Instrumentation for patient dosimetry measurements

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Disclosure

- **Larry DeWerd has a partial interest in Standard Imaging**

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  - Malcolm McEwen
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  - Cliff Hammer
  - Francescon
  - And others (forgive me if I forgot you)

Introduction

- Patient dosimetry measurements can be verified by in – vivo dosimetry
- Starts with the measurement which becomes more uncertain with small fields
  - Ion chambers and in particular reference chambers
  - Other instruments for small fields
  - Brachytherapy checks with in-vivo measurements

Ionization chambers

- The ionization chamber is the basic instrumentation for Therapy Medical Physicists. (e.g. TRS 398 or TG 51)
- A reference class chamber must be used. (Definition as given in TG 51 addendum-Medical Physics 41:041501-1 through 20 (2014))
- There are precautions with small fields no matter what instrument is used.

Ionization Dosimeters

- Chambers are high precision but need calibration.
- Reference class chamber meets the following conditions
  - Long term stability change ≤0.5% in 1 hour and leakage <0.5%.
  - Polarity between .997 and 1.003
  - Recombination <0.5%

Specification for (cylindrical) chamber type

- 3 sub-types (NOTE: WGTG51 definitions) –
  i. 0.6 cm^3 reference chambers (e.g., NE2571, PR-06C)
  ii. 0.125 cm^3 scanning chambers (e.g., PTW31010, IBA CC13)
  iii. 0.02 cm^3 micro chambers (e.g., Exradin A16, Exradin A26, Pinpoint™)

Chambers meeting reference class

- **Majority are 0.6 cm^3 'Farmer-type' chambers**
- **A-150 chambers explicitly excluded**
- **5 scanning chambers, NO microchambers**
- **(Possible Exception A26 from some preliminary measurements. Long term to come)**
- **No parallel plate chambers are included**

Chambers in small fields

- **Remember conditions of TRS 398 or TG51 calibration: 30 cm x 30 cm x 30 cm phantom with the correct scatter conditions.**
- **Small fields violate these scatter conditions – a modification needs to be made.**

Small field Modification

- TG 51 modification for ion chambers. This is still an area of discussion.

$$D_W = MN_{DW}^{^{60}Co} k_Q k$$

- k is modification caused by phantom scatter conditions being different and other effects. This is a complex quantity that is being researched

