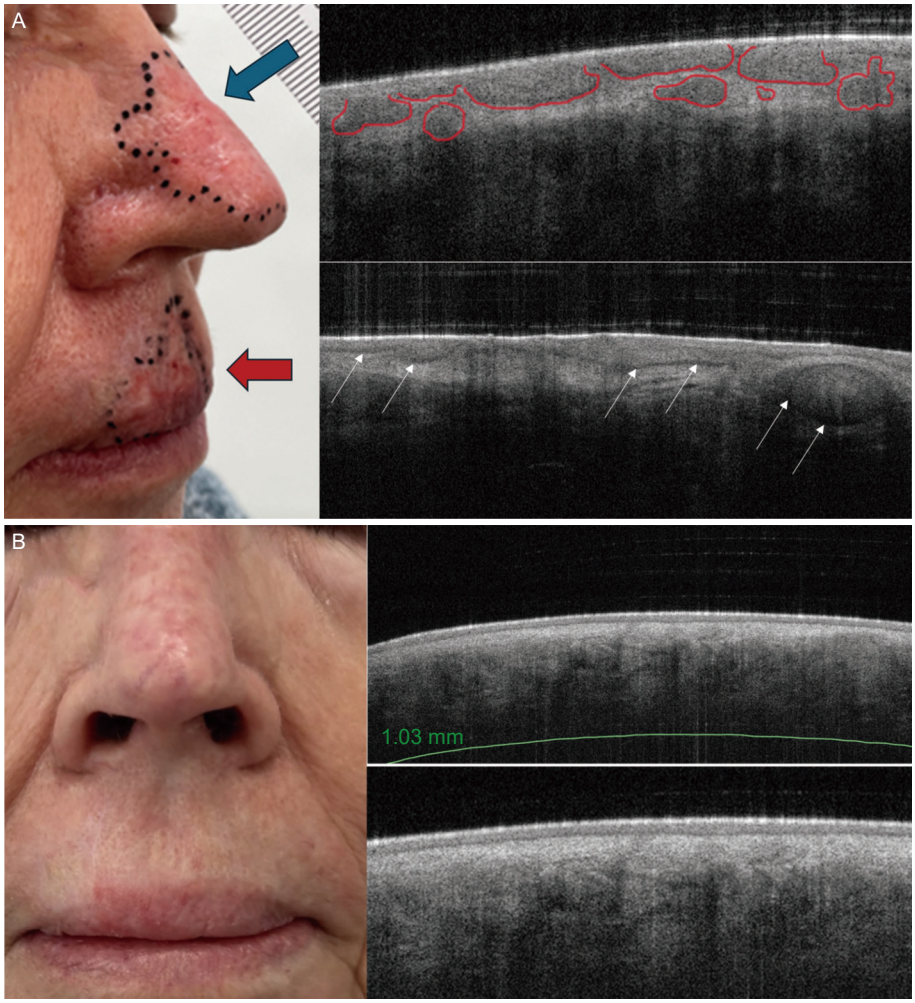

Fig. 5. Representative OCT images from case one.
A. Patient one. Left image: Photograph of right anterior projection of OCT, the blue arrow showing the much smaller area delineated as involved by BCC as compared with the RO initial GTV as seen in . Note the red arrow showing the lip OCT which is similar to the RO markup. Upper right image, corresponding OCT: Red markings delineate basaloid epidermal protrusions and basaloid subepidermal lobules within the upper dermis. Right lower image, corresponding OCT: Clefting (dark edges) surrounding basaloid structures is a typical finding in basal cell carcinomas (white arrows) with OCT.
B. Patient one, left image: Anterior photograph taken at last follow up 12 months following definitive RT showing continuing clinical complete response (CR) in the treated areas. Right upper image, corresponding OCT image at six month shows CR: Epidermis without basaloid protrusions or tumoral structures within dermis down to a depth of 1 mm (usual imaging depth used OCT device). Lower right image, magnified OCT image: Typical post-radiation changes within the skin showing reduced adnexal skin structures (with loss of hair follicles) with mildly atrophic epidermis (red asterisk) and increased fibrotic (bright) tissue within the dermis (blue asterisk).

Our study had several drawbacks. Essentially this was a small, retrospective, single institution, case series. Not all the patients went for post-treatment OCT. The follow up was short. However, it does represent the first publication of using OCT to define radiation skin cancer fields, a truly multidisciplinary innovation to aid skin cancer patient care.

Conclusion

This study represents the first publication of using OCT to define radiation skin cancer fields in the Australian setting, a truly multidisciplinary innovation to aid skin cancer patient care. Using OCT was found to be beneficial in delineating biopsy-proved BCCs with unclear margins and that OCT can be used to define RT fields for head and neck BCCs, leading to a 28% reduction in the size of the RT field GTV. OCT also confirmed disease, found occult disease, and assessed CR at follow up. Eight patients with ten lesions were treated with definitive RT. RT was planned using the OCT area as the correct area. All had clinical CR at post-RT follow up. In the five patients having OCT following RT, all had a continuing CR at an average of 6.8 months post-RT. Further research including longer follow-up is necessary to assess the effectiveness of OCT to improve skin cancer patient care.

Abbreviations

#, fraction; Ave, Average; BCC, Basal Cell Carcinoma; CR, Complete Response; Cryo, Cryotherapy; Diff, Difference; F, Female; FU, Follow up; GBM, Glioblastoma; GTV, Gross Tumour Volume; Gy, Gray; Histo, Histology; Inf, Infiltrative; M, Male; mm^2, millimetres squared; Mod, Modality; Mor, Morpheaform; No., Number; Nod, Nodular; OCT, Optical Coherence Tomo-

graphy; OVT, Oncolytic Viral Therapy; Prev Rx, Previous Treatment; RO, Radiation Oncologist; Rpt, Repeat; RT, Radiotherapy; Rx, Treatment; Surg, Surgery; SXRT, Superficial radiotherapy; Tot, Total; TTFields, Tumour Treating Fields; VMAT, Volumetric Modulated Arc Therapy.

Ethics approval and consent to participate

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

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Authors' contributions

GBF was responsible for study conception, clinical data collection and analysis, and drafting the manuscript. GBF, JG, JP, AF and CS participated in clinical case management, assisted in data collection, and provided professional advice. All authors (GBF, EJP, JG, JP, AF and CS) contributed to the study design discussion, reviewed and revised the manuscript, and approved the final version for publication.

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