CLINICAL IMPLEMENTATION OF MOSFETS FOR ENTRANCE DOSE IN-VIVO DOSIMETRY WITH HIGH ENERGY PHOTONS FOR EXTERNAL BEAM RADIATION THERAPY

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Abstract

In external beam radiotherapy quality assurance is carried out on the individual components of the treatment chain. The patient simulating device, planning system and linear accelerators are tested regularly according to set protocols developed by national and international organizations. Even though these individual systems are tested errors can be made in the transfer between systems. The best quality assurance for the system is at the end of the treatment planning chain. In-vivo dosimetry measures the dose to the target volume through indirect measures at the end of the treatment planning chain and is therefore the most likely method for picking up errors which might occur earlier in the chain.

Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) have been shown to have a similar error in estimating entrance dose for in-vivo dosimetry to diodes, but no studies have been done clinically with entrance dose in-vivo dosimetry with MOSFETs. The time savings for using MOSFETs makes them preferable to TLD's. Due to their small size and versatility in other applications they are useful as more than dedicated in-vivo dosimetry systems using diodes. Clinical implementation of external beam in-vivo dosimetry would add another use to the MOSFETs without purchasing more specialized equipment.

My studies have shown that MOSFETs can be used clinically for external beam in-vivo dosimetry using entrance dose measurements. After the MOSFET measurement system was implemented using a custom built aluminium build up cap clinical measurements were performed. A total of 23 patients and 54 fields were studied. The mean for all clinical measurements was 1.3%, with a standard deviation of 2.6%. Results were normally distributed around a mean with skewness and kurtosis as -0.39 and 0.34 respectively. For breasts the mean was 1.8%, with a standard deviation of 2.7%. For prostates and hips the

mean was 1.3% with a standard deviation of 2.9%. These results are similar to studies conducted with diodes and TLD's. From these results one can conclude that MOSFETs can be used for entrance dose in-vivo dosimetry and are no worse than diodes or TLD's in terms of their measurement accuracy.

Disclaimer

I, Jason Morton declare that the thesis contains no material which has been accepted for the award of any other degree or diploma in any university and that, to the best of my knowledge and belief, the thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis. I consent to the thesis being made available for photocopying and loan if accepted for the award of the degree.

Signed:……..

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II Abbreviations

MOSFET	Metal Oxide Semiconductor Field Effect Transistor
IVD	In-vivo dosimetry
TLD	Thermoluminescent dosimeter
IC	Ion chamber
PMT	Photomultiplier tube
ICRU	International Commission of Radiation Units and Measurements
WHO	World Health Organization
AAPM	American Association of Physicists in Medicine
ESTRO	European Society for Therapeutic Radiology and Oncology
SSD	Source to surface distance
SAD	Source to axis distance

III Definitions

In-Vivo Dosimetry Definitions

Clinical Target Volume (CTV): "*The clinical target volume (CTV) is the tissue volume that contains a demonstrable GTV and/or sub-clinical microscopic malignant disease, which has to be eliminated*." (ICRU Report No. 50, cited in Andreo et al. 2005).

Discrepancy: The difference (in percent) between the measured entrance dose and the calculated entrance dose based on treatment planning system information.

Entrance Dose (D_{ent}): The dose at D_{max} below the surface on the central axis (Figure 0-1).

Exit Dose (D_{exit}): The dose at D_{max} before the exit surface on the central axis (Figure 0-1).

Isocentric Dose (D_{iso}): The dose to the isocentre.

Midline Dose (D_{mid}): The dose to the midline of a patient or phantom on the central axis (Figure 0-1).

Target: See CTV.

Transmission: The ratio of the dose at a depth on the central axis to the dose at D_{max} on the central axis (See PDD).

