Co-60 or Ir-192 for HDR Brachytherapy?

Evaluating Source Parameters, CTV & OAR Doses, Optimal Prescribing & Economics

Palmer A, Mzenda B, Hayman O, Nagar Y, Hosseini-Ashrafi M,
Queen Alexandra Hospital, Portsmouth Hospitals NHS Trust, UK

Purpose

An analysis is presented of the various clinical, physical and economic factors to be considered when choosing between a high-specific activity Co-60 source and the more common Ir-192 source for high dose rate (HDR) brachytherapy treatments.

A study of clinical treatment plans and an evaluation of the physical and practical differences in using the two sources are undertaken.

Method

At Portsmouth, UK, we have experience of using both Ir-192 and Co-60 sources with the IBt-Bebig HDR MultiSource® brachytherapy unit. A combination of direct measurements, simulations and clinical studies were used to compare the two available isotopes, including the following:

- A 3D-image based treatment planning study compared Co-60 and Ir-192 dose distributions, ICRU Report 38 (1985) reference points and GEC-ESTRO Working Group (2005) reporting parameters for 8 gynaecological cancer patients, analysing differences in coverage of the high-risk clinical target volume (HR-CTV) and minimising dose to organs at risk (OAR). The effect of prescribing to ICRU Point A or HR-CTV, and the effect of different 'standard' dwell distributions compared to inverse planning optimised dwell distributions was also included to provide context to the differential dose distributions resulting from choice of isotope alone. The IBt-Bebig HDRplus® treatment planning system was used for dose calculations, with DICOM dose grids analysed in IBA Dosimetry OmniPro-Accept® software.
- The physical properties of the sources, affecting dose distribution, compared using mathematical modelling, based on Monte Carlo calculated data.
- The capital and ongoing support costs, as well as typical treatment times, for the two sources, for a contextual background to the clinical results.

Results

Treatment Planning

Table 1 provides the differences in dosimetric quality indices for Co-60 compared to Ir-192, based on GEC-ESTRO (2005) and ICRU 38 (1985) reporting parameters, for a consecutive series of 8 gynaecological patients. These were planned using prescription to ICRU Point A using standard loading patterns, prescription to GEC-ESTRO HR-CTV using inverse planning techniques, and with 'alternative' loading patterns for Co-60 prescribed to Point A.

When prescribing to Point A, the rectum receives on average 3.8% higher D2cm³ and 3.5% higher ICRU rectal reference point dose with Co-60 compared to Ir-192. Figure 2. The bladder and sigmoid receive < 1.5% lower D2cm³ with Co-60. When prescribing to HR-CTV, the mean % difference is reduced to 0.9% higher rectal D2cm³ with Co-60. The mean V100% for HR-CTV coverage is 1.8% higher with Co-60 when prescribing to Point A, and 0.9% higher when prescribing to HR-CTV, compared to Ir-192. D90Gy for HR-CTV is not significantly affected by isotope choice.

There is a relatively large standard deviation associated with the mean values of the dosimetric indices, indicating the significant influence of individual patient anatomy in assessing the differential dose distributions between Co-60 and Ir-192 sources.

Figure 1 shows the percentage difference between Co-60 and Ir-192 dose distributions for a typical gynaecological treatment, prescribed to ICRU Point A. The colour wash indicates the +2% to -2% range, equivalent to deviations of +/- 17cGy for a 8.5Gy prescription dose. In general, Co-60 delivers higher doses within the HR-CTV and lower doses to the organs at risk, except along the extension of the source axis: most clearly seen as elongated higher dose regions in the sagittal view.

Figure 1 (a) shows the effect of changing the standard loading pattern for Co-60 to specifically reduce the rectal dose (reduced dwells in the ring applicator) compared to standard Ir-192 loading. Figure 1 (b) shows the effect on the difference between the dose distributions for Co-60 and Ir-192 when the prescription is to the HR-CTV rather than ICRU Point A..

Table 1. Percentage difference in GEC-ESTRO and ICRU dose reporting indices between treatment plans created with Co-60 and Ir-192 sources. Mean and standard deviation results are presented for a consecutive series of 8 clinical treatment plans prescribed to ICRU Point A and then to HR-CTV. Results of modified loading for Co-60, to reduce rectal dose, compared to conventional loading with Ir-192, prescribed to Point A, are also presented.

