Data Article

Data on estimations of relative dose rates along central axis of symmetric and asymmetric $^{106}$Ru/$^{106}$Rh applicators used in eye brachytherapy

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ABSTRACT

Beta particles radiation doses have important applications in medicine. In particular, curved and symmetric as well as curved and asymmetric applicators containing the beta emitting $^{106}$Ru/$^{106}$Rh isotopes are widely used in radiotherapy for the treatment of various ocular diseases. Nevertheless, a great problem in the use of these applicators is the inaccurate determination of the dose rates around them. Difficulties arise mainly because of the very short distances involved, and in this scenario theoretical calculation methods play an important role. In this work a simple approach based on the beta-point dose function integration over the total surface of each plaque was used to estimate the dose rates along their central axis. Results of relative dose rates for concave and symmetric (CCA, CCB, CXS, CCX/Y/Z, CCD, CGD and CCC) and concave and asymmetric (CIA, CIB/CIB-2, COB and COC) ruthenium/rhodium plaque types are shown.

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Specifications Table

| Subject                        | Medical physics       |
|-------------------------------|-----------------------|
| Specific subject area         | Radiation therapy, brachytherapy |
| Type of data                  | Tables                |
| How data were acquired        | Numerical integration of the beta-point dose function over the radioactive surface of the plaques |
| Data format                   | Raw                   |
| Parameters for data collection| Data presented are formed by depths versus relative dose rates for concave and symmetric (CCA, CCB, CXS, CCX/Y/Z, CCD, CGD and CCC) and concave and asymmetric (CIA, CIB/CIB-2, COB and COC) ruthenium/rhodium model applicators |
| Description of data collection| A Fortran code was developed to carry out numerical calculations for each of the 14 plaques analysed. For the symmetric plaques an IF command makes the compiler to skip the points within the cut-out section |
| Data source location          | Division of Medical Physics, Institute of Radiation Protection and Dosimetry (Rio de Janeiro, Brazil) |
| Data accessibility            | Data provided within this article |
| Related research articles     | E. De Paiva. Estimates of relative beta radiation doses on central and lateral axes of ruthenium/rhodium COB-type plaque used in eye brachytherapy. Applied Radiation and Isotopes 156, 108991 (2020). doi: 10.1016/j.apradiso.2019.108991 |

Value of the Data

- Symmetric and asymmetric applicators containing the $^{106}$Ru/$^{106}$Rh beta emitters play an important role in radiotherapy to treat various diseases. However, mainly because of the short distances involved, there is a scarcity of dosimetric data on them, specially for the asymmetric plaques. Therefore, all dataset on dose rates around these plaques are welcome and makes the results shown here valuable.
- Users from small radiotherapy facilities, mainly located in low-income and developing countries where computational resources may be limited, can take advantage of these rough estimates to plan doses around these types of applicators.
- Due to the great lack of published experimental and theoretical data on these kinds of applicators the results presented here, mainly for the asymmetric plaques, may be used as a reference for future studies on them.
- On the clinical usability of the data we highlight that the dataset can be used as input in the developing of a treatment planning system; users/researches around the world may also develop a software to estimate the doses around these beta applicators and results can be compared to the data presented.

1. Data Description

Some details on the plaques studied are shown in Table 1. In Table 2 are shown the dose rates as a function of depths along central axis of the plaques. Results are normalised to 100% at 1 mm depth on the central axis of the concave and symmetric ruthenium/rhodium CCA, CCB [1] and CXS, CCX/Y/Z, CCD, CGD, CCC model plaques.

In Table 3 are shown the dose rates as a function of depths along central axis of the plaques. Results are normalised to 100% at 1 mm depth on the central axis of the concave and asymmetric ruthenium/rhodium CIA, CIB/CIB-2, COB [2] and COC model plaques.
Table 1
Applications and dimensions of the ruthenium/rhodium plaques analysed.

| Plaque type | Medical application | Radius of curvature [mm] | Active diameter [mm] |
|-------------|---------------------|--------------------------|---------------------|
| CXS         | Retinoblastoma      | 12                       | 7.7                 |
| CCX/Y/Z     | Retinoblastoma      | 12                       | 9.5                 |
| CCA         | Uveal and choroidal melanomas | 12  | 13               |
| CIA         | Melanomas close to the iris | 12  | 13               |
| CCD         | Uveal and choroidal melanomas | 12  | 15.5              |
| COB         | Tumours close to the optical nerve | 12  | 17.1              |
| CCB         | Uveal and choroidal melanomas | 12  | 17.8              |
| CIB/CIB-2   | Melanomas close to the iris | 12  | 17.8              |
| CGD         | Uveal and choroidal melanomas | 13  | 19.9              |
| CCC         | Uveal and choroidal melanomas | 13  | 22.5              |
| COC         | Tumours close to the optical nerve | 14  | 22.7              |