K_{Qclin}

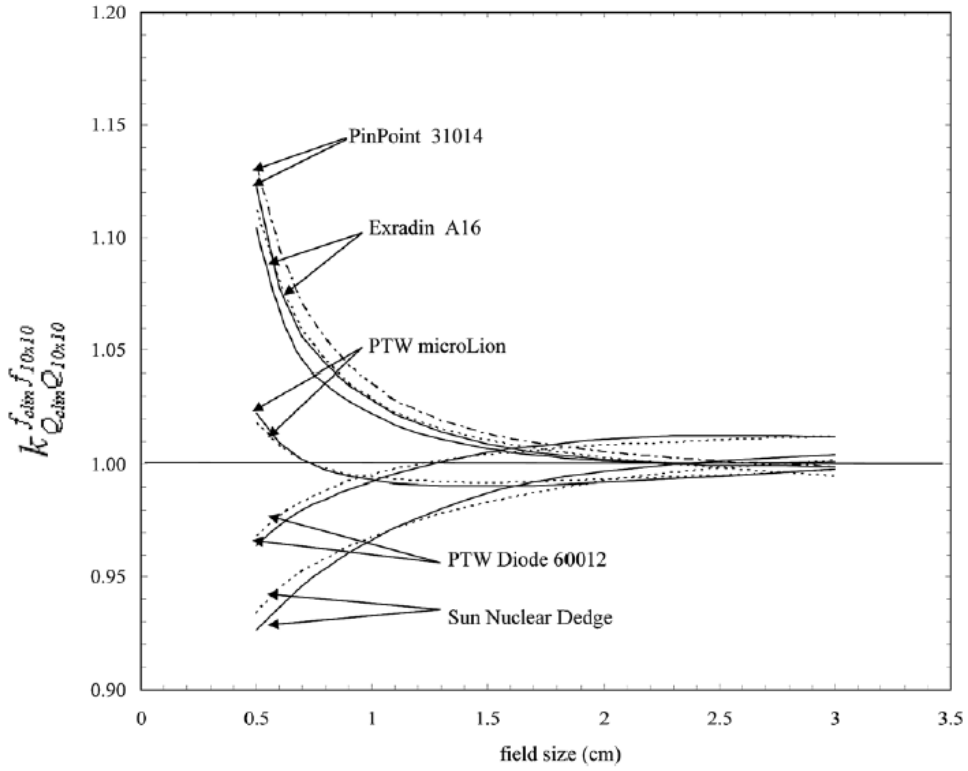


FIG. 7. Correction factor $k_{Q_{clin},Q_{10\times10}}^{f_{clin},f_{10\times10}}$ for five detectors as a function of the field size, for 6 MV beams of Siemens (dotted line) and Elekta (continuous line) linacs.

- Francescon 2011, Med Phys 38 (12) 6513

Modification

- The other modification that is especially appropriate for very small fields is the flatness of the field.
- The chamber must be small enough to fit within the field

Small Fields

- Note that the measured field size for very small fields (FWHM) will be <u>larger</u> than the actual field setting, due to penumbra broadening!

