

# A COMPARISON OF THE CHARACTERISTICS OF MEGAVOLTAGE ELECTRON BEAMS AND SUPERFICIAL X-RAY BEAMS USED IN KELOID TREATMENT

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## Running Title

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## BACKGROUND

At the 5th International Keloid Symposium, a cost-effectiveness comparison of post-operative superficial kilovoltage (kV) X-ray beam treatment and linear-accelerator megavoltage (MeV) electron beam treatment was presented. Both modalities are employed for treatment of keloids and this comparison identified kV X-ray units as being more cost effective and simpler to quickly “set up” for patient treatment<sup>1</sup>. Cancer treatment capacity pressures, limiting linear accelerator access, may also be present as an issue in some centres.

Subsequent post-presentation discussion identified the need for an explicit physical comparison of the beam characteristics of these two treatment modalities to provide a more comprehensive perspective of their relative utility. The present study therefore compares those MeV electron beam and superficial X-ray beam characteristics most relevant to clinical decision-making in post-excisional keloid radiotherapy, namely: beam energy, depth-dose, field flatness/uniformity, penumbra, sensitivity to curvature/stand-off, surface coverage and management of long treatment fields.

## METHODS

A structured literature review was combined with clinically reasoned reconstruction of representative beam data. Superficial X-ray comparisons were based on Xstrahl-style beam qualities at 25 cm focus-to-skin distance, with representative qualities spanning approximately 60–150 kV and BJR-consistent penetration behaviour<sup>7</sup>. Electron comparisons used representative Elekta/Varian-style 6, 9 and 12 MeV electron beams at 100 cm source-to-surface distance, with 0.5 cm “bolus” for 6 MeV and 1.0 cm “bolus” for 9–12 MeV, bolus being a sheet of tissue equivalent plastic material placed over the treatment area to raise the post-bolus skin dose to > 90% of the maximum dose under the skin<sup>2,4</sup>.

Comparisons focused on target depths relevant to keloid treatment (approximately skin surface, 0.5cm and 1.0 cm depths), lateral field characteristics, and practical implications for long or curved fields, as well as consideration of residual dose beyond the target depths

## RESULTS

Both modalities provide adequate treatment coverage of the epidermal basal layer depth. However, for a more clinically relevant postoperative scar-bed target, beam behaviour diverged:

1. Reconstructed superficial X-ray beam data showed 100% surface doses with approximate doses at 0.5 cm depth of 71%, 87% and 96% for representative 60, 100 and 150 kV beams respectively, with corresponding 1.0 cm depth doses of 50%, 69% and 90%. This supports 100kV as a potential option for treatment at up to 0.5 cm postoperative targets<sup>4,5</sup>.
2. By contrast, bolused electron beams achieved surface coverage of > 90% together with stronger 0.5–1.0 cm coverage and steeper distal fall-off: 6 MeV with 0.5 cm bolus gave about 91% at the skin surface, 98% at 0.5 cm and 90% at 1.0 cm; 9 MeV with 1 cm bolus gave about 95%, 98% and 100% respectively. This supports 6 MeV plus 0.5 cm bolus as a potential option for postoperative targets up to approximately 0.5cm depth, while 9 MeV plus 1 cm bolus is more suitable when coverage towards 1.0 cm is desired<sup>2,4</sup>.

Superficial X-ray beams had a smaller penumbra (border fringe) and broader lateral coverage within smaller fields, but large 60kV fields were increasingly affected by anode “heel-effect” related nonuniformity. Electron beams typically showed 0.5cm wider penumbra effects around the edge of the field and corner rounding for square or rectangular fields. However, a single large electron field was still generally preferable to a matched-field junction for a field length > 10cm because junction hot/cold spots are highly sensitive to set-up uncertainty. Curvature analysis also showed that a 1 cm stand-off causes an inverse-square reduction to about 93% for a 25 cm FSD X-ray beam, whereas, for a small 6 MeV electron field, the corresponding dmax-based geometric factor is about 97% for a typical effective/virtual SSD of 65 cm. However electron beam obliquity effects, which are also present, must not be overlooked<sup>4,6</sup>.

## CONCLUSIONS

For post-excisional keloid radiotherapy, 100kV superficial X-ray beams are attractive for lesions where: the basal layer is < 0.5cm in depth; and the field is < 10cm in length. Only

narrow (0.5-1.0 cm) treatment margins are required because of their sharp penumbra and simple surface coverage. However, their greater sensitivity to short FSD geometry and a large field “heel effect” limits their usefulness for long or broad targets<sup>3,5</sup>.

Bolused 6–9 MeV electron beams provide versatile coverage for typical postoperative scar-bed depths, with less persistent dose at greater depth than harder (150kV) superficial X-ray beams and better scalability to long fields. On the basis of beam physics alone, 6 MeV with 0.5 cm bolus appears well suited to many routine postoperative keloid beds, while 9 MeV with 1 cm bolus is preferable when a deeper target is suspected, though wider (1.0-1.5 cm) treatment margins are required for electron beams, due to their wider penumbra<sup>2-4,6</sup>.

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