HDR Brachytherapy: Dissemination of air-kerma strength

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Disclosure

- Larry DeWerd has a partial interest in Standard Imaging

Determination of air-kerma strength

- Traceability to NIST via calibration points on ionization chamber
- Measurement in air – ADCL realization of quantity
- Comparison of various sources
- Transfer to well chambers
- Uncertainties involved in the process

Establishing NIST traceability

- The ionization chamber is calibrated at two energy points to interpolate to the weighted average energy of the HDR ^{192}Ir source, which is approximately 397 keV.
- The original method (Goetsch method) included M250 and Cs-137 with an A_{wall} factor.
- See Med Phys 38:6721-6728 (2011)

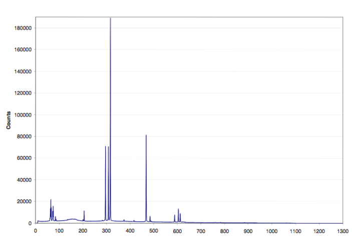
Ionization Chamber Calibration

- Goetsch, et al method
- Existing NIST ^{137}Cs and 250M x-ray calibration points may be used for ^{192}Ir by interpolation

$$(N_k)_{Ir} = \frac{[(A_w N_k)_{x-ray} + (A_w N_k)_{Cs}]}{2(A_w)_{Ir}}$$

- **The same buildup cap with thickness sufficient to provide CPE for highest energy must be used for both NIST calibrations**

Ir-192 Spectra



HDR Ir-192 chamber response

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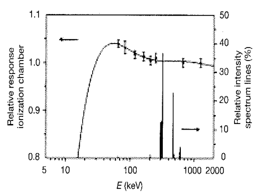


FIG. 1. Response curve of the NE 2561 ionization chamber, normalized to ^{137}Cs, in relation to the air kerma weighted spectrum lines of an ^{192}Ir HDR source.

Establishing traceability

- **Multiple points were suggested by van Dyke, however NIST traceable air-kerma calibration coefficients for the discrete photon energies do not exist.**
- **Mainegra-Hing and Rogers argued that it is reasonable that an interpolation between M250 and Cs-137 for a flat energy response chamber can be used.**
- **The inverse of the calibration coefficients should be used.**

Reasonable NIST traceable technique

- **The air kerma calibration coefficient is then determined by**

$$\frac{1}{(N_K)_{^{192}Ir}} = \frac{1}{2}\left[\frac{1}{(N_K)_{M250}} + \frac{1}{(N_K)_{^{137}Cs}}\right]$$

- **A comparison of the air kerma coefficient for an Exradin A3 from Goetsch and the inverse technique shows a difference of -0.03 %**
- **The inverse technique is now used.**

Chamber traceability to NIST

- The uncertainty for the air-kerma coefficient using M250 and Cs-137 beams for our chamber as calibrated by NIST is

Quantity	Type A	Type B
NIST Air kerma calibration	-	0.7 %
Chamber interpolation to ^{192}Ir	0.25 %	-
Calibration uncertainty	0.74 % (k=1)	

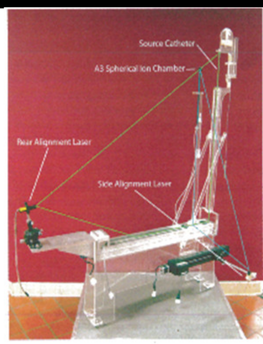
Determination of Air-kerma strength of ^{192}Ir source

- There are two methods that are in use:
  - Shadow shield (Measurement at 1 meter and then a lead block in front of chamber for scatter measurement.)
  - 7 distance technique: first proposed at the University of Wisconsin by Goetsch *et al*. in 1991
- These agree within 0.5% based on round-robin results among ADCLs

7- distance In-air Technique

- Measures the output of the source at seven source-to-chamber distances from 10 cm to 40 cm, using charge readings at each position.
- A verified computer algorithm solves the 35 equations to over determine the Air-kerma strength