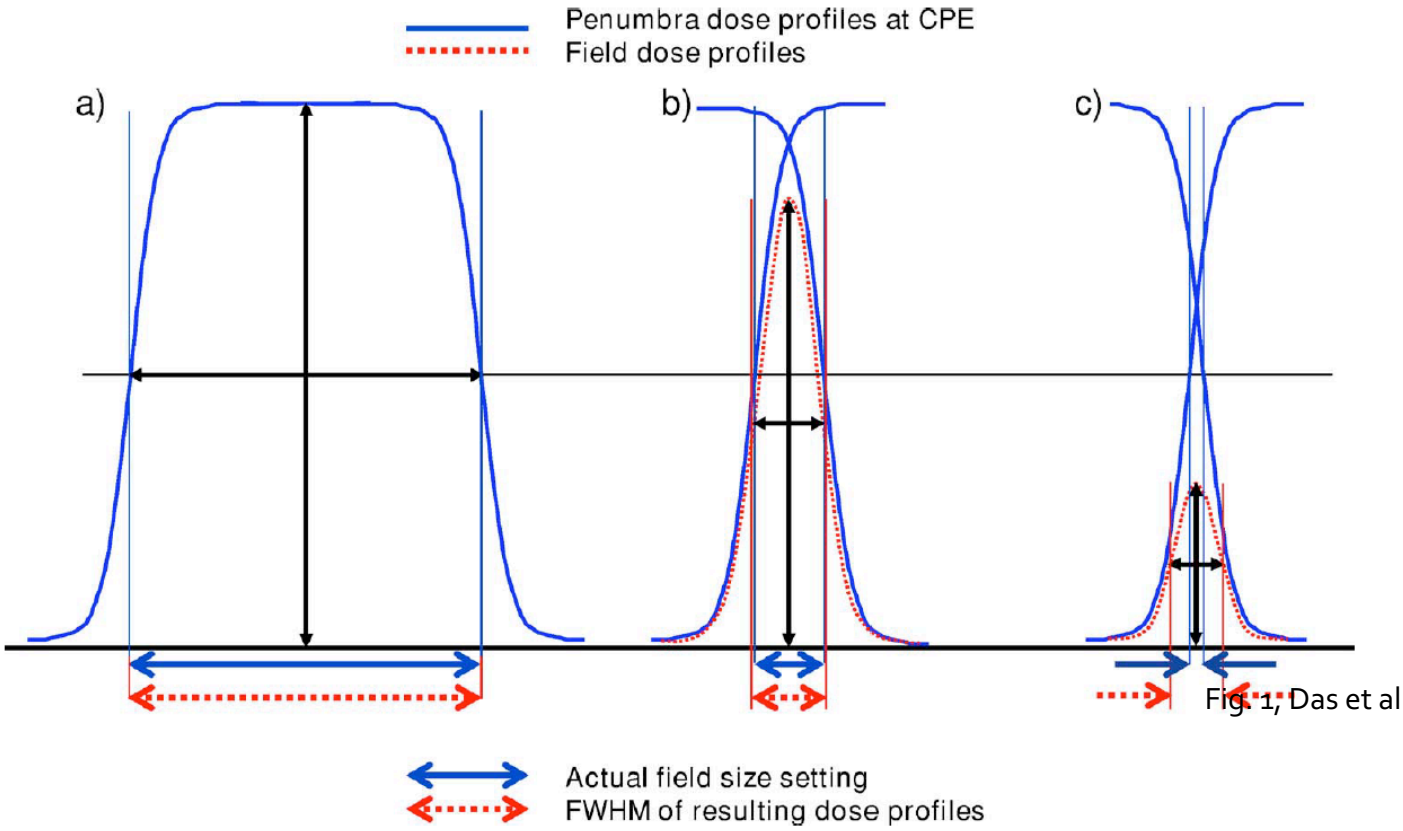
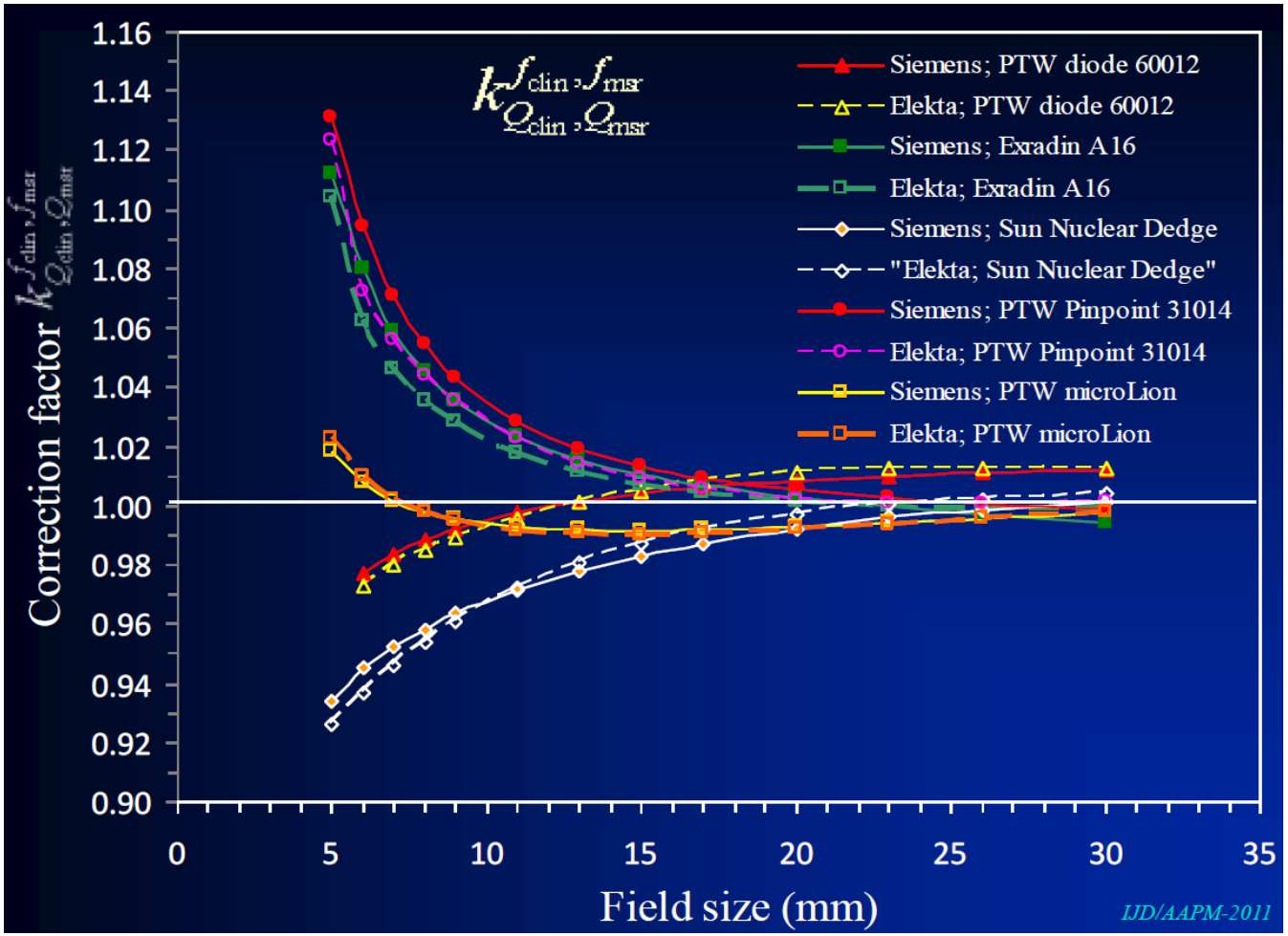


