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Calibration of Well-type Chambers for Novoste ^{90}Sr-^{90}Y Intravascular Brachytherapy Source Trains

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Abstract

Growing interest in the use of brachytherapy sources for intravascular treatment of restenosis has led to the development of ^{90}Sr-^{90}Y source trains by Novoste Corporation. Due to the shorter range of the beta particles emitted by these sources, there are measurement challenges in comparison to gamma emitting sources. Measurements of the NIST calibrated Novoste 30, 40, and 60 mm ^{90}Sr-^{90}Y source trains have been performed, and a variety of well chambers have been calibrated for these trains. A comparison of various types of source holders for these trains in well chambers was made, and representative dose rate calibration factors for the 30, 40, and 60 mm ^{90}Sr-^{90}Y source trains are given.

Introduction

- Novoste Corporation has developed ^{90}Sr-^{90}Y source trains for intravascular treatment of restenosis. Source trains are manufactured in lengths of 30 mm, 40 mm, and 60 mm. At this time the 30 and 40 mm trains have been FDA approved for clinical use.

- Novoste ^{90}Sr-^{90}Y source trains consist of a number of ^{90}Sr-^{90}Y seeds approximately 2.5 mm long, with a gold marker at each end of the train. The seeds and markers are not linked, and each is free to rotate or shift about its longitudinal axis.

- The UW ADCL has measured NIST calibrated source trains of known dose rate in several commercially available well chambers. This data was then used to generate dose rate calibration factors for the 30 mm, 40 mm, and 60 mm trains in each chamber.

Methods

- Three NIST calibrated Novoste source trains were measured to determine response characteristics in five commercially available well chambers.

- The measurement of sources that exclusively emit beta particles presents some challenges in comparison to the measurement of gamma emitting sources in well chambers.

- One must consider whether calibrations of well chambers should be based upon measurement of the beta particles themselves, or by creating bremsstrahlung and measuring the resultant x-rays.

- Each chamber’s characteristics must be considered in determining the best source holder geometry for measuring the Novoste source trains in that chamber.

Methods (cont.)

- In an effort to obtain good reproducibility in measurement, the sources were suspended along the “sweet spot” of a given well chamber as determined by an axial scan with a single ^{90}Sr-^{90}Y pellet (see Figure 1). Readings at four compass points over a 360 degree rotation of the source train within the chamber are averaged.

- The source train’s NIST calibrated dose rate to water at a depth of 2 mm (mGy/s) was divided by the rotationally averaged current reading (nA) to determine the chamber’s dose rate calibration factor (mGy/s/nA) for each train length.

