The Physics, Economics and Clinical Use of Co-60 for High Dose Rate Brachytherapy

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Introduction

Portsmouth Oncology Centre recently became the first UK installation of a high dose rate (HDR) brachytherapy treatment unit capable of utilising a Co-60 source. Why was this procurement decision taken? What aspects were considered? And have there been any changes to treatment planning or prescribing?

This poster provides an overview of the relevant physics of Co-60 compared to the more conventional Ir-192 HDR source, considers the economic benefits of Co-60, and reports on a clinical treatment planning study on the differences between the two sources. Key findings from commissioning of the Eckert & Ziegler IBt-Bebig HDR MultiSource® afterloading brachytherapy treatment unit are also presented.

Portsmouth initially commenced treatments with an Ir-192 source moving to Co-60 soon afterwards, the HDR unit being capable of taking either source.

Commissioning the E&Z IBt-Bebig HDR MultiSource Treatment Unit

A comprehensive commissioning and characterisation was undertaken of the HDR brachytherapy unit, shown in Figure 1, see activities listed in Table 1.

The results of this work showed that the performance of the IBt-Bebig HDR system is sufficient for the device to be used clinically for brachytherapy treatments, and overall performance is similar to other HDR treatment units available in the UK. However, it is essential that the advice given by the manufacturer to avoid significant curvature of transfer tubes is followed in all cases, in order to avoid deviations in the delivered source dwell configurations from those planned; of up to 3 mm for moderate curvature due to 'lag' of the source cable movement, see full description in reference [1]. It was also discovered that no transit dose correction is made for source travel to the first dwell point, or from the last dwell point, but these resulted in insignificant dose affects. The manufacturer has however undertaken to imminently issue updated software to address these issues.

Good agreement was obtained in the source strength measurement using a PTB-calibrated thimble chamber (NE2611) in a Kreiger perspex cylindrical phantom, PTW-calibrated well chamber (type 33004) and NPL-calibrated instruments, and the results fell within quoted uncertainties.

The characterisation of the HDR Multisource unit showed it to be a reliable system capable of high quality HDR treatments, with some unique features including a high specific activity Co-60 source and integrated in-vivo dosimetry.

Table 1. HDR unit commissioning activities

- Critical examination, radiation shielding survey, local rules
- Manufacturer's acceptance testing schedule
- Mechanical and electrical safety tests
- Interlocks, safety features and basic operational checks, including timer accuracy checks
- Source positioning
- Source dwell time
- Source transit time
- Source specification data
- Manufacturer's source certificate
- Source strength measurement with a well chamber
- Source strength measurement with a thimble ionisation chamber in-phantom
- Data transfer from the treatment planning system (TPS)
- TPS algorithm, functionality tests and source data
- Applicator commissioning including labelling, rigidity and consistency with TPS library
- Applicator and shield transmission measurements
- Definition of, and baseline results for, routine quality checks
- Training materials and documentation

Figure 1. Eckert & Ziegler IBt-Bebig HDR MultiSource brachytherapy treatment unit

Physical Properties

Delivered dose to a point is proportional to source strength, dose rate constant, air kerma rate constant and dwell time, and the geometric factor, radial dose function and anisotropy function all determine the dose 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, figure 2 (left), 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, figure 2 (right), the anisotropy function is 40% larger for Co-60 than Ir-192. However, Figure 2 shows the total delivered dose as a function of distance from the source is largerly 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.

The interplay between these factors is complex. It is expected there will generally be insignificant clinical affects 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 a more uniform dose distribution around the ends of the Co-60 source compared to Ir-192.

Table 2. 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

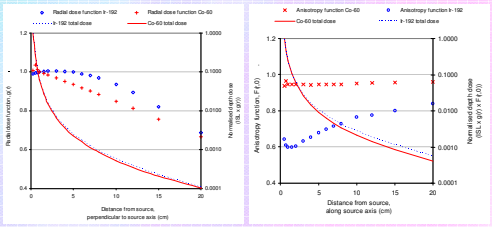

Figure 2. Affect of radial dose function and anisotropy on dose curves in (left) direction perpendicular to source axis and (right) distance along source axis

Economics and Practicalities

Cost

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. (Assumes sources replaced at maximum length of clinical use: 4 months for Ir-192 and 5 years for Co-60).

The capital expenditure for a room with increased radiation shielding for Co-60 compared to Ir-192 may offset some of the cost saving of Co-60 sources.

