Case series

Volumetric modulated arc therapy (VMAT) for extensive skin field cancerisation (ESFC) – exploring the limits of treatment volumes with a case series of backs

Abstract

Skin field cancerisation arises from prolonged sun exposure and increases with age. Multiple areas of the skin can be involved resulting in poor quality of life and cosmesis and even death. The long-term efficacy of traditional treatments such as topical creams is disappointing. Volumetric modulated arc therapy (VMAT) is a relatively new radiation technique that allows the definitive treatment of large convex fields. Extra dose can also be delivered simultaneously using a boost technique to proven areas of macroscopic invasive disease. In what we believe is the first publication of its kind, we present a retrospective case series of 15 patients with 21 areas treated with VMAT to the back. Treatment is feasible but areas of skin cancerisation over 800 cm^2 should not be treated in one course but broken into smaller fields separated by adequate breaks. Care should be taken when treating large areas of the spine as pancytopenia may result and routine blood counts between treatment courses should be considered. More research is warranted to confirm the dose and efficacy outcomes, but this technique may represent a new therapeutic option for patients with extensive skin field cancerisation of the back.

Keywords: skin neoplasms, radiotherapy, actinic keratosis, Bowen's disease, in situ squamous cell carcinoma, basal cell carcinoma, volumetric modulated arc therapy, intensity modulated radiotherapy, case series, back

Volume 7 Issue 6 - 2020

Bradley Wong,[1] David Christie,[2] James Hellyer,[3] Corinne Henningsen,[5] Tania Brogmus,[1] Gerald B. Fogarty[4]

[1]GenesisCare, Buderim, QLD, Australia
[2]GenesisCare, Tugun, QLD, Australia
[3]GenesisCare, Bundaberg, QLD, Australia
[4]GenesisCare, Darlinghurst, NSW, Australia
[5]GenesisCare, Chermside, QLD, Australia

Correspondence: Bradley Wong, GenesisCare Buderim, 10 Kings Street, Buderim, Queensland 4556, Australia, Tel +61 (0)7 5374 8100, Email Bradley.Wong@genesiscare.com

Received: November 16, 2020 | **Published:** November 27, 2020

Abbreviations: AK, actinic keratosis; BCC, basal cell carcinoma; Ca, carcinoma; cm, centimetre; CR, complete response; DSAP, disseminated superficial actinic porokeratosis; ESFC, extensive skin field cancerisation; FU, follow-up; Gy, Gray; H&N, head and neck; IEC, intra-epithelial carcinoma; IMRT, intenstity-modulated radiation therapy; LTFU, lost to follow-up; MM, malignant melanoma; MNMSC, multiple non-melanoma skin cancers; No, number; PDT, photodynamic therapy; PR, partial response; Pt, patient; PTV, planning target volume; QoL, quality of life; RT, radiotherapy/radiation therapy; SCC, squamous cell carcinoma; SCCHN, squamous cell carcinoma of the head and neck; SIB, simultaneous integrated boost; SK, solar keratosis; SXRT, superficial radiotherapy; TML, total mutational load; VMAT, volumetric modulated arc therapy; # fractions

Introduction

Prolonged sun exposure can cause skin field cancerisation (ESFC) especially in patients with Fitzpatrick skin type 1 and 2.[1,2] The incidence increases with age,[3] particularly in the immunosuppressed.[4] These patients can have poor quality of life, with pruritus, flaking hyperkeratotic skin and poor cosmesis.[5] Multiple areas of skin can be involved. Invasive cutaneous squamous cell carcinoma (cSCC) can arise in these fields[6] causing morbidity and even mortality. Comorbidities in this usually older population can make definitive treatment difficult. The problem is increasing on a worldwide scale and particularly in Australia.[7,8] The durability of traditional field treatments such as topical 5-fluorouracil, diclofenac and imiquimod is disappointing with sustained clearance rates commonly limited to around 50%.[9]

New radiation techniques have been developed, especially volumetric modulated arc therapy (VMAT) which is a further evolution of intensity modulated radiotherapy (IMRT).[10–12] VMAT allows definitive radiation treatment of large convex fields (e.g. scalp, forehead, cheeks, forearms and legs). Some ESFC fields may have one or more smaller areas of biopsy-proven macroscopic invasive disease that are likely to be more deeply invasive and thus require more radiation dose than the surrounding field. This extra dose can be delivered with VMAT simultaneously, using a higher dose per fraction to that area, rather than needing to add a further phase of lesion-directed treatment. This further refinement of the VMAT technique is known as the addition of a simultaneous integrated boost (SIB).[13]

Extensive skin field cancerisation (ESFC) has been defined as that which has a clinically detectable surface area of over 50cm^2.[14] In some anatomical sites (e.g. lower legs) a break in a treatment course has been required to enable the prescribed does to be delivered with acceptable toxicity.[15] Initially, radiation oncologists (ROs) would only treat defined anatomical areas (e.g. a forearm, or a forehead), but technical progress has enabled a homogenous dose to be delivered to contiguous areas during the same treatment course (e.g. forearm plus dorsum of hand, forehead plus scalp). This improves patient quality of life as they can attend a facility for one rather than multiple sequential courses of fractionated treatment. It also decreases the inherent risk when junctioning sequential radiation treatment volumes - within the junction zone, tumour-bearing tissue may be underdosed, or normal tissue may be overdosed due to over-lapping, resulting in unacceptable late effects.[16]