7-D apparatus



Calibration of Source (formula used)

- **Primary radiation falls off as the inverse square of the source-to-chamber distance**

$$f = (M_d - M_s)(d + c)^2$$

- **M_s and c are constants independent of position**
- **The distance between chamber positions, Δd, is known to +/- 0.1 mm**
- **Three measurements are needed to find f, M_s and c**
- **7 distances are used to provide a more accurate result**

Air kerma from 7-D technique

- **Air kerma rate is given by**

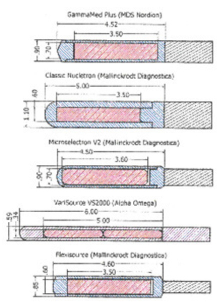
$$\dot{K} = \frac{f_{ave}(N_k)_{Ir}}{(d+c)^2 \Delta t}$$

- **Air-kerma strength is determined by taking it into vacuum.**

Various HDR sources

- There are 5 HDR sources on the market
- Monte Carlo modeling shows that there may be a difference between them.
- We investigated all sources using the 7-D technique
- Published in Med Phys 38: 6721-6729 (2011)
- UWADCL measurement was originally based on the "Classic" Nucletron HDR source

HDR Sources



20 years of measurement

- The classic Nucletron source has been measured over a 20 year period.
- Each individual source has been compared to the other via 3 well chambers
- The value for the well chamber after measurement by the 7 distance technique is always within ± 0.5%

Changes over the years

- The NIST standard changed in 2003
- The Air kerma Interpolation method shown to be $1/N_K$
- Additional HDR sources introduced
- 7-D for all individual repeats of source air-kerma strength within 0.5%
- Comparisons with other labs (Henri – Becquerel, NPL, PTB, NRCC) within 0.5%
- Summary of measurements with all sources – statistically different but all within 1% of the mean

Average percent differences

HDR Source Model	% difference from Working Standard
Classic Nucletron	0.47
Nucletron V2	-0.10
VariSource VS2000	-1.13
GammaMed Plus	-0.20
Flexisource	0.89
Average for all sources	-0.01

Air-kerma strength uncertainty

Parameter	Type A (%)	Type B (%)
Charge Measurement	0.05	0.05
Air Density	0	0.2
Beam divergence	0	0.1
Air attenuation/scatter	0	0.04
NIST N_K	0	0.74
Electrometer Cal Coeff	0	0.11
Timing error	0	0.005
Independent trials standard dev	0.43	0
Solution algorithm	0	0.2
Time (half life)	0	0.03
Quadratic Sum	0.433	0.81
AKS Uncertainty (k=1)	0.92	

Calibration in clinic

- For the clinical physicist, a calibrated well chamber should be used.
- Calibration point should be at the sweet spot.
- The clinic needs to monitor the output of the well chamber using QA techniques
- The ADCL will calibrate the well chamber

Uncertainty for well chamber calibration

Parameter	Uncertainty (%)
The ADCL chamber and response to Source model effects	0.96
Air kerma strength source calibration	0.92
Customer Well chamber	0.309
Customer Electrometer calibration	0.166
Overall Uncertainty (k=1)	1.37
Overall expanded uncertainty (k=2)	2.75

Clinical HDR measurements

- Use a well chamber calibrated at an ADCL
- ADCL uses the technique mentioned here to give N_k which is used in clinic to give S_k

$S_k = Rdg*N_{sk} *C_e * C_{tp}$

Where Rdg is the electrometer reading in amperes

N_{sk} is the calibration factor provided by the ADCL (U/A)

C_e is the electrometer scale correction factor

C_{tp} is the air density correction factor (if needed)

Summary

- When all techniques ($1/N_K$) and all sources are averaged, various points tend to counteract others
- The average for all sources is within -0.01% of the factor in use for 20 years.
- The ADCL has changed but the clinic stays with the same number regardless of the type of source, with an uncertainty of 2.75% (k=2)

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