The Need for National Standards: Calibration Laboratories OR Dose?

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Standards

- There are Standards for a number of quantities such as Absorbed dose to water. These are done with precision and uniformly.
- Calibration of chambers and sources essential for radiation therapy or Brachytherapy.
- Unfortunately, some manufacturers improvise dosimetry to market their product

"Ain't no rules in a knife fight"
Butch Cassidy

Improvise

- When Manufacturers improvise, the patient becomes the dosimeter and there can be great variation.
- AAPM probably needs to insist that there be some kind of NIST traceable calibration as in LDR brachytherapy
- This should be completed within a reasonable time period.

Address 2 Questions for Medical Dosimetry

- 1. What happens when manufacturers improvise for Standards? Two examples: A and B
  - Errors! NIST, ADCLs, AAPM should insist on a standard
- 2. What happens when there is a standard but it doesn't fully apply?
  - Apply standards with understanding.

Establishing Standards

- There is a need to have traceability delivered by the Accredited Dosimetry Calibration Laboratories
- Hospital Physicists generally have requests and ask questions about the traceability or "how to measure"
- Users must insist on traceable standards from NIST through the ADCLs

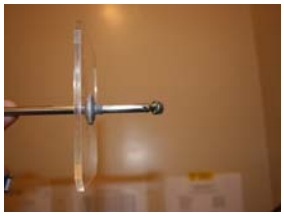
Accredited Dosimetry Calibration Laboratories

- NBS petitioned AAPM to create "Regional Calibration Laboratories" in 1975- In 1983 called ADCLs.
- NBS acknowledges traceability to primary standards (Proficiency tests)
- Agreement for Proficiency tests and round robins $\leq$ 0.5%
- Now 3 ADCLs: UW, M.D. Anderson and K&S
- The ADCLs have proven track records of providing precise calibrations of equipment

Manufacturers improvise Case A.

- Sr-90 Ophthalmic Applicators 1983-2001
- Sr-90 applicators introduced in 1950. Plane or concave. 28 year half life
- Typical 8mm diameter with a beta shield
- Extremely high dose rate
- Calibrated by each mfr *wrt* Bragg-Gray theory
- Bizarre units like "reps, beta-Roentgens"
- Hospitals asked UW ADCL accuracy of dose

Ophthalmic Beta Therapy Source



Pterygium and Sr-90 Beta Applicators

- "Wing-like" growth in conjunctiva
- Requires surgery to remove
- Surgery fails 90% of time
- One dose with Sr-90 prevents recurrence in roughly 90% of patients treated
- Advantage very forgiving re: dose

How to measure?

- Sr-90 sources had only been inter-compared IN AIR at distances of 20 to 30cm
- Desired "dose rate" is IN CONTACT with Sr-90 on surface of silver matrix
- Chris Soares developed an extrapolation chamber for calibration and determined absorbed dose to water at surface.
- This quantity was transferred to the UWADCL

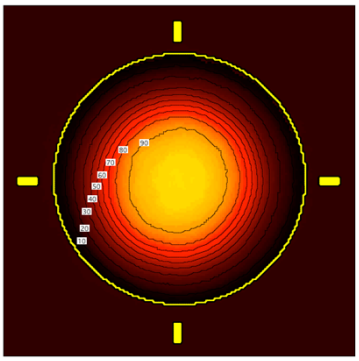
Comparison with Standard

- Routine ADCL calibrations from UW ADCL using radiochromic film to calibrate the ophthalmic applicators began in 1996.
- NIST quotes uncertainty of 7 %
- Calibration disagreement (old values converted versus new) average 30 %.