This case series is a retrospective review of VMAT and IMRT treatments to areas of ESFC affecting the back. The back is the largest relatively flat skin expanse in the body. It can be defined as

stretching from the hair line of the occiput superiorly to the beginning of the intergluteal cleft inferiorly, and from midline palpable spinous processes to the posterior axillary lines bilaterally. The back can be sun exposed and suffer from ESFC. This large area of skin is being used to answer what the maximum area of EFSC is that can be safely and effectively treated with VMAT to the prescription dose in one treatment course. This will be compared to treatments of contiguous areas on the back treated sequentially with a multiple number of courses, separated by treatment breaks. Some of these areas needed SIB for in-field macroscopic invasive disease.

To our knowledge, this is the first description of VMAT for ESFC of the back. We also believe it to be the first description of VMAT SIB to biopsy proven macroscopic disease on the back.

Methods

Cases of ESFC treated with VMAT/IMRT to the back were sourced from our Australian skin radiation oncology community. Medical histories were reviewed for patient demographics and tumour characteristics and these data were tabulated. Radiation plans, prescriptions and on-treatment review summaries were investigated, and the relevant results tabulated. Outcomes data, such as field clearance and invasive disease in SIB volumes, recurrence since RT, function and cosmesis (as measured by the RO) and patient satisfaction were inferred from the review notes. Patients who had previously undergone RT to skin sites and who subsequently requested additional treatment to more fields of ESFC were also noted. The cases were planned and treated according to our published technique.[15] Briefly, after providing informed consent, patients were simulated in a stable and reproducible prone posture with their arms up. First, the RO defined the areas needing field treatment and any area of invasive disease within the same field that required SIB. The RO also marked on the patient's skin how the area could be divided into different areas to be treated sequentially, if required. Planning photos and a template of the treatment area were constructed, and tattoos were applied to the patient to assist reproducibility. All marks were wired so that they would be visible on the planning computed tomography (CT) scan for contouring purposes. Bolus was used to ensure adequate dose to the surface with megavoltage photons. The RO, using computer planning software, then contoured the volumes needing treatment and the organs at risk (OARs) and wrote the prescription. The contour of the areas being treated included a depth (usually 1 cm) and so resulted in a volume called the planning target volume (PTV). This enabled the volume of skin being treated to be recorded. The prescribed dose to the field was usually at least 45 Gray (Gy) in 25 daily fractions (#'s) over five weeks and at least 55 Gy in 25#'s to the SIB areas. The plan was then calculated before undergoing RO review and acceptance. Once accepted, quality assurance was carried out with a phantom to ensure that the planned dose could be delivered. Prior to treatment, two separate plans were created comparing the PTV coverage and the dose to OAR for a VMAT/ IMRT technique. When treating large areas of the posterior thorax, careful attention was paid to the low dose lung wash as represented by the combined lung V5. This was especially critical as many patients required multiple courses of treatment to both the posterior and anterior thorax.

Treatment could then start. In vivo dosimetry was routinely performed to ensure the correct dose was delivered in real time. Treatment verification films were taken to ensure that the planned volumes were being treated. The RO reviewed the patient regularly during treatment to assess response and any acute side effects - these were documented and treated if present. A break could be planned at two weeks or initiated when symptoms warranted it. Treatment was recommenced when the RO was satisfied that the skin reaction or pain had settled. Treatment was stopped if there were unacceptable acute effects such as severe pain.

Results

Fifteen cases of VMAT/IMRT for ESFC of the back were found. Patient and tumour characteristics are summarised in Table 1.

Radiotherapy treatment details are summarised in Table 2. Radiation therapy outcomes are summarised in Table 3. Fifteen patients with 21 areas of ESFC treated with VMAT/IMRT to the back were sourced from our Australian skin cancer radiation oncology community. Fourteen patients with histologically proven non-melanomatous skin and one with histologically proven lentigo maligna were treated in six treatment facilities. Patient demographics were 12 males, 3 females, average age 72 years (range 56-91) and ECOG performance status 0-2. Histopathology ranged from unresected large volume basal cell carcinoma (BCC) to smaller volume intraepithelial carcinoma (IEC) resected with clear margins. One patient had lentigo maligna. All histological diagnoses arose from a background of widespread solar damage. Fourteen patients experienced skin cancer recurrence despite previous treatments including multiple excisions, cryotherapy, topical creams, nicotinamide and black salve. A single elderly male patient had not undergone previous treatment to skin cancers on his back.