Table 2
Relative depth-doses for the curved and symmetric $^{106}$Ru/$^{106}$Rh model applicators. Depths increase from the plaque center.

| depth [mm] | Relative dose rates |
|------------|---------------------|
|            | CXS    | CCX/Y/Z | CCA | CCD | CCB | CGD | CCC |
| 0.5        | 1.443  | 1.390    | 1.338 | 1.319 | 1.309 | 1.309 | 1.306 |
| 1.0        | 1.000  | 1.000    | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| 1.5        | 0.750  | 0.775    | 0.804 | 0.815 | 0.821 | 0.821 | 0.823 |
| 2.0        | 0.578  | 0.616    | 0.662 | 0.681 | 0.692 | 0.692 | 0.696 |
| 2.5        | 0.450  | 0.493    | 0.548 | 0.573 | 0.588 | 0.588 | 0.594 |
| 3.0        | 0.350  | 0.393    | 0.453 | 0.481 | 0.498 | 0.499 | 0.507 |
| 3.5        | 0.271  | 0.312    | 0.372 | 0.402 | 0.422 | 0.423 | 0.432 |
| 4.0        | 0.210  | 0.246    | 0.304 | 0.335 | 0.356 | 0.358 | 0.368 |
| 4.5        | 0.162  | 0.194    | 0.248 | 0.278 | 0.299 | 0.302 | 0.313 |
| 5.0        | 0.125  | 0.152    | 0.200 | 0.229 | 0.250 | 0.254 | 0.265 |
| 5.5        | 0.096  | 0.119    | 0.161 | 0.188 | 0.209 | 0.212 | 0.224 |
| 6.0        | 0.074  | 0.093    | 0.130 | 0.154 | 0.173 | 0.177 | 0.189 |
| 6.5        | 0.057  | 0.073    | 0.104 | 0.125 | 0.143 | 0.147 | 0.159 |
| 7.0        | 0.044  | 0.056    | 0.082 | 0.101 | 0.117 | 0.121 | 0.133 |
| 7.5        | 0.034  | 0.044    | 0.065 | 0.081 | 0.096 | 0.100 | 0.111 |
| 8.0        | 0.026  | 0.034    | 0.051 | 0.065 | 0.078 | 0.081 | 0.092 |
| 8.5        | 0.020  | 0.026    | 0.040 | 0.051 | 0.062 | 0.066 | 0.075 |
| 9.0        | 0.015  | 0.020    | 0.031 | 0.040 | 0.050 | 0.053 | 0.062 |
| 9.5        | 0.011  | 0.015    | 0.024 | 0.031 | 0.039 | 0.042 | 0.050 |
| 10.0       | 0.008  | 0.011    | 0.018 | 0.024 | 0.031 | 0.033 | 0.040 |
| 10.5       | 0.006  | 0.008    | 0.014 | 0.018 | 0.024 | 0.026 | 0.032 |
| 11.0       | 0.004  | 0.006    | 0.010 | 0.014 | 0.018 | 0.020 | 0.025 |
| 11.5       | 0.003  | 0.004    | 0.007 | 0.010 | 0.013 | 0.015 | 0.019 |
| 12.0       | 0.002  | 0.003    | 0.005 | 0.007 | 0.010 | 0.011 | 0.014 |
| 12.5       | -      | -        | -     | -     | -     | 0.007 | 0.010 |
| 13.0       | -      | -        | -     | -     | -     | 0.005 | 0.007 |

2. Methods

The relative depth-doses for the curved and symmetric and curved and asymmetric $^{106}$Ru/$^{106}$Rh plaques were obtained by the following integral, evaluated over the plaque surface $S$.

$$\hat{D} = a_S \int_S J(\xi) \cdot dS,$$  (1)

where $\hat{D}$ is the absorbed dose rate at the point of calculation, $a_S$ is the total activity per area and $J(\xi)$, known as the beta-point dose function, is the dose rate at a distance $\xi$ from a point-source.
Table 3
Relative depth-doses for the curved and asymmetric $^{106}$Ru/$^{106}$Rh model applicators. Depths increase from the plaque center.

