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Comparison of CyberKnife multileaf collimator and variable circular aperture collimator in renal SBRT

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Background

Stereotactic Body Radiotherapy (SBRT) is being investigated as a treatment alternative in patients with primary renal carcinoma, deemed unsuitable for surgery. Traditionally, radiotherapy is not used in this context, since renal tumours are thought to be relatively radioresistent, and are situated in close proximity to the surrounding kidney and bowel. SBRT may overcome these issues and enable the delivery of higher radiation dose. The InCise™ Multileaf Collimator (MLC), available with CyberKnife® M6 System, is capable of forming a variety of irregularly shaped fields, and therefore could achieve dosimetrically equivalent plans using fewer beams in comparison to the Iris™ variable aperture collimator (Iris), potentially reducing treatment time and total monitor units (MU).

Methods

15 renal cancer cases were selected (maximum tumour diameter of ≤6 cm and total kidney volume > 200cc). Contouring was completed using diagnostic CT imaging, and a 5mm CTV –PTV margin was employed. Iris and MLC plans for each case were created by a single planner, using the MultiPlan® treatment planning system. Plans were setup for Synchrony respiratory motion management and fiducial tracking. A ray-tracing algorithm was used for dose calculation.

Table 1. Dose constraints, as per UK consensus, NHS England Commissioning through Evaluation SBRT programme (CTE).

Dose Limiting Structure	Constraint
Kidney (combined) **Solitary Kidney***	At least 200 cc < 16 Gy V8.5 Gy <10 % (optimal), <45 % (mandatory)
Small Bowel	Dmax (0.5 cc) < 25.2 Gy D5 cc < 17.7 Gy
Colon	Dmax (0.5 cc) < 28.2 Gy

* Adapted from five-fraction CTE constraint as no three-fraction constraint specified.

Plans were optimised to achieve ≥ 95% PTV coverage at a dose of 45 Gy in three fractions, prescribed to the 78 – 82 % isodose. while meeting the required dose constraints (**Table 1**). The prescribed dose could be reduced in 3Gy increments to a minimum of 36Gy in order to meet constraints. Total MU and time reduction methods were utilised, without exceeding dose constraints, and maintaining nCI (new conformity index) ≤1.15.

- Primary objective: to compare the proportion of plans achieving the 45Gy prescription dose.
- Secondary objectives: to compare coverage (%), conformity (nCI), OAR dose, estimated treatment time and total monitor units (MU).

Results

The mean PTV volume was 44.7 cc (range 15.0 – 156.9 cc). The optimal prescription dose of 45 Gy was achieved in 14 out of 15 MLC and Iris plans. In one case, the dose was reduced to 42 Gy in both plans in order to meet constraints (**Figure 1**). Plans were equivalent in terms of coverage and conformity, and there was no clear difference in mean OAR doses between modalities.

Figure 1. MLC plan, prescription dose 42 Gy in 3 fractions prescribed to 79% isodose. This image demonstrates the close proximity of PTV to small bowel.

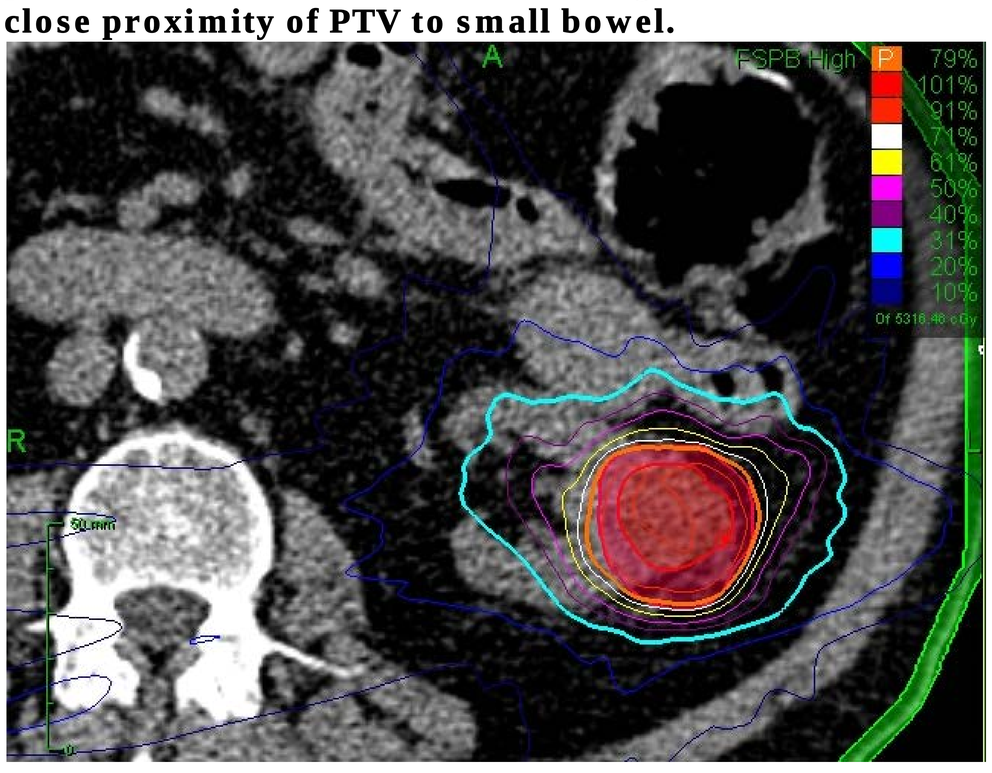

Table 2. Dose delivery efficiency for Iris and MLC plans.

		Estimated Treatment Time (min)*	Total Monitor Units (MU)
Iris	Mean	51	31616
	Range	34 - 77	14356 - 55671
MLC	Mean	43.33	28365
	Range	36 - 60	19614 - 40148

* Includes 15 minutes setup time.

As expected, the MLC plans utilised a smaller mean number of beams (43 beams) compared to Iris (113 beams), but with a relatively modest mean MU reduction of 3251 (10%) (**Table 2**). There was a mean time reduction of 7.67 mins with MLC compared to Iris plans, and after allowing for 15 mins set up time, the MLC reduced the estimated treatment time by 21.31%. A greater reduction in treatment time and MU was achieved with MLC in the more complex cases (PTV >50cc and/or within 20mm of OAR).

Conclusion

- SBRT planning with CyberKnife for primary renal carcinoma is feasible up to a dose of 45 Gy in 3 fractions.
- Iris and MLC plans were dosimetrically equivalent, but MLC plans demonstrated improvement in dose delivery efficiency.
- Although numbers are small, results suggest this benefit may be more pronounced in the treatment of larger renal tumours, with close proximity to surrounding normal structures.

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