Table 1 Patient and tumour characteristics

Pt No.	Age /sex	Relevant comorbidities /medications	Histology of back	Previous therapies to back	Total area of skin (cm^2) + any SIB Y/N	Total treatment volume (PTV)(cm^3) + depth of PTV in skin (mm)
1	70M	Prostate Ca (prostatectomy) in remission	SCC, SK	Excision Cryotherapy Effudix	1850 / N 2 fields treated sequentially with 4 months between courses	1850 / 5mm
2	63M	Prostate Ca (prostatectomy) in remission	BCC	Excision	1793 / N 3 fields treated sequentially with 3-4 months between courses	1793 / 5mm
3	84M	Prostate Ca (radiotherapy) in remission; larynx SCC (radiotherapy) in remission	BCC	Multiple surgeries	1282 / N	1282 / 5mm

Citation: Wong B, Christie D, Hellyer J, et al. Volumetric modulated arc therapy (VMAT) for extensive skin field cancerisation (ESFC) – exploring the limits of treatment volumes with a case series of backs. *Int J Radiol Radiat Ther.* 2020;7(6):184–192. DOI: 10.15406/ijrrt.2020.07.00286

Table continued

Pt No.	Age /sex	Relevant comorbidities /medications	Histology of back	Previous therapies to back	Total area of skin (cm^2) + any SIB Y/N	Total treatment volume (PTV)(cm^3) + depth of PTV in skin (mm)
4	62M	Nil, nil	BCC, IEC	Surgery	1137/ N	1137 / 5mm
5	65M	Nil, nil	BCC	Aldara	884 / N	884 / 5mm
6	59F	Hepatitis C cured	IEC	Excision Effudix Nicotinamide	856 / N 2 fields treated sequentially with 6-week break between courses	1114 / 7mm
7	77M	Nil, nil	SCC, DSAP, in situ melanoma excised	Excision Cryotherapy Effudix PDT	848 / N	848 / 5mm
8	74M	Nil, nil	BCC	Excision, Cryotherapy	805 / N	903 / 5mm
9	56M	Nil, nil	SK, IEC, BCC	Excision, Cryotherapy	740 / N	740 / 7mm
10	80M	Bladder ca (cystectomy), H&N Ca (XRT complicated by radionecrosis), Nivolumab	SCC, BCC, melanoma	Excision	433 / N	433 / 5mm
11	77F	Pacemaker Prednisolone Rivaroxaban	BCC (large volume disease)	Cansema (black salve)	304 / Y (283) 2 fields treated simultaneous, 2cm gap left between fields	456 / 15mm
12	91F	Nil, nil	BCC, lentigo maligna	Excision	249 / Y (15)	299 / 7mm
13	71M	Nil	Lentigo maligna	Resection with flap	243 / N	292 / 5mm
14	71M	Crohns disease Adalimumab	SCC, AK (large volume disease)	Excision	225 / Y (52) 2 fields treated simultaneous, 7cm gap left between fields	271 / 7mm
15	90M	Aortic valve replacement Warfarin	IEC, SCC	Nil	216 / Y (22)	324 / 7mm
Summary 15 pts	Average age 72 years, 4:1 male	3 immuno-compromised with medications	14/15 MNMSC. Single patient with lentigo maligna alone	14/15 prior management for skin cancer on back	791 / 93 4 patients received boosts	842 / 6mm

Abbreviations: AK, actinic keratosis; BCC, basal cell carcinoma; ca; carcinoma; cm, centimetre; DSAP, disseminated superficial actinic porokeratosis; H&N, head & neck; IEC, intra-epithelial carcinoma; PDT, photodynamic therapy; Pt, patient; MNMSC, multiple non-melanoma skin cancers; No., number; PTV, planning target volume; SCC, squamous cell carcinoma; SIB, simultaneous integrated boost; SK, solar keratosis; XRT, radiation therapy/radiotherapy.

Citation: Wong B, Christie D, Hellyer J, et al. Volumetric modulated arc therapy (VMAT) for extensive skin field cancerisation (ESFC) – exploring the limits of treatment volumes with a case series of backs. *Int J Radiol Radiat Ther.* 2020;7(6):184–192. DOI: 10.15406/ijrrt.2020.07.00286

