Technical Report

North American Scientific I-125 Brachytherapy Seed Nomogram

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INTRODUCTION:

A nomogram-based approach to intra-operative planning of ^{125}I permanent seed implantation has been previously established for a particular ^{125}I seed design and shown to provide acceptable levels of dose coverage (1-5). The method for extending this nomogram approach to other source designs is not obvious, as different models exhibit differences in anisotropy, dose-rate constants and radial dose functions they may not be directly transferred to another source that contains the same radionuclide but configured in a different design (6). For the same reasons it would be inappropriate to apply a nomogram developed for one source to another. Simple ratios of dose constants may yield inaccurate estimates and relationships between activity and dose-coverage. Complicating the situation further has been the change in the NIST calibration standards for ^{125}I with the associated revision of the TG-43 dose-rate constants (7,8). With this background there was support for the independent generation of a look-up table for use with intra-operative planning with the North American Scientific MED3631-A/M seed.

Developing a new nomogram or look-up table for clinical use requires the use of a model system for simulating implants of different dimensions incorporating those dosimetry characteristics of a given seed design. Recently a model was developed that allows the generation of volume-activity relationship, similar to a nomogram (5). To this end the sphero-cylindrical dose model was recently developed to simulate the affects of seed positions and activity as a function of volume, establishing a volume-activity relationship for the North American Scientific MED3631-A/M ^{125}I brachytherapy seed.

METHODS AND MATERIALS:

The sphero-cylindrical model assumes that the needles and seed distributions for a prostate implant may be represented by a combination of a hemi-sphere (base of the prostate) and cylinder of equivalent diameters. The distribution of activity is weighted to the peripheral needles relative to the core needles, typically 75%/25%. The ends of the sphero-cylinder are effectively weighted more by placing two sources along a needle in a contiguous fashion (i.e., without spacing). The remaining seeds are evenly spaced along

the needles. The activity necessary to achieve complete coverage with the prescription dose of 145Gy is determined for a variety of radial dimensions of the model. This arrangement of seeds preserves the urethral dose-sparring affect of peripherally-weighted implants compared to uniform distributions of seed activities.

TG-43 parameters incorporating the NIST 1999 ^{125}I calibration standards were used in the model. For the North American Scientific MED3631-A/M brachytherapy seed the dose-rate constant, Λ_{99}, was 1.06 $cGyh^{-1}U^{-1}$. A point source model was assumed with an anisotropy constant, ϕ_{an}, equal to 0.95 (9).

A number of factors contribute to differences in the seed geometry of an actual implant compared to the plan, which results in a lower dose coverage of the prostate. To account for the variations in the seed geometry of an actual implant, the total activity has been increased by 15% over the plan, as suggested in the literature (10-12).

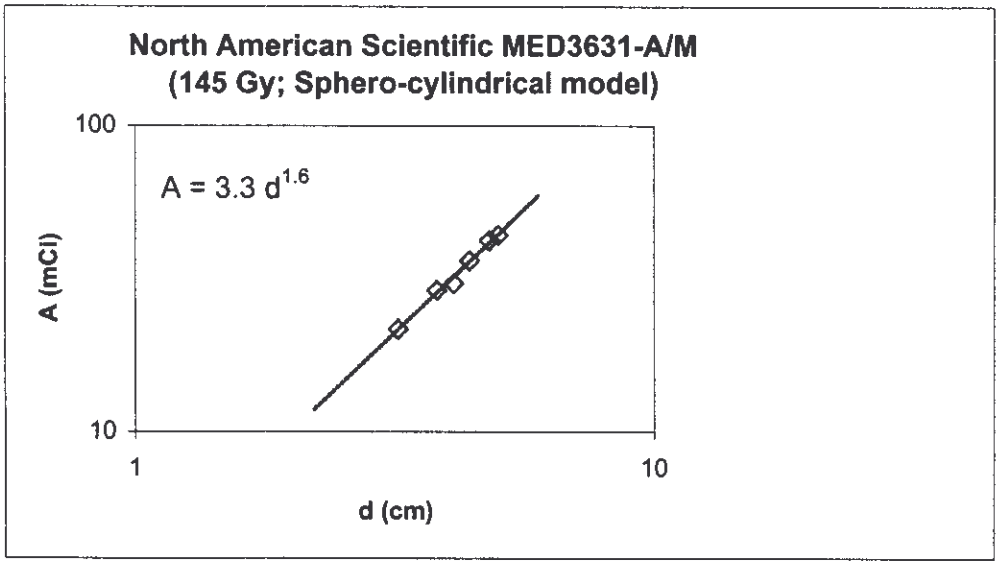
RESULTS:

The results of the simulation for diameters of 3.2 to 5.00 cm are shown in Table 1 and graphically represented as a power-law function in Figure 1.