Fig. 1, Das et al

From Das et al 2000



Important Points for the Physicist

- A knowledge of the equipment dealt with, and of its calibration parameters.
- Care in how the equipment is used and the variability of parameters.
- Attention should be paid to quality assurance procedures so traceability at the lowest uncertainty is maintained.

Dosimetry Comparison of Detectors

Effect	Diamond detector	Scintillators	Diodes
Small size	Yes	Yes	Relative Yes
Price	Expensive	Moderate	Moderate
Variable Response	Yes (qualify)	No	No (decreased signal with increasing dose)
Tissue equivalence	Yes Carbon	Yes if organic	No
Calibration Needed	Yes	Yes	Yes with some frequency

Nominal size of OSLD and TLD

- OSLD approximately 1 cm x 1 cm
- TLD
  - 3 mm x 3 mm x 1 mm
  - 1 mm^3
- Smaller size is better for small fields

Use of TLD for checks

- UW MRRC program
- Know the response of TLD within ± 2%
- Send 9 chips for calibration on clinic's linac, bracketing the expected dose.
- For small fields we use 1 mm^3 TLDs
- Institution must pay attention to placement of TLDs – Is it in field when small field.
- The TLD measures the dose where it is placed.

Use of in-vivo TLDs

- TLD on patient during treatment for checking out of field (e.g. pacemaker), checks on dose, critical organs, etc.
- Pacemakers: Dose generally ≤ 10 cGy (0.1Gy)
- Whole body treatment: Range ± 15%
- Critical organs:
  - Out of field: reduction by a factor of 0.005
  - Shielded: reduction by a factor of 0.01
- Variation in scalp treatment: up to 40%

QA check on TPS

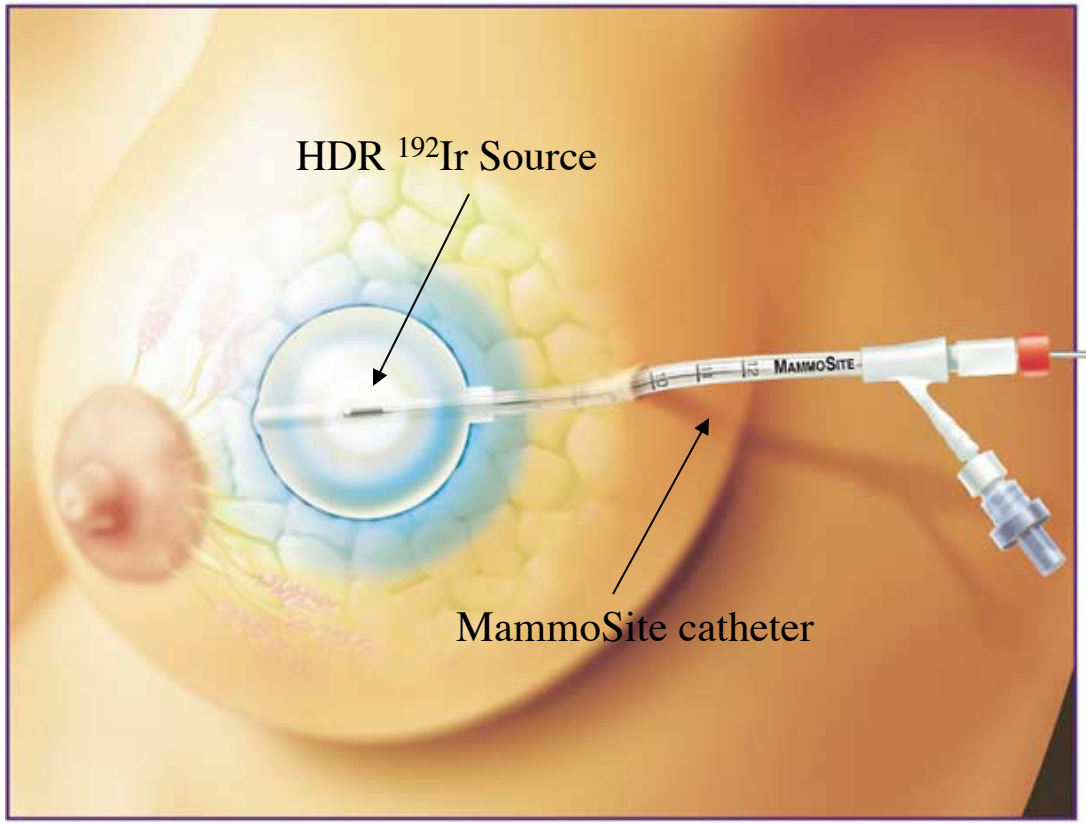
- The treatment planning system does not always calculate what you expect
- An example is the skin dose for mammosite treatments in Brachytherapy

