Technique and early clinical outcomes for spinal and paraspinal tumours treated with stereotactic body radiotherapy

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Aim

Stereotactic body radiotherapy (SBRT) involves the precise delivery of highly conformal and image-guided hypofractionated external beam radiotherapy to an extra-cranial target.\textsuperscript{1,2}

SBRT is increasingly being applied in the management of benign and malignant spinal and paraspinal tumours.\textsuperscript{3-7} Settings where spinal SBRT may be advantageous include:

- De novo treatment in patients with oligometastatic or bone-only metastatic disease
- De novo treatment for tumours considered resistant to conventional fractionation
- Re-treatment where previous conventionally fractionated radiotherapy has failed
- Post debulking or stabilization surgery

Princess Alexandra Hospital introduced a program of spinal SBRT in early 2010. We describe our initial experience, focusing on treatment technique and early clinical outcomes.
Methods and materials

Patient characteristics, dosimetry and clinical outcomes for all patients who received SBRT for spinal/paraspinal disease were reviewed. Mann-Whitney and two-tailed Fischer’s exact tests were used to compare clinical and dosimetric parameters with outcomes of survival, local relapse and vertebral compression fracture (VCF).

SBRT technique

Patients were educated regarding the duration of SBRT, with analgesic and anxiolytic medications prescribed as required. Method of immobilisation varied according to spinal level. Planning CT scans were co-registered with diagnostic MR images, as well as CT myelogram in selected post-operative cases.

Clinical target volumes were delineated according to international consensus guidelines. Planning target volume (PTV) and planning organ at risk volume (PRV) expansions were 3mm. The PTV was optimised to exclude the spinal cord PRV/thecal sac.

Planning technique evolved over the study period, from intensity modulated radiotherapy (IMRT) prescribed to a reference point, to volumetric modulated arc treatment (VMAT) prescribed to a covering isodose.

Dose prescription depended on volume of disease and complexity of target, commonly 20 Gy in a single fraction or 24-28 Gy in 2-3 fractions. Maximum point dose to the spinal cord PRV/thecal sac (SC PRV/TS) was adapted according to number of SBRT fractions, previous radiotherapy dose, and accepted probability of myelopathy.

SBRT was delivered using an Elekta Axesse linear accelerator with 4mm multi-leaf collimator thickness (Elekta AB, Stockholm, Sweden). Image guidance utilising cone beam CT was performed in order to minimise inter- and intra-fraction positional error. The introduction of a robotic (HexaPOD) couch allowed correction of positional errors in six degrees of freedom (Medical Intelligence, Schwabmuenchen, Germany).
Results

Patient characteristics
Thirty-six courses of spine SBRT in 34 adult patients were delivered between May 2010 and December 2013. Mean patient age was 58 years (range 29-81). Patient characteristics are summarised in the Table 1.

Dosimetry
Dosimetric data for the cohort, separated according to previous irradiation, is provided in Table 2.

The median total dose was 26 Gy in 2 fractions in the de novo group and 24 Gy in 3 fractions in the re-treatment group. The previously irradiated patients generally received lower maximum, minimum, and D90 doses, in order to meet stricter dose constraints on SC PRV/TS.

Planning to a covering isodose, rather than a reference point, resulted in a relative dose escalation. Representative isodose lines for cases using different planning techniques are depicted in Figures 1 and 2.

Toxicity
Treatment was generally well tolerated. Reported acute toxicity was as follows:

- Five patients (14%) grade I-II nausea
- Three patients (8%) grade I oesophagitis
- Two patients (6%) post-treatment pain flare
- No grade III-IV acute toxicity.

At median follow-up of 7.4 months (range 1.7-22.2), no cases of late radiation myelopathy were observed.

The overall incidence of new or worsening VCF was 22% (n=8), however only one case was a new fracture. Risk of VCF was significantly associated with increasing SINS score (p=0.0002, FDR=0.0092).

Local control
In-field control was 86%, with LR occurring at a median interval of 2.8 months (range 1.9-4.7) post-treatment. The majority of LR occurred at the epidural space.
Imaging of one patient who had a complete radiographic response to treatment is depicted Figure 3.

**Distant relapse**
LR was accompanied by distant failure in all but one case. The overall rate of distant progression was 76%, diagnosed at a median of 2.8 months (range 1.2-11.9) post-treatment.

**Overall survival**
At median follow-up 7.4 months, 74% of patients remain alive and median overall survival for the group has not yet been reached. In the cohort who received SBRT to the sole site of known disease, 87% remain alive with a median follow-up of 9.3 months (range 2.9-22.2).
Table 1: Patient characteristics. †Other tumours included renal cell carcinoma, pancreatic adenocarcinoma, squamous cell carcinoma, Leydig cell cancer of testis, non-small cell lung cancer). ‡Excluding patients with prior stabilisation surgery. Abbreviations: ECOG = Eastern Cooperative Oncology Group Performance Status Score; SINS = Spinal Instability Neoplastic Score.

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Table 2: Dosimetric characteristics. Abbreviations: PTV = planning target volume; D90 = dose received by 90% of PTV; V90 = volume of PTV receiving 90% of prescribed dose; SC PRV = spinal cord planning organ at risk volume; TS = thecal sac.

Fig. 1: Dosimetry for a lumbar spinal metastasis treated with volumetric modulated arc treatment planned to a covering isodose. Gross tumour = red; clinical target volume = blue; planning target volume = shaded red; thecal sac = shaded blue; isodose lines in Gy as per legend top left, with prescription isodose in bold green.
Fig. 2: Dosimetry for a thoracic spinal metastasis treated with intensity modulated radiotherapy planned to a reference point. Gross tumour = red; clinical target volume = orange; planning target volume = shaded red; isodose lines in Gy as per legend top left.
**Fig. 3:** Complete radiographic response in patient treated with 24Gy in 3 fractions for T11 spinal metastasis. Sagittal MRI pre-treatment (left) and 9 weeks post-treatment (right).

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Conclusion

SBRT in this study cohort was predominantly for metastatic disease. At 86%, our local control rate is in keeping with larger international series that also included mixed populations of de novo, retreatment and post-operative spinal SBRT.\textsuperscript{12-14}

No cases of late radiation myelopathy have been observed in our series to date. Conservative dose constraints were applied, respecting maximum point doses to SC PRV/TS. However, given that 12 month median time to myelopathy development has been reported,\textsuperscript{10} longer follow-up of our series is required.

Other published series have reported risk of VCF ranging from 11 to 39% following spine SBRT, occurring at median intervals of 2 to 3 months.\textsuperscript{15-17} At 22%, our VCF rate is in keeping with these results, and contains a low proportion of de novo fractures.

SBRT is an evolving technology with promising early efficacy and safety results, but does require careful patient selection. This contemporary Australian series is comparable with international literature, with longer follow-up awaited.
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