| depth [mm] | CIA  | COB  | CIB/CIB-2 | COC  |
|-----------|------|------|------------|------|
| 0.5       | 1.402| 1.339| 1.360      | 1.367|
| 1.0       | 1.000| 1.000| 1.000      | 1.000|
| 1.5       | 0.777| 0.807| 0.797      | 0.802|
| 2.0       | 0.625| 0.700| 0.656      | 0.668|
| 2.5       | 0.510| 0.562| 0.546      | 0.564|
| 3.0       | 0.415| 0.471| 0.456      | 0.478|
| 3.5       | 0.337| 0.395| 0.380      | 0.405|
| 4.0       | 0.273| 0.330| 0.316      | 0.343|
| 4.5       | 0.221| 0.275| 0.263      | 0.291|
| 5.0       | 0.178| 0.228| 0.218      | 0.245|
| 5.5       | 0.143| 0.189| 0.180      | 0.207|
| 6.0       | 0.114| 0.155| 0.148      | 0.174|
| 6.5       | 0.091| 0.127| 0.122      | 0.145|
| 7.0       | 0.072| 0.104| 0.099      | 0.121|
| 7.5       | 0.056| 0.084| 0.081      | 0.100|
| 8.0       | 0.044| 0.068| 0.065      | 0.083|
| 8.5       | 0.034| 0.054| 0.052      | 0.068|
| 9.0       | 0.027| 0.043| 0.041      | 0.055|
| 9.5       | 0.020| 0.034| 0.033      | 0.044|
| 10.0      | 0.016| 0.026| 0.026      | 0.035|
| 10.5      | 0.012| 0.020| 0.020      | 0.027|
| 11.0      | 0.009| 0.015| 0.015      | 0.021|
| 11.5      | 0.006| 0.011| 0.011      | 0.016|
| 12.0      | 0.004| 0.008| 0.008      | 0.011|
| 12.5      | -    | -    | -          | 0.008|
| 13.0      | -    | -    | -          | 0.005|
| 13.5      | -    | -    | -          | 0.003|
| 14.0      | -    | -    | -          | 0.001|

on the plaque to the point of interest and is expressed by [3,4]

$$J(\xi) = \frac{B}{(\rho v_\xi)^2} \left\{ c \left[ 1 - \frac{\rho v_\xi}{c} \exp\left(1 - \frac{\rho v_\xi}{c}\right)\right] + \rho v_\xi \exp(1 - \rho v_\xi) - \rho v_\xi \exp\left(1 - \frac{\rho v_\xi}{2} - f^2\right) \right\}. \tag{2}$$

where $\rho$ is the density of the absorbing medium, $v$ is the apparent absorption coefficient, and $c$ and $f$ are dimensionless parameters. The factor $B$ is a normalization constant given by

$$B = 0.046\rho^2 v^3 E_\beta \alpha. \tag{3}$$

where $E_\beta$ is the mean kinetic energy of the beta particles, and the factor $\alpha$ is related to parameters $c$ and $f$ as

$$\frac{1}{\alpha} = 3c^2 - (c^2 - 1) \exp(1) + (3 + f) \exp(1 - f) - 4 \exp\left(1 - \frac{f^2}{2}\right). \tag{4}$$

In the integration, through Eqs. (1) to (4), let us initially suppose that all the plaques are symmetric, i.e., the cut-out section does not exist, so that using spherical coordinates we can write

$$D = a_3 R^2 \iiint J(\xi) \sin \phi \, d\phi \, d\theta,$$  \tag{5}$$

where $R$ is the constant plaque radius of curvature; the angle $\theta$ is the azimuthal angle in the $xy$-plane from the $x$-axis; $\phi$ is the polar angle from the positive $z$-axis. We can easily determine
the distance $\xi$ from a point on the plaque to a point $P(0,0,z_0)$ on the central axis as

$$\xi = \sqrt{R^2 + z_0^2 - 2Rz_0 \cos \phi}.$$  

(6)

The problem of the asymmetry of the actual plaques (CIA, CIB/CIB-2, COB, COC) can be solved by not considering the contribution of points on the source located inside the cut-out section. For every point-source inside the cut-out section an instruction makes the compiler to skip the calculations, and this is accomplished with an IF command within the code in order to skip the points in the $xy$-plane within the cut-out section.

The integration described above was carried out by means of a Fortran code based on the trapezoidal rule and the results of such calculations (normalised to 100% at 1 mm depth) are shown in Tables 2 and 3, respectively for curved and symmetric and curved and asymmetric ruthenium/rhodium plaques. These dataset can be used as input in the developing of a treatment planning system; users/researches around the world may also develop a software to estimate the doses around these beta applicators and results can be compared to the data presented. Users/researches interested in use the Fortran code can obtain it at the GitHub repository (https://github.com/edu2112923/Eduardo.git) or under request.

**Ethics Statement**

No humans and animals were involved in the data collection.

**Declaration of Competing Interest**

The author declares that he has no known competing financial interests or personal relationships which could be perceived to have influenced the work reported in this article.

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