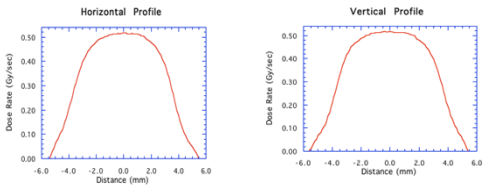
Sr-90 Calibration with Radiochromic Film

- **NIST traceable determination of the absorbed dose to water rate in the central 4 mm of the applicator including color enhanced contour plots and two dimensional dose profiles to determine uniformity of activity.**

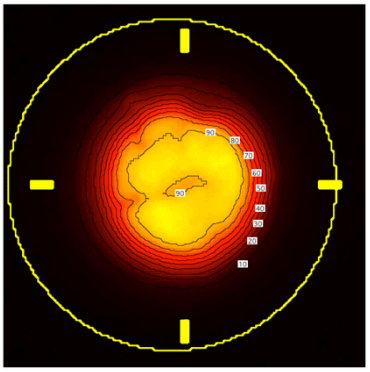
Example of a color enhanced contour plot of a uniform Sr-90 ophthalmic applicator. The dose weighted isocenter is equidistant from the hash marks. The outer circle represents the source physical diameter.



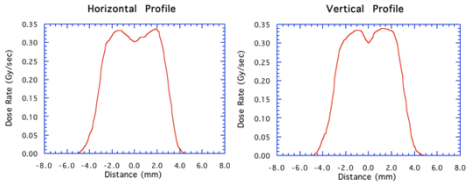
2-dimensional dose profile uniform source



Example of a color enhanced contour plot of a *non*-uniform Sr-90 ophthalmic applicator. Notice the offset or shift of the dose weighted isocenter from the physical source center, and the non-uniform dose distribution.

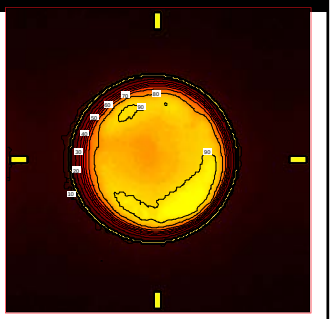


2-dimensional dose profiles nonuniform source

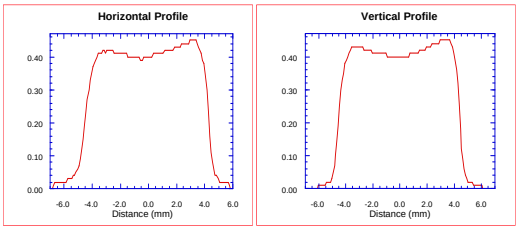


Skewed Dose Sr-90 Source

Example of a color enhanced contour plot of a *skewed*-Sr-90 ophthalmic applicator. Notice the offset or shift of the dose weighted isocenter from the physical source center, and the non-uniform dose distribution.



2-Dimensional dose profiles for a *skewed* source.



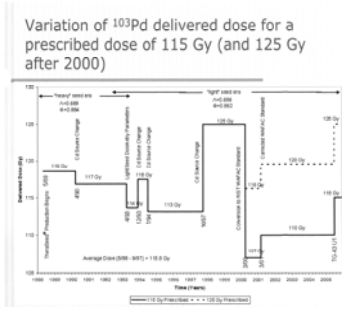
Improvise Part B Palladium-103 seeds for brachytherapy 1987-2001

- Palladium 103 introduced in 1987 with NO NIST standard
- Pd-103 has very short half-life (17.0 d) so NIST traceable ^{109}Cd source (half-life of 463.2d) was used as a reference source for 12 years, then replaced in 1997
- However, self-shielding of the source encapsulation was different between these two isotopes
- This resulted in a sudden 9% shift in calibration by letter to users in 1997

Catch up

- NIST releases Pd-103 national standard in 1999
- AAPM recommended in 2000 that all vendor calibrations be traceable to NIST WAFAC
- DeWerd published ADCL recommendations for mfrs and users in 2004 (13 I-125 and 7 Pd-103 seeds by that time)
- AAPM issues Ad Hoc Committee report in 1998 recommending at least 2 external evaluations BEFORE new radioactive seeds distributed

Analysis of calibration variation over the years by Wayne Butler, Wheeling Hospital