Table 2 Radiotherapy treatment details

Pt No.	Total No. of areas	Area volume (cm^2)	Total dose Gy/ # prescribed	Method	Missed days + stopped	Was break planned or unplanned	Was treatment given as prescribed?
1	2	Upper 1120	50/25	VMAT	9	Unplanned	Yes
		Mid 730	45/25	IMRT	8	Unplanned	Yes
2	3	Upper 736	45/25	IMRT	2	Unplanned	Yes
		Middle 640	45/25	VMAT	6	Unplanned	Yes
		Lower 417	45/25	IMRT	2	Unplanned	Yes
3	1	Single 1282	45/25	VMAT	Stopped	Unplanned	No 30.6/17
4	1	Single 1137	45/25	IMRT	Stopped	Unplanned	No 36/20
5	1	Single 884	50/25	VMAT	17	Unplanned	Yes
6	2	Upper 486	45/25	VMAT	12	Unplanned	Yes
		Lower 370	45/25	IMRT	2	Unplanned	Yes
7	1	Single 848	50/25	IMRT	13	Unplanned	Yes
8	1	Single 805	50/25	IMRT	Stopped	Planned + Unplanned	No 48/24
9	1	Single 740	45/25	VMAT	5	Unplanned	Yes
10	1	Single 433	50/25	IMRT	0	-	Yes
11	2	Upper 115	45/25 with SIB to 55/25	VMAT	12	Planned	Yes
		Lower 189	45/25 with SIB to 55/25	VMAT	12	Planned	Yes
12	1	Single 249	45/25 with SIB to 55/25	VMAT	1	Unplanned	Yes
13	1	Single 243	48/20	VMAT	2	Unplanned	Yes
14	2	Right 175	54/30 with SIB to 60/30	VMAT	18	Unplanned	Yes
		Left 50	54/30 with SIB to 60/30	VMAT	18	Unplanned	Yes
15	1	Single 216	45/25 with SIB to 55/25	VMAT	6	Unplanned	Yes
Summary	21 fields	Avg 565cm^2	Most 45-50/25 with SIB to 55/25	13/21 VMAT, 8/21 IMRT	3/21 Stopped. Avg 8 days missed for those that completed	18/21 received unplanned breaks	18/21 completed treatment

Abbreviations: Avg, average; Gy, gray; IMRT, intensity-modulated radiation therapy; No., number; Pt, patient; SIB, simultaneous integrated boost; VMAT, volumetric modulated arc therapy; #, fractions

Table 3 Radiation therapy outcomes

Pt No.	Last FU (duration from RT completion In months)	Clearance of field and invasive disease in SIB volume at 1 month follow up	Recurrence since RT- clinically/ histologically proven at latest follow up	Functional and cosmetic outcome	Pt satisfaction	Has pt requested more RT for ESFC of another site?
1	12	Yes / NA	No / No	Positive	Moderate	-
	6	Yes / NA	No / No	Positive	Positive	No

Citation: Wong B, Christie D, Hellyer J, et al. Volumetric modulated arc therapy (VMAT) for extensive skin field cancerisation (ESFC) – exploring the limits of treatment volumes with a case series of backs. *Int J Radiol Radiat Ther.* 2020;7(6):184–192. DOI: 10.15406/ijrrt.2020.07.00286

Table continued

Pt No.	Last FU (duration from RT completion In months)	Clearance of field and invasive disease in SIB volume at 1 month follow up	Recurrence since RT- clinically/ histologically proven at latest follow up	Functional and cosmetic outcome	Pt satisfaction	Has pt requested more RT for ESFC of another site?
2	9	Yes / NA	No / No	Positive	Positive	-
	4	Yes / NA	No / No	Positive	Positive	-
	1	Yes / NA	No / No	Positive	Positive	Yes
3*	13	Yes / NA	No / No	Positive	Moderate	No
4	1	Yes / NA	No / No	Positive	Positive	No
5	18	Yes / NA	No / No	Positive	Moderate	No
6	17	Yes / NA	No / No	Positive	Positive	-
	15	Yes / NA	No / No	Positive	Positive	Yes
7	1	Yes / NA	No / No	Negative Breathlessness from pancytopenia	Negative. Planned hiking holiday cancelled due to pancytopenia	No
8	11	Yes / NA	No / No	Positive	Moderate	Yes
9	8	Yes / NA	No / No	Positive	Positive	Yes
10	1	Yes / NA	No / No	Positive	Positive	No
11	18	Yes / Yes	No / No	Positive	Positive	-
	18	Yes / Yes	Yes / No	Positive	Positive	Yes
12	3	Yes / Yes	No / No	Positive	Positive	No
13	1	Yes / NA	No / No	Positive	Positive	No
14	20	Yes / Yes	No / No	Positive	Positive	-
	20	Yes / Yes	No / No	Positive	Positive	Yes
15	24	Yes / Yes	No / No	Positive	Positive	Yes
Summary	10.5 average	21/21 fields developed CR and 6/6 boost areas developed CR at 1 month	1/21 fields developed recurrence in boost area at latest follow up	20/21 fields reported positive functional and cosmetic outcome	16/21 fields positive, 4/21 fields moderate, 1/21 negative	7/15 patients requested further radiotherapy

Abbreviations: CR, complete response; ESFC, extensive skin field cancerisation; FU, follow-up; No., number: Pt, patient; RT, radiation therapy/radiotherapy; SIB, simultaneous integrated boost.