Table 1.

d (cm)	Volume (cc)	A(mCi)
3.20	17.00	21.61
3.80	28.50	28.92
4.10	35.80	30.47
4.40	44.30	36.23
4.80	57.50	42.10
5.00	65.00	43.95

For 145 Gy: $A\ (mCi) = 3.30 \times d^{1.6}$ d: diameter in cm



Using this relationship, a nomogram for Volume vs. Activity may be constructed as shown in Table II for prescribed doses of 145 Gy and 110 Gy. The power-law relationship differs from that derived for the Nycomed Amersham 6711 ^{125}I seed. This difference is illustrated in Figure 2. The departure of the two nomograms for the two ^{125}I seeds increases as the volume of the prostate increases, with the Nycomed Amersham 6711 ^{125}I seed requiring more activity for the larger glands. This is partially due to the relatively small radial dose function, g (r), of Nycomed Amersham 6711 ^{125}I seed, at larger distance.

Table 2.
Nomogram for North American Scientific MED3631-A/M ^{125}I brachytherapy seeds for 145 Gy and 110 Gy.

Volume (cc)	Activity (mCi)	
	145 Gy	110 Gy
12	17.6	13.4
14	19.1	14.5
16	20.5	15.6
18	21.8	16.5
20	23.1	17.5
22	24.3	18.4
24	25.4	19.3
26	26.5	20.1
28	27.6	20.9
30	28.6	21.7
32	29.6	22.5
34	30.6	23.2
36	31.6	24.0

38	32.5	24.7
40	33.4	25.3
42	34.3	26.0
44	35.1	26.6
46	36.0	27.3
48	36.8	27.9
50	37.6	28.5
52	38.4	29.1
54	39.2	29.7
56	39.9	30.3
58	40.7	30.9
60	41.4	31.4

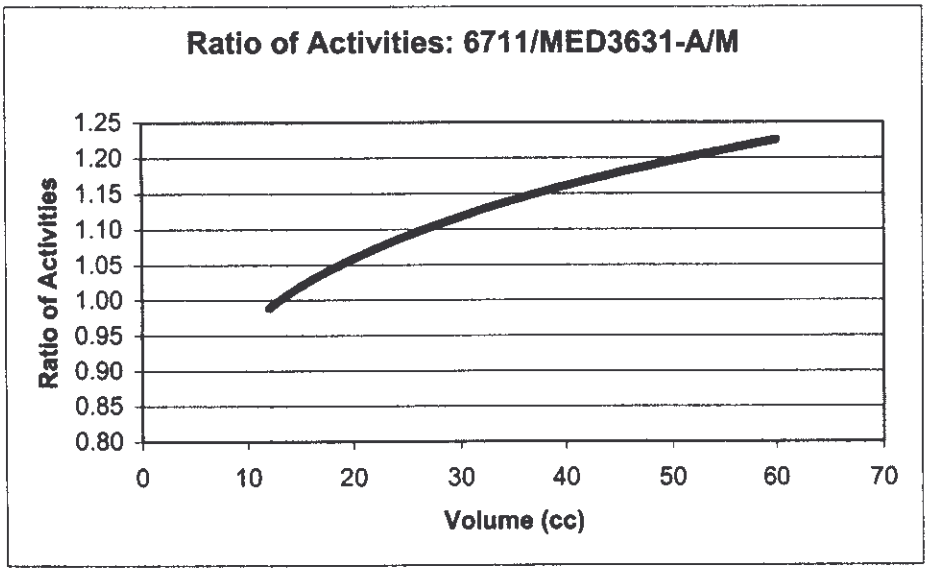


Figure 2. Relative activities required for complete coverage of the prostate gland as determined from the sphero-cylindrical model (5) for the Nycomed Amersham 6711 ^{125}I seed compared to the North American Scientific MED3631-A/M ^{125}I brachytherapy seed.

CONCLUSIONS:

A nomogram has been generated incorporating the NIST99 changes for ^{125}I calibrations for the North American Scientific MED3631-A/M brachytherapy seed. This nomogram was developed utilizing a sphero-cylindrical model in accordance with a peripheral weighting of the implant activity and a 15% increase in the total activity to account for the variations in seed geometry that exists between an actual implant and the planned seed locations.

The model has shown that the use of nomogram table values developed for the Nycomed Amersham seed are not transferable to the North American Scientific seed and may result in significant increases in dose delivered to the prostate and associated normal structures within and around the prostate.

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