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 the investigation at 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.

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

A comprehensive commissioning and characterisation was undertaken of the HDR brachytherapy unit, as 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 curvatures 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 curvatures due to tag of the source cable movement, see full description in reference [1]. It was also discovered that if transit dose correction is made for source travel to the first dwell point, or from the last dwell point, these resulted in insignificant dose affects. The manufacturer has however underlined to annually issue updated software to address these issues.

Good agreement was obtained in the source strength measurement using a PTB-calibrated thimble chamber (NE5811) in a Kruger parapex cylindrical phantom, 3 cm in diameter, 5 cm in length, and 1 cm in height. The results fell with 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.

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 100Gy 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 axis, and Figure 2 (right) shows the anisotropy function, along the axis of the sources. At 3 cm distance from the source perpendicular to the axis, figure 2 (left), the radial dose function is 7% larger for Ir-192 compared to the Co-60 source. The inverse from the source along the 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 largely dependent on the geometric factor rather than anisotropy or radial dose function differences. There is a small residual difference between the dose-distance curve for Co-60 and Ir-192 even when the geometric factor is equal.

The interplay between these factors is complex. It is expected there will generally be insignificantly clinical affects on the dose distributions from Co-60 and Ir-192 as a result of the differences in the 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.

Economics and Practicalities
Cost

Figure 3 compares the cumulative indicative cost of Co-60 and Ir-192 sources over a 10 year period. The total cost is less with Co-60 after ~19 months, (Ir-192 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 (Co-60) compared to Ir-192 may offset some of the cost-saving of Co-60 sources.

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 day 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.

Clinical Treatment Planning

Figure 6 shows the isodose distributions around a typical 3-channel geometrical HDR insert for Co-60 (solid line) and Ir-192 (dashed line), both treatments normalised to ICRU Point A. Depending on location, dose from Co-60 may be higher or lower than -10% (isodose displacements up to 5mm).

Treatment plans using Co-60 and Ir-192 were compared for five patients, with prescriptions to both ICRU point A and OAR. Variations in dose to OAR, were observed for up to 5.5% for Co-60 and Ir-192, and OAR D50% of up to 8.5%, were observed between Co-60 and Ir-192.

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

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 prescription, 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).

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

Figure 2. Radial dose function, g(r), and anisotropy function, F(r,0)

Table 1. HDR unit commissioning activities

- Critical examination, radiation shielding survey, local rules
- Manufacturer’s acceptance testing schedule
- Mechanical and electrical safety tests
- Tracking, safety become aerosol optical elements, machine, including timer accuracy checks
- Height measurement, source handle, source strength, source identification, measurements, temperature, air kerma rate, dose rate, half life, source strength and source specification data
- Applicator commissioning (handling, alignment and stability with TPS accuracy)
- Applicator and dose transmission measurements
- Definition of, and baseline results for, routine quality checks
- Training manual and documentation

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

<table>
<thead>
<tr>
<th>Source</th>
<th>Half life (yrs)</th>
<th>Initial source strength</th>
<th>Air kerma rate constant (mGy/h)</th>
<th>Dose rate constant (cGy/h.U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-60</td>
<td>5.26</td>
<td>74370 (GBq)</td>
<td>306108 (mGy/h)</td>
<td>1.084 (cGy/h.U)</td>
</tr>
<tr>
<td>Ir-192</td>
<td>74.4</td>
<td>25.4</td>
<td>306108 (mGy/h)</td>
<td>1.108 (cGy/h.U)</td>
</tr>
</tbody>
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Figure 3. Indicative cost of Co-60 and Ir-192 sources over 10 years

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

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

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

Figure 7. Indication time comparison time for Co-60 and Ir-192 sources

Figure 8. Indicative treatment time at the end of each month, based on a typical 10min treatment time for a new Ir-192 source. The physical properties and treatment times for Co-60 are ~20% larger than Ir-192 over the 5 year life of a Co-60 source, ~46% larger in the worst-case 5 year.

Figure 9. 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 Co-60 source change every 4 months and Co-60 source change every 5 years).

Figure 10. Indication time for Co-60 are mostly within the variation of times from an Ir-192 source. However the total clinical indication 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 5 year of the Co-60 source.