*Patient suffered from self-limiting keratoacanthomas post RT.[18]

Citation: Wong B, Christie D, Hellyer J, et al. Volumetric modulated arc therapy (VMAT) for extensive skin field cancerisation (ESFC) – exploring the limits of treatment volumes with a case series of backs. *Int J Radiol Radiat Ther.* 2020;7(6):184–192. DOI: 10.15406/ijrrt.2020.07.00286

Radiotherapy treatment

Of 21 fields, 13 were treated with VMAT and eight with IMRT. The IMRT plans consistently showed less low dose lung wash compared to the corresponding VMAT plan whilst maintaining adequate PTV coverage, especially when treating the mid-lower back. The upper back and shoulders were more commonly treated with VMAT due to improved PTV coverage across the curved surface of the shoulders with only minimal lung volumes irradiated in the lung apices and a shorter treatment time. The overall treatment area ranged from 225 cm^2 to 1850 cm^2. Ten patients were treated with a single continuous field. Five patients were treated with multiple fields either simultaneously or sequentially. The individual field sizes ranged from 50 cm^2 to 1282 cm^2. Three patients were treated in two to three sequential phases and a one to two-centimetre strip of skin was left between the fields to prevent overlap between phases. Breaks between six weeks and four months were given between sequential treatment courses. These patients had large volume disease and there was concern that a single phase of treatment would not be tolerable. One patient was treated in a single phase with a seven-centimetre strip of skin left between the left and right fields as the strip between fields did not clinically require radiotherapy. Another patient was treated in a single phase with a two-centimetre strip of skin left between the upper and lower fields to allow for wound healing. There was concern that as large volumes of gross disease regressed, she would be left with a non-healing ulcer. Three patients within the group of six patients with the largest field sizes struggled with completing the prescribed course of treatment. These patients reported negative or moderate patient satisfaction and missed 9 to 17 treatment days before completing the prescribed course. None requested more radiotherapy for ESFC. The field sizes for these patients ranged from 848 to 1137cm^2.

Another three patients did not complete the prescribed treatment. These included the two largest field sizes and the sixth largest field size. These field sizes ranged from 805 cm^2 to 1282 cm^2. Despite not completing treatment, all had a positive functional and cosmetic outcome; patient satisfaction ranged from moderate to positive, and one patient requested more radiotherapy for ESFC. All patients except one had planned treatment breaks due to public holidays and machine service days. There were also unplanned treatment breaks due to machine breakdowns and toxicity. All patients who completed treatment missed between 0 – 18 treatment days of their planned course. Of these, only two patients received a planned mid-treatment break of two weeks.

During treatment, 14 patients developed a grade 1-2 skin reaction according to Common Terminology Criteria for Adverse Events (CTCAE) version 5 and were managed with topical creams and analgesia as required. The patient with large areas of gross disease developed a grade 3 skin reaction as the disease resolved and required daily dressings and patch opiate analgesia. Upon completion of treatment, physical examination revealed a complete or near complete tumour response in all patients. Photos were taken in the last week of treatment showing the expected radiation dermatitis within the treatment field as well as the response to treatment. Follow-up for patients ranged between 1 – 24 months (average 10.5 months). All patients initially developed complete clinical clearance within the treatment field including the invasive disease within the simultaneous integrated boost volume. The patient with the large areas of gross disease, who was treated with two fields simultaneously with a two-centimetre gap between the fields, was found to have recurred at the 18-month review in the boost area of the lower field that covered the greatest burden of disease. Functional and cosmetic outcomes were positive in all but a single patient. All four patients who reported only moderate patient satisfaction were in the cohort of the largest six individual treated fields. All other patients reported positive patient satisfaction. Shortly after completion of treatment, one patient developed breathlessness and was found to be pancytopenic. He reported negative functional and cosmetic outcomes and negative patient satisfaction. Seven of the 15 patients requested more radiotherapy or have already undergone more radiotherapy for ESFC at the time of writing.

Discussion

Our study shows that for areas of ESFC on skin of the back can be successfully treated with VMAT. However, for areas that are over 800 cm^2 treatment with radiotherapy should be delivered sequentially to smaller sub-areas to enable the prescribed dose to be delivered with lower and acceptable levels of toxicity. The authors recommend that treatment of areas over 800 cm^2 should not be attempted in one unbroken course. Treatments broken into smaller fields separated by adequate breaks to allow acute reactions to resolve are well tolerated. A treatment break of at least two weeks should be planned for all areas over 400 cm^2 as well as for areas over 200 cm^2 with large volumes of gross disease requiring boost doses, especially in the elderly and immunocompromised. Due consideration should be given when treating large areas of the spine as this may result in pancytopenia. Routine blood counts between treatment courses should be considered. Treatment of ESFC poses significant challenges to the treating physician. Surgery is unlikely to be feasible and topical therapies or photodynamic therapy have a high recurrence rate.[17] In a 2012 Cochrane review involving 83 randomised controlled trials and 10,036 participants,[9] Gupta and colleagues assessed the effects of topical, oral, mechanical, and chemical interventions for the treatment of actinic keratosis - precancerous lesions from which squamous cell carcinoma can arise. As a field-directed treatment, the primary objective of patient complete clearance significantly favoured diclofenac, 5-fluorouracil, imiquimod and ingenol mebutate. Efficacy was similar across all treatments however adverse events and cosmetic outcomes differed and a significant number of patients withdrew from treatment.[9]