% differences of Co-60 compared to Ir-192 plans	Bladder D2cm³	Rectum D2cm³	Sigmoid D2cm³	HR-CTV		ICRU reference points			
				V100%	D90Gy	A-point (R)	A-point (L)	Rectum	Bladder
Plans prescribed to Point A using 'standard loading patterns':									
mean over 8 patients	-0.9	3.8	-1.4	1.8	0.0	0.3	0.1	3.5	2.1
standard deviation	5.5	2.2	3.5	2.3	3.0	2.7	1.6	4.1	4.0
Plans prescribed to HR-CTV using optimised inverse planning techniques:									
mean over 8 patients	-0.4	0.9	-0.3	0.7	-0.2	-0.1	-0.4	2.4	0.1
standard deviation	2.6	3.3	3.5	1.4	2.0	3.3	2.5	2.8	2.9
Plans prescribed to Point A comparing two 'modified loading patterns' for Co-60 compared to 'standard loading pattern' for Ir-192:									
reduced no. Co-60 dwells in ring	1.3	-1.1	-4.5	0.0	-5.2	4.3	-3.8	4.1	0.0
reduced no. Co-60 dwells in ring & IUT	5.3	-9.7	0.0	3.2	0.0	4.3	-3.8	-12.2	1.5

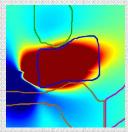

Fig 1 (a). Percentage difference in dose distribution between non-standard dwell position loading for Co-60, to minimise rectal dose, compared to conventional loading for Ir-192, both prescribed to ICRU Point A

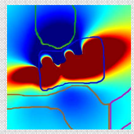

Fig 1 (b). Percentage difference in dose distribution between Ir-192 and Co-60 when prescribed to HR-CTV using high-penalty rectal and bladder constraints

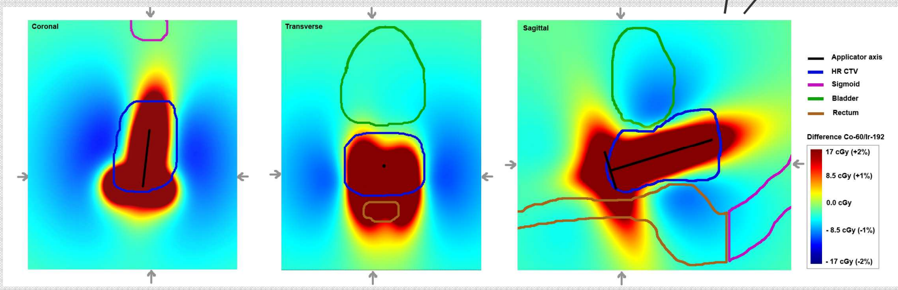

Fig 1. Percentage difference in dose distribution between Co-60 and Ir-192 sources with the IBt-Bebig HDR MultiSource® brachytherapy unit, in coronal, transverse and sagittal planes, for a typical 3 channel gynaecological treatment prescribed to ICRU Point A. Colour wash shows the +2% to -2% differences. The applicator axes and outlines of the HR-CTV and OARs are shown.

Physical Properties

The dose delivered to a point is proportional to source strength, dose rate constant, air kerma rate constant and dwell time, while the geometric factor, radial dose function and anisotropy function all determine the distribution around the source.

Table 2 compares the key physical properties of Co-60 and Ir-192, in terms of dose delivering strength, illustrating that 1GBq Co-60 is equivalent to 2.77 GBq Ir-192. Figure 2 (left) shows the radial dose function perpendicular to the Co-60 and Ir-192 source axes. Figure 2 (right) shows the anisotropy function, along the axis of the source. At 5cm distance form the source perpendicular to the source axis, the radial dose function is 7% larger for Ir-192 compared to Co-60. At 5 cm distance from the source along the source axis, the anisotropy function is 40% larger for Co-60 than Ir-192. However, figure 2 shows that the total delivered dose as a function of distance from the source is largely dependent on the geometric factor rather than anisotropy or radial dose function differences. There is a small residual difference between the dose-distance curves for Co-60 and Ir-192 even when the geometric factor is applied, being most evident along the source axis.

The interplay between these factors is complex. It is expected there will generally be insignificant clinical effects on the dose distributions from Co-60 and Ir-192 as a result of the differences in physical properties of the two sources, the only observable change being an increased relative dose around the ends of the Co-60 source compared to Ir-192, as a result of reduced self-absorption in the source and encapsulation.