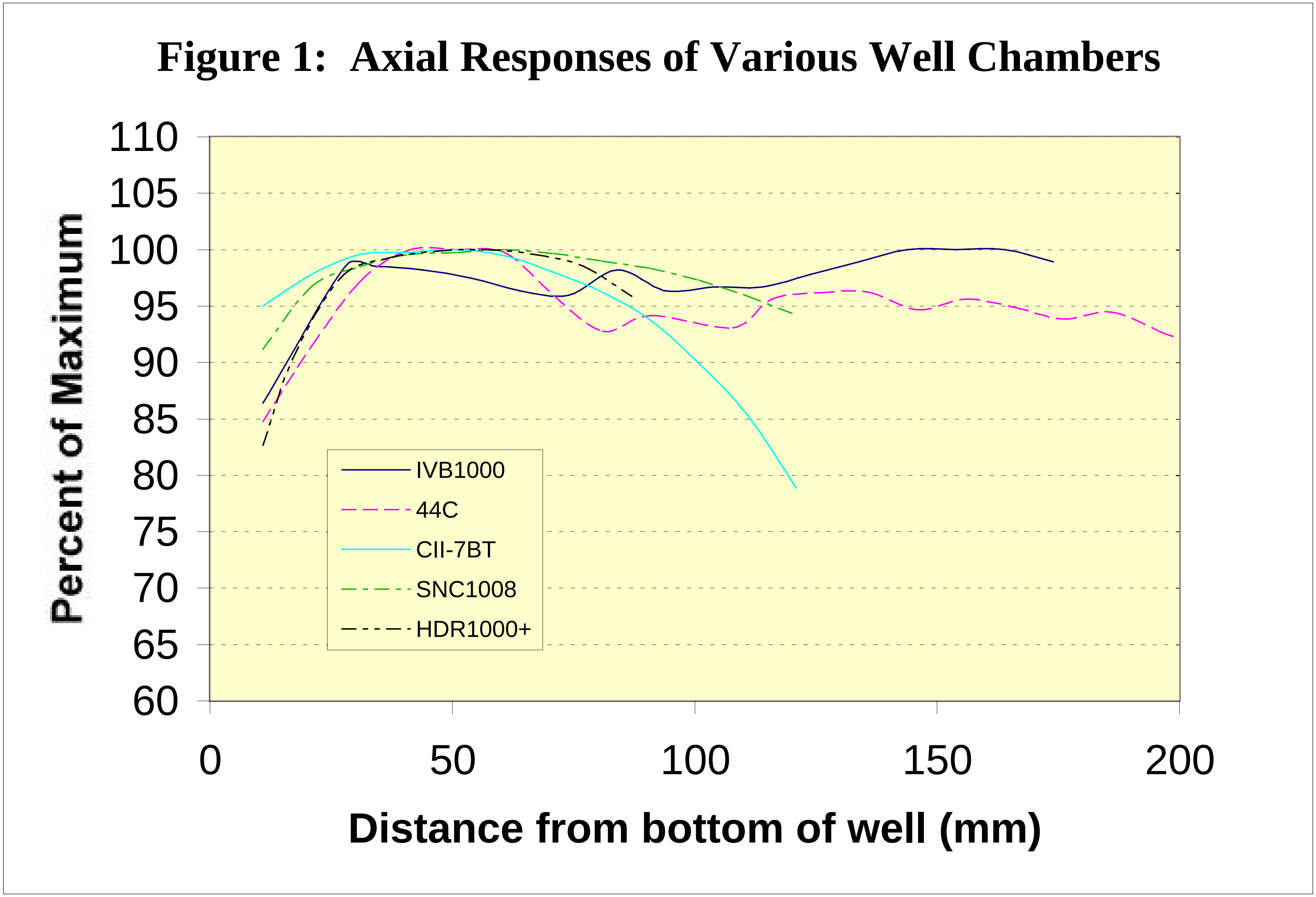

Figure 1: Axial Responses of Various Well Chambers
Percent of Maximum
110
105
100
95
90
85
80
75
70
65
60
0
50
100
150
200
Distance from bottom of well (mm)
IVB1000
44C
CII-7BT
SNC1008
HDR1000+

Results

- Various source holders of different thicknesses and materials were measured in the IVB1000 well chamber to determine the optimum signal to noise and precision of measurement.

- Filtering out the low energy beta particles with approximately 2 mm of acrylic and measuring the high energy beta particles gives the best precision for the greatest signal to noise ratio for the IVB1000 chamber (see Table 1).

- Table 1 also shows a comparison of the rotational variation which is representative of that occurring in well chamber measurements of the Novoste source trains.

Table 1: Comparison of Rotational Variation for IVB1000 Source Holders

Source Holder	Characteristic	Average Current	% Rotational S.D.
0.051 mm Kapton	Pass most beta particles	9.93 pA	0.5%
0.076 mm SS	Create bremsstrahlung	7.83 nA	0.6%
0.15 mm SS	Create bremsstrahlung	5.74 nA	0.8%
0.5 mm SS	Create bremsstrahlung	0.745 nA	1.5%
0.53 mm SS	Create bremsstrahlung	0.849 nA	1.5%
2.1 mm Acrylic	Block low energy beta particles	3.44 nA	0.9%
5.3 mm Acrylic	Block mid energy range betas	0.16 nA	1.5%
11.3 mm Acrylic	Block most beta particles	8.86 pA	0.1%

Results (cont.)