In 2019, Jansen and colleagues[17] published a randomised trial aimed at answering the efficacy question regarding four treatment options for actinic keratosis in the head and neck region. In this trial, 624 patients were equally assigned to 5% fluorouracil cream, 5% imiquimod cream, methyl aminolevulinate photodynamic therapy (MAL-PDT), or 0.015% ingenol mebutate gel. While efficacy significantly favoured 5-fluorouracil, treatment failure after one cycle was observed in 14.8% of these patients and in 37.2%, 34.6% and 47.8% of those who received imiquimod therapy, MAL-PDT, and ingenol mebutate therapy, respectively. Adherence to treatment in patients receiving 5-fluorouracil or imiquimod, both of which require application for four consecutive weeks, was high in the trial, but the authors commented that in daily practice it may be lower. Ingenol mebutate, despite only requiring application for three consecutive days, was not considered suitable due to the low probability of being free from treatment failure (only 28.9%) in the long term.[17] VMAT for ESFC given according to our technique controlled all but a single in-field invasive area of disease in 21 areas of 15 backs with a median field size of 565 cm^2 at a median FU of 10.5 months. To our knowledge, this is the first description of VMAT for ESFC of the back and may represent a new treatment option for patients suffering from this not uncommon condition. Of the fifteen patient cases, twelve completed treatment but three did not. This study has

significant limitations. The sample size is small, and the data was retrospectively collected; however, it is the first publication of VMAT in ESFC of the back. As such, it also raises questions that could be investigated further: Can toxicity due to treating large areas of the spine be reduced by contouring vertebral bodies as organs at risk with a mean dose below 5 Gy? How does the efficacy of VMAT in ESFC compare with the best topical therapeutic option? Which treatment option(s) do patients prefer? The lessons learnt from our experience should serve as a template for ongoing research and treatment of this potentially morbid or even fatal condition.

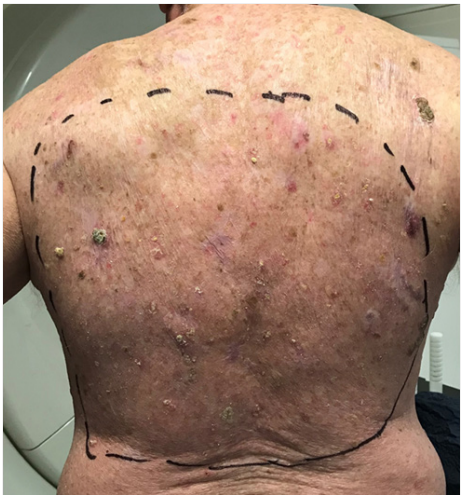
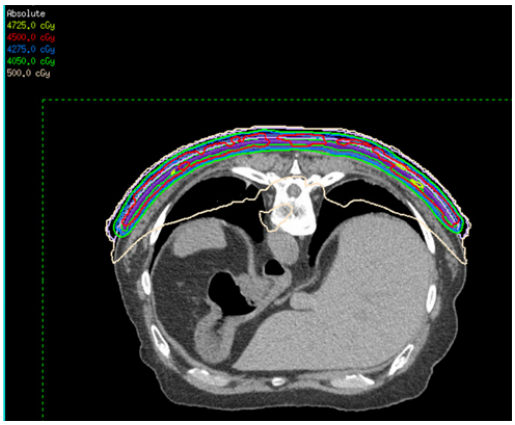
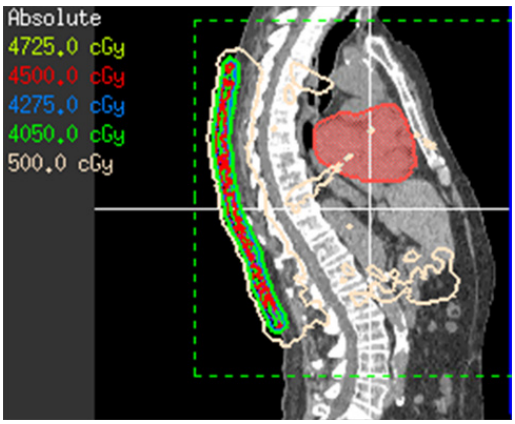


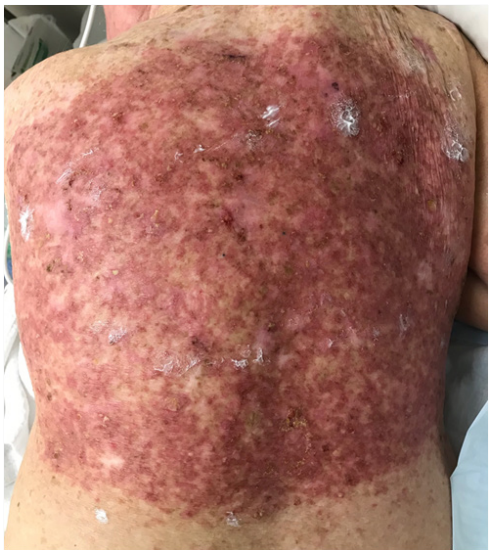
Figure 1 Patient 7. (A) At planning.