Conclusion for Question 1

- There can be significant errors
- If traceable to NIST, even if wrong, everyone is consistent if traceable standard- at least traceable through ADCL
- NIST, ADCLs and CIRMS need to insist upon standards.
- Manufacturers try hard but they need to rely on NIST and ADCLs for standards

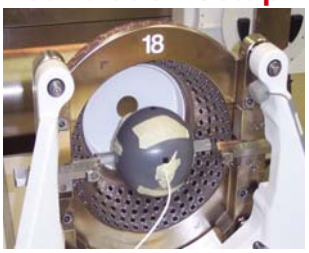
The need to use standards correctly

- Case 2. there is a standard but it doesn't fully apply.
  - Absorbed dose to water, air kerma standards modified to fit small fields
  - Modification is not correct
  - Majority of Medical Radiation Therapy depends on Cobalt or Cesium standard.

Gamma Stereotactic Radiosurgery Calibration 1968 to Present

- Lars Leksell invented "Gamma Knife" using 201 cobalt sources with 18 mm, 14 mm, 8 mm and 4 mm helmets.
- Commercial Model U introduced in 1987
- Elekta Corporation invented entire dosimetry chain. Only one manufacturer.
- 16cm diameter "mystery plastic" sphere included
- Physicist must establish absorbed dose rate at center of sphere
- No consideration of materials absorption

Calibration Setup



- Calibrate with 18mm helmet
- Need SMALL ion chamber
- Apply Physics

Relation to Protocol (TG51)

Gamma Knife	External Beam
40 cm SAD	100 cm SAD
18 mm field	10 cm x 10 cm
3 D Spherical symmetry	Flat 2 dimensional field
Calibration depth fixed at 8 cm	Calibration depth 10 cm but do % dd

Apply Physics Principles

- Calculate absorbed dose rate using physics from old AAPM TG21 protocol
- Made measurements in-air and in-phantom using the physics principles in TG 21 so can move from standard to specialized application.

Calibration Agreement in-air and in PMMA phantom

Location	Media	Measured $\dot{D}_{water}$ $\frac{Gy}{min}$	% difference In-Air to PMMA
Unit A	In-Air	3.918	
	PMMA	3.904	0.37
Unit B	In-Air	2.636	
	PMMA	2.641	-0.18
Unit C	In-Air	3.105	
	PMMA	3.097	0.26
Unit D	In-Air	1.334	
	PMMA	1.334	-0.06

Comparison of 7 centers (Measured vs. TPS)

Location	Measured $\dot{D}_{water}$ $\frac{Gy}{min}$	TPS $\dot{D}_{water}$ $\frac{Gy}{min}$	% difference Measured to TPS
Unit A	3.918	3.828	2.3
Unit B	2.636	2.587	1.9
Unit C	3.105	3.059	1.5
Unit D	1.334	1.303	2.3
Unit E	2.224	2.159	2.9
Unit F	3.068	2.992	2.5
Unit G	2.853	2.796	2.0

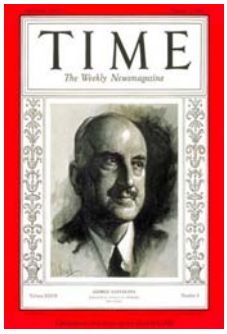
New Unit - Perfexion

- Comparison of measurement with the treatment planning system up to 5 % different.
- Manufacturer saying it is basically the same as the old units.
- Just applying a standard without understanding is not appropriate.

Lesson to ponder

"Those who do not remember the past are condemned to repeat it."

George Santayana, Harvard Professor and poet



Conclusions

- If you can't be right, at least be consistent
- NO manufacturer should EVER invent their own standards *("Don't try this at home")*
- The AAPM and CIRMS should insist that new devices should have a standard
- NIST needs more support
- ADCLs can play a vital role in resolving calibration problems

Acknowledgements

- All of my graduate students
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