Limitations of TG-43 for APBI dosimetry (Julie Raffi)

- Exit skin dose
  - TG-43 formalism assumes full backscatter
- Breast tissue vs. water
  - Effect of medium varies for different energies
- Inhomogeneities
  - TG-43 does account for effect of ribs, lung, contrast, etc.
- Discussed in Med Phys 37: 2693 (2010)

MammoSite Radiation Therapy System (RTS)

MammoSite® RTS (Cytyc Corporation)



Remote afterloader

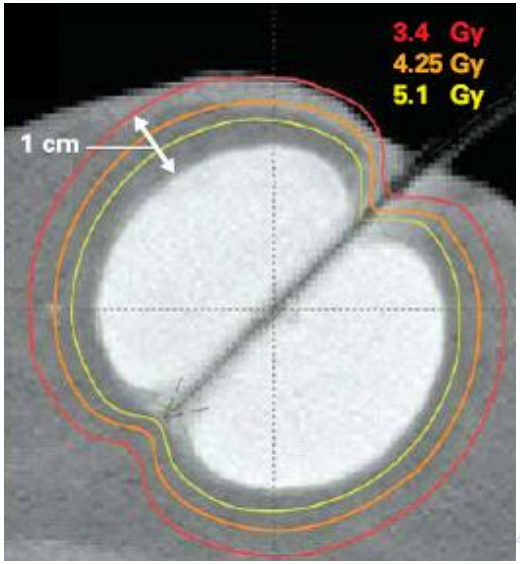


Figure courtesy of Cytyc Corporation and dose distribution reproduced from Arthur and Vicini (2005)

Exit dose investigations

- Developed method of determining exit skin dose with TLD measurements
- Determined exit skin dose for 59 ^{192}Ir intracavitary APBI patients at three collaborating clinics
- Compared measured skin dose to TPS determined values

^{192}Ir exit dose patient results

- TPS overestimated skin dose for 57 of 59 patients
  - Average overestimation of 16%
  - MammoSite: Overestimate by 22%,
  - Contura: Overestimate by 8%
- Performed phantom measurements and TPS comparison and Acuros comparison

^{192}Ir TPS dose comparison results

- Acuros GBBS:
  - Agreed with TLD within 10% for 39 of 53 positions
  - All 14 points with > 10% discrepancy had < 5 cGy difference
- TG-43:
  - Agreed with TLD within 10% for 19 of 53 positions
  - 11 of 34 points with > 10% discrepancy had > 5 cGy difference
  - Maximum discrepancy of 26 cGy at breast surface

^{192}Ir phantom experiment conclusions

- GBBS calculated doses are in better agreement with TLD measurements than TG-43 doses
- Discrepancies are more pronounced at further distances from the source and at breast surface
- TG-43 dosimetry formalism
  - overestimates dose in regions with reduced backscatter (e.g., surface and proximal lung locations)
  - underestimates dose in regions with reduced attenuation (e.g., in and beyond lung)

Overall conclusions

- **Physicists need to know their measurements and what they are really measuring**
- **Don’t only trust the TPS as giving the correct values**
- **Do some in-vivo measurements, TLD or otherwise, to demonstrate the accuracy of dose.**

Conclusion

- **Be aware of the conditions, e.g. field size, phantom size.**
- **Apply corrections as needed.**
- **This area is still under construction but be consistent so we can all be wrong together.**

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