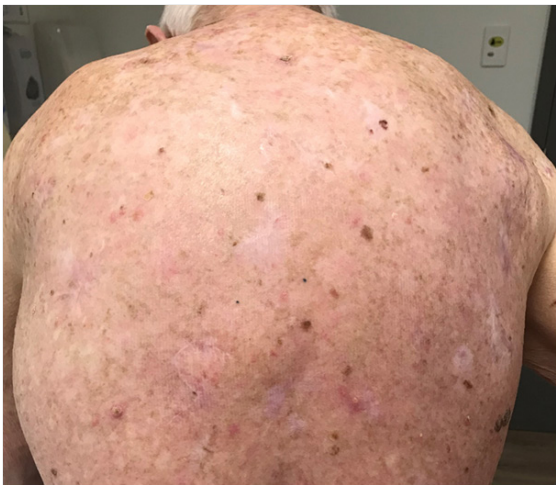
(1B) Treatment plan – transverse view.



(1C) Treatment plan – midline sagittal view.



(1D) At 30.6 Gy – treatment stopped at this time.



(1E) 47 days post RT - complete response.

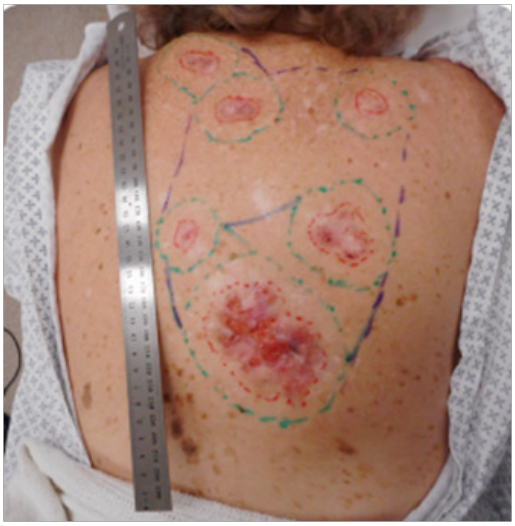
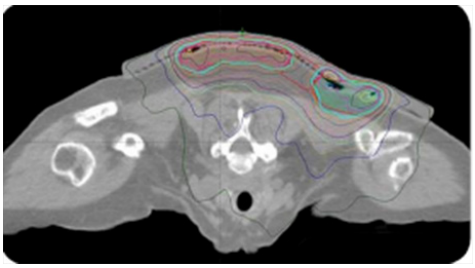
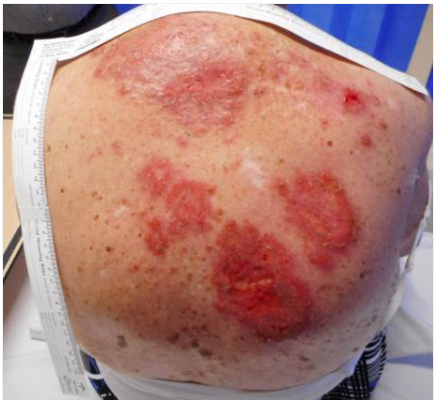


Figure 2 Patient 11. (2A) At planning.

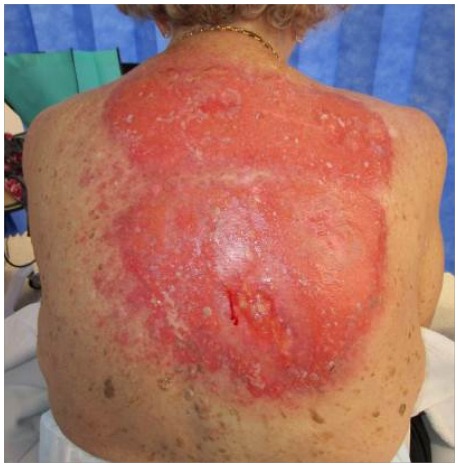
Citation: Wong B, Christie D, Hellyer J, et al. Volumetric modulated arc therapy (VMAT) for extensive skin field cancerisation (ESFC) – exploring the limits of treatment volumes with a case series of backs. *Int J Radiol Radiat Ther.* 2020;7(6):184–192. DOI: 10.15406/ijrrt.2020.07.00286



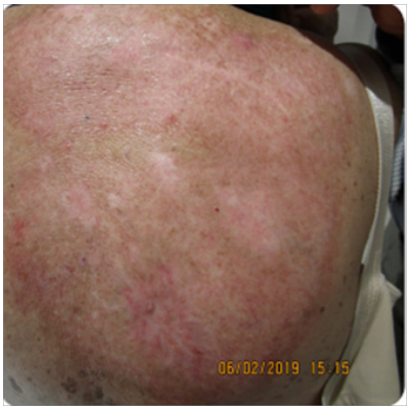
(2B) Treatment plan – transverse view.



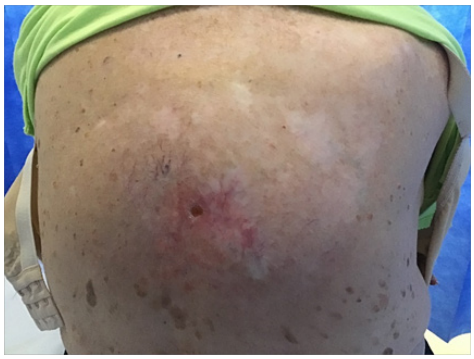
(2C) Mid-treatment – fraction 11 of 25.