- The characteristics of the well chambers investigated are given in Table 2. Particularly of interest is each chamber's wall material, since the chamber absorption of beta particles and the production of bremsstrahlung is dependent on this material and its thickness.

- A summary of the well chamber calibration factors is given in Table 3.

- The dose rate calibration factor of a particular source train in a given well chamber was averaged over the length of the source train. Therefore the calibration factor for the 40 mm train in a given well chamber should be 0.75 that of the 30 mm train, while the 60 mm train should have a well chamber calibration factor 0.5 that of the 30 mm train. This assumption is only valid for chambers exhibiting a flat and symmetric response over a region at least as long as the measured source train.

Table 2: Description of Well Chambers Investigated

Chamber Manufacturer	Model	Wall Material	Active Volume
Sun Nuclear	44C	Al	5 atm.
Sun Nuclear	1008	Al	1.5 atm
SI	IVB1000	Butyrate (CAB) / Foil	475 cc.
SI	HDR1000+	Butyrate (CAB) / Foil	245 cc.
Capintec	7BT	Al	1 atm.

Table 3: Summary of Well Chamber Dose Rate Calibration Factors

Chamber	30 mm D_{CF} [mGy/s/nA]	40 mm D_{CF} [mGy/s/nA]	Ratio of D_{CF} 40 / D_{CF} 30	Δ% from expected 0.75 ratio	60 mm D_{CF} [mGy/s/nA]	Ratio of D_{CF} 60 / D_{CF} 30	Δ% from expected 0.5 ratio
UW IVB1000	26.7	20.0	0.75	0	13.4	0.50	0
Prototype IVB1000	27.6	20.8	0.75	0	14.0	0.51	2
NIST IVB1000	26.0	19.7	0.76	1	13.1	0.50	0
HDR1000+	10.9	8.3	0.77	2	5.6	0.52	4
44C	38.3	28.2	0.74	2	18.6	0.49	2
1008 / 44D	605	445	0.74	2	303	0.50	0
CRC-7BT	1077	890	0.83	11	803	0.75	50

Discussion

- The Standard Imaging IVB1000 and both Sun Nuclear well chambers correspond well within the expected dose rate calibration factor ratios for both the 40 mm and 60 mm trains (see Table 3), given the overall experimental uncertainty of 16% (of which 15% is the primary NIST calibration uncertainty).

- The 1 atm Argon Capintec 7BT chamber does not correspond to the expected ratio for either the 40 mm or 60 mm trains.
  (A typical Capintec 11 atm Argon chamber was not available during this study, but appears to meet the response and axial flatness criteria.)

- The Standard Imaging HDR1000+ chamber corresponds to within 4% of the expected ratio, but the 60 mm train must be placed within 1 cm of the bottom of the well chamber, which may cause increased geometry variation from chamber to chamber. Although the HDR1000+ chamber is adequate for calibration of the 30 mm train, it does not appear to be well suited for calibration of the 60 mm train.

Conclusions

- For most well chambers, the best compromise with respect to signal to noise ratio and rotational variation is obtained by filtering out low energy beta particles without the creation of additional bremsstrahlung. For this reason a 2 mm acrylic holder was chosen for use with the IVB1000 chamber.

- These results suggest that most standard well chambers with a large enough sweet spot can be used successfully to measure Novoste intravascular brachytherapy trains.

- Most of the well chambers surveyed to date are suitable for measurement of the Novoste ^{90}Sr-^{90}Y trains in the range of 30 to 60 mm. It is important that trains be measured in the well chamber at the point of calibration, and that the sweet spot be considered. Appropriate multiplication factors, such as 0.5, can be used for the calibration of longer trains in chambers with a calibration factor for a 30 mm train.

Future Work

- Further investigate the dose rate calibration factors of the Capintec pressurized well chambers.

- Examine catheter variations and source geometry, including dose rate uniformity effects.

- Investigate radiochromic film exposures at depth in various water phantom geometries for catheter variations.

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