Table 2. Selected Co-60 and Ir-192 source parameters

	Co-60	Ir-192
Half life (months)	63.3	2.4
Iniital source strength (GBq)	74	370
Air kerma rate constant (mGy/h)	306	108
Dose rate constant (cGy/hU)	1.084	1.108

ratio of product (Co-60/Ir-192) = 332/120 = 2.77
1 GBq Co-60 delivers the same dose as 2.77 GBq Ir-192

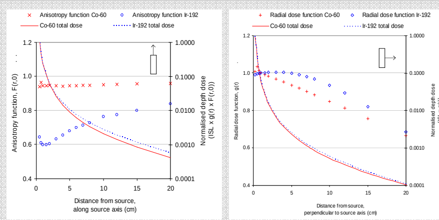

Fig 2. Effect of radial dose function and anisotropy on dose curves in (left) direction perpendicular to source axis and (right) distance along source axis

Economics

Figure 3 compares the cumulative indicative costs of Co-60 and Ir-192 sources over a 10 year period. The total cost is less with Co-60 after ~19 months, assuming source replacement at the maximum length of clinical use: 4 months for Ir-192 and 5 years for Co-60. The capital expenditure for a treatment room with increased radiation shielding for Co-60 compared to Ir-192 may offset some of the cost saving of Co-60 sources.

Figure 4 shows a comparison of the planned clinical down-time for Co-60 and Ir-192 source HDR units. (Based on 0.5 days per month for routine QC, and 1 day per source change. Co-60 source change every 5 years and Ir-192 source change every 4 months). Difference in planned clinical down-time may not be significant, except for very busy clinical workload, or where the room is shared with other equipment. However, 40% more physics support time is required for Ir-192 compared to Co-60.

Figure 5 shows typical treatment time at the end of each month, based on a typical 10min treatment time for a new Ir-192 source, compared to an equivalent treatment from a Co-60 source. (Based on Ir-192 source change every 4 months and Co-60 source change every 5 years). Individual treatment times for Co-60 are mostly within the variation of times from an Ir-192 source. However the total clinical irradiation time for Co-60 is ~20% larger than Ir-192 over the 5 year life of a Co-60 source, ~46% larger in the worst-case 5th year of the Co-60 source.

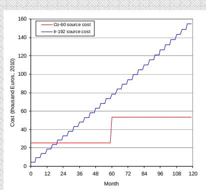

Fig 3. Indicative cumulative cost of Co-60 and Ir-192 sources over 10 years

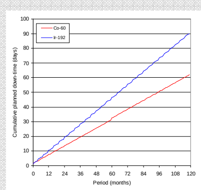

Fig 4. Indicative total planned down-time for HDR unit with Co-60 and Ir-192 sources

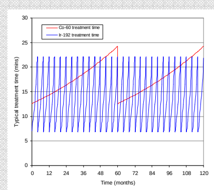

Fig 5. Indicative treatment time comparison for Co-60 and Ir-192 sources (source changes at 5 years and 4 months respectively)

Conclusion

While there are small physical differences in the dose distribution around the IBt-Bebig Co-60 and Ir-192 sources, most notably along the axis of the source, the treatment planning comparison showed clinically insignificant changes to target coverage or OAR doses, particularly when plan dwells were optimised via inverse planning techniques. Even for identical dwell patterns, small differences in D2cc for OARs is affected more by the prescribing method, to HR-CTV or ICRU Point A, than by the choice of isotope.

Significant cost savings may be achieved with Co-60 source replacements every 4-5 years compared to Ir-192 every 3-4 months, but the capital costs of equipment and room shielding may be greater for Co-60. Physics support time savings of around 40% may be achieved with Co-60 in comparison to Ir-192.

The economic and practical advantages of Co-60 over Ir-192 have been demonstrated. A clinical treatment planning study has showed no significant difference in achievable dose distributions; and a theoretical benefit to OARs with Co-60 is dependent on the dose planning and prescribing method. Over 50 treatments have now been performed using the IBt-Bebig HDR Multisource at Portsmouth, UK; approximately half of these were treated with an Ir-192 source before moving to a Co-60 source.

Further information may be obtained from Tony Palmer: antony.palmer@porthosp.nhs.uk.
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