(2D) End of treatment – fraction 25 of 25.



(2E) 99 days post RT – complete response.



(2F) 561 days post RT - in-field recurrence .

Conclusion

Volumetric-modulated arc therapy (VMAT) for the treatment of extensive cancerisation of the back is feasible and offers patients a useful therapeutic option. Areas of skin cancerisation over 800 cm^2 should not be treated in one course but broken into smaller fields separated by adequate breaks. Care should be taken when treating large areas of the spine. More research is warranted.

Acknowledgments

The authors wish to thank Aileen Eiszele of A&L Medical Communications for editing, writing assistance and manuscript preparation. They also wish to thank the physics and nursing teams at the GenesisCare centres where this research was carried out and the patients who contributed.

Conflicts of interest

The authors have no conflicts of interest to declare. No financial assistance was received to produce this manuscript.

References

1. Figueras Nart I, Cerio R, Dirschka T, et al. Defining the actinic keratosis field: a literature review and discussion. *J Eur Acad Dermatol Venereol.* 2018;32(4):544–563.
2. Hofbauer G, Anliker M, Boehncke WH, et al. Swiss clinical practice guidelines on field cancerization of the skin. *Swiss Med Wkly.* 2014;144:w14026.
3. Pandeya N, Olsen CM, Whiteman DC. The incidence and multiplicity rates of keratinocyte cancers in Australia. *Med J Aust.* 2017;207(8):339–343.
4. Iannacone MR, Sinnya S, Pandeya N, et al. Prevalence of skin cancer and related skin tumors in high-risk kidney and liver transplant recipients in Queensland, Australia. *J Invest Dermatol.* 2016;136(7):1382–1386.
5. Staples MP, Elwood M, Burton RC, et al. Non-melanoma skin cancer in Australia: the 2002 national survey and trends since 1985. *Med J Aust* 2006;184:6–10.
6. Green AC. Epidemiology of actinic keratoses. *Curr Probl Dermatol.* 2015;46:1–7.
7. Perera E, Gnaneswaran N, Staines C, et al. Incidence and prevalence of non-melanoma skin cancer in Australia: A systematic review. *Australas J Dermatol.* 2015;56(4):258–267.
8. Australian Institute of Health and Welfare & Cancer Australia 2008. *Non-melanoma skin cancer: general practice consultations, hospitalisation and mortality.* Cancer series no. 43. Cat. no. CAN 39. Canberra: AIHW.

9. Gupta AK, Paquet M, Villanueva E, et al. Interventions for actinic keratoses. *Cochrane Database Syst Rev.* 2012;12:CD004415.
10. Daniel Santos E, Green JA, Bhandari N, et al. Tangential volumetric modulated radiotherapy – A new technique for large scalp lesions with a case study in lentigo maligna. *Int J Bioautomation.* 2015;19(2);223–236.
11. Martin TD, Moutrie Z, Tighe D, et al. Volumetric modulated arc therapy (VMAT) for skin field cancerisation of the nose - A technique and case report. *Int J Radiol Radiat Ther.* 2018;5(3):142–148.
12. Fogarty GB, Christie DRH, Kaminski A, et al. A radiation oncology approach for using definitive radiotherapy with volumetric modulated arc therapy (VMAT) for skin field cancerisation (SFC). *Int J Radiol Radiat Ther.* 2018;5(4):227–234.
13. Martinage G, Hong AM, Fay M, et al. Quality assurance analysis of hippocampal avoidance in a melanoma whole brain radiotherapy randomized trial shows good compliance. *Radiat Oncol.* 2018;13(1):132.
14. Fogarty GB, Christie D, Spelman LJ, et al. Can modern radiotherapy be used for extensive skin field cancerisation: An update on current treatment options. *Biomed J Sci &Tech Res.* 2018;4(1):BJSTR. MS.ID.000998.
15. Potter A, Price M, Papworth D, et al. A technique for treating extended skin field cancerisation using volumetric modulated arc therapy. Int J Radiol Radiat Ther. 2019;6(4):111–119.
16. Diamantopoulos S, Thalassinou S, Efstathopoulos E, et al. In vivo dosimetry in the field junction area for 3D-conformal radiation therapy in breast and head & neck cancer cases: A quality assurance study. *J Buon.* 2016;21(5):1104–1112.
17. Jansen MHE, Kessels JPHM, Nelemans PJ, et al. Randomized trial of four treatment approaches for actinic keratosis. *N Engl J Med.* 2019;380(10):935–946.
18. Mullin SJ, Lochhead A, Haddad R, et al. Keratoacanthomas following definitive volumetric modulated arc radiotherapy for skin field cancerization. *Int J Radiol Radiat Ther.* 2019;6(6):225–232.

Citation: Wong B, Christie D, Hellyer J, et al. Volumetric modulated arc therapy (VMAT) for extensive skin field cancerisation (ESFC) – exploring the limits of treatment volumes with a case series of backs. *Int J Radiol Radiat Ther.* 2020;7(6):184–192. DOI: 10.15406/ijrrt.2020.07.00286