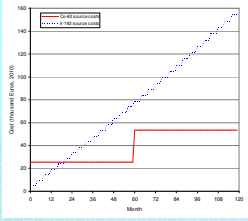

Figure 3. Indicative cost of Co-60 and Ir-192 sources over 10 years

Physics support time

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.

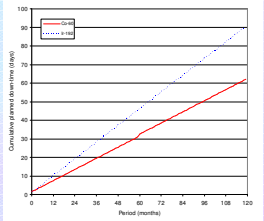

Figure 4. Indicative total planned down-time for HDR unit with Co-60 and Ir-192 sources

Treatment times

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.

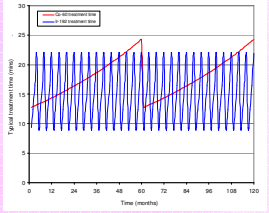

Figure 5. Indicative treatment time comparisons for Co-60 and Ir-192 sources.

Clinical Treatment Planning

Figure 6 shows the isodose distributions around a typical 3-channel gynaecological HDR insertion for Co-60 (solid line) and Ir-192 (dashed line), both treatments normalised to ICRU Point A. Depending on location, doses from Co-60 may be higher or lower than Ir-192 (isodose displacements up to 5mm).

Treatment plans using Co-60 and Ir-192 were compared for five patients, using prescriptions to both ICRU point A and GEC-ESTRO HR-CTV (D_{90} and $V_{100\%}$), and considering dose to organs at risk (OAR): bladder, rectum and sigmoid ($D_{0.1cc}$, D_{1cc} and D_{2cc}). Variations in CTV D_{90} of up to 7.5% and V_{100} of up to 10%, and OAR D_{1cc} of up to 8.5%, were observed between Co-60 and Ir-192.

Results show that differences in CTV coverage and OAR doses is more dependent on the prescription method and dwell optimisation technique, than the isotope used.

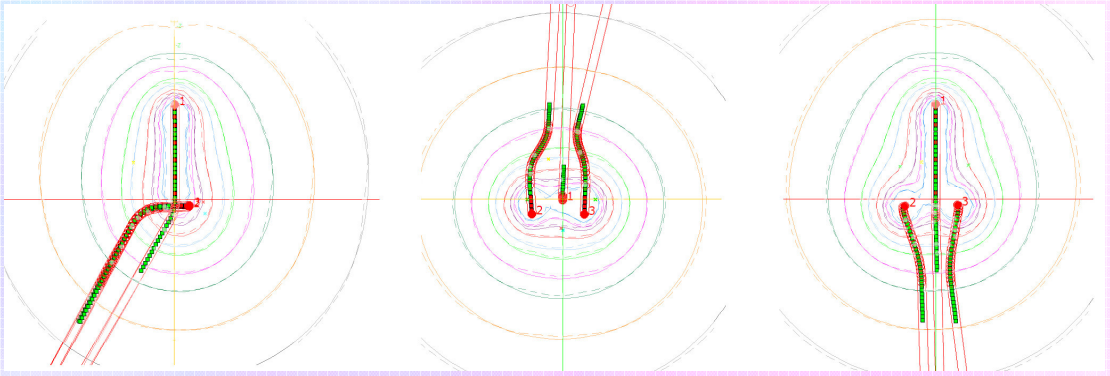

Figure 6. Isodose comparison between Co-60 (solid lines) and Ir-192 (dashed lines) for a typical 3-channel gynaecological HDR treatment, showing sagittal (left), transverse-oblique (centre), and coronal (right) projections

Conclusions

The first Eckert & Ziegler IBt-Bebig HDR MultiSource® afterloading brachytherapy treatment unit in the UK has been successfully commissioned into clinical use.

The economic and practical advantages of Co-60 over Ir-192 have been demonstrated. There are no significant clinical differences between the two isotopes in dose prescribing, treatment planning, or resultant isodose distributions.

In excess of 30 patients have been treated using the HDR MultiSource brachytherapy unit at Portsmouth to date (May 2010).

We would like to thank IBt-Bebig for their assistance in evaluating the performance of the HDR treatment unit and the Co-60 source.

Further information on this work may be obtained from Tony Palmer: antony.palmer@porthosp.nhs.uk. The IBt-Bebig HDR unit is marketed in the UK through **SeeDOS Ltd**, contact Colin Walters: cwalters@seedos.com.

[1] Palmer A, Mzenda B 2009. Performance assessment of the IBt-Bebig Multisource high dose rate brachytherapy treatment unit. Phys. Med. Biol. 54; 7417-7434.