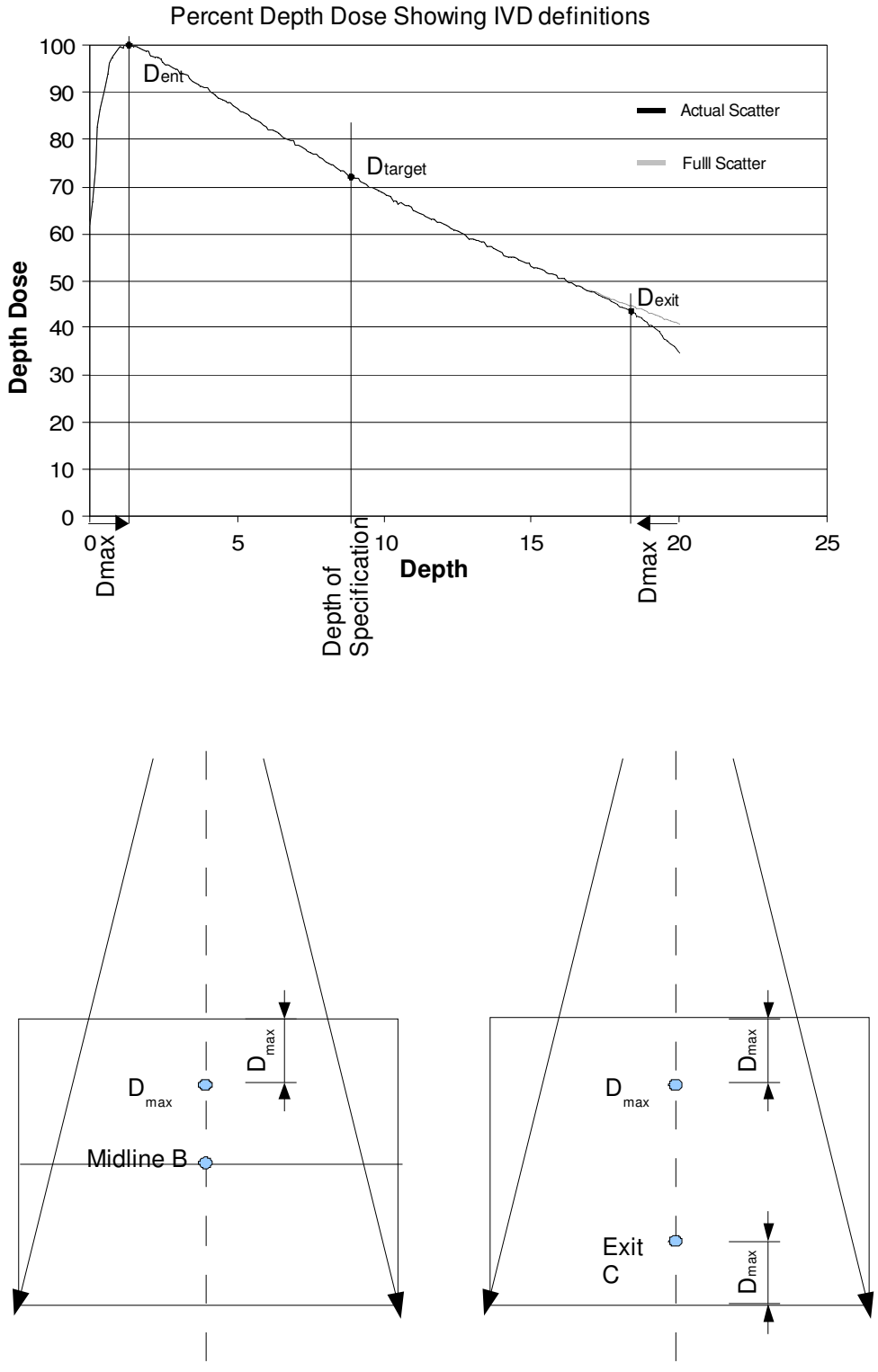

Figure 0-1: In-vivo dosimetry definitions

General Dosimetry Definitions

Depth of Dose Maximum (D_{max}): The depth of maximum dose on the beam central axis.

Tissue Air Ratio (TAR): TAR(z, A, $h\nu$) is the ratio of the dose D_Q at point Q on the central axis in the patient or phantom to the dose $D_{\phi Q}$, the 'dose to small mass of water in air', at the same point Q on the beam central axis (Andreo et al. 2005). The TAR depends on the depth z, field size A, and beam energy $h\nu$ (Figure 0-2).

Percent Depth Dose (PDD): The PDD is defined as follows: $PDD(z, A, f, h\nu) = 100 D_Q / D_P$ where D_Q is the dose at point Q at depth z on the central axis of the phantom and D_P is the dose at point P at D_{max} on the central axis of the phantom (Andreo et al. 2005). z, A, f, $h\nu$ are depth, field size, SSD and energy respectively.

Tissue Phantom Ratio (TPR): The TPR is defined as follows: $TPR(z, A, h\nu) = \frac{D_Q}{D_{Qref}}$,

where D_Q and is dose in a phantom at arbitrary point Q on the beam central axis and D_{Qref} is the dose in a phantom at a reference depth $z$ref (typically 5 or 10 cm) on the beam central axis (Andreo et al. 2005).

Tissue Maximum ratio (TMR): The TMR is a special case of a TPR, where the reference point depth is D_{max} (Figure 0-3).

Peak Scatter Factor (PSF): PSF(A, $h\nu$) is the ratio of the dose to D_{max} in a phantom at a point on the central axis to the dose in a mini-phantom at the same point. The PSF is a special case of the TAR, where the reference depth is at D_{max}.

PSF: Ratio of the dose in a mini phantom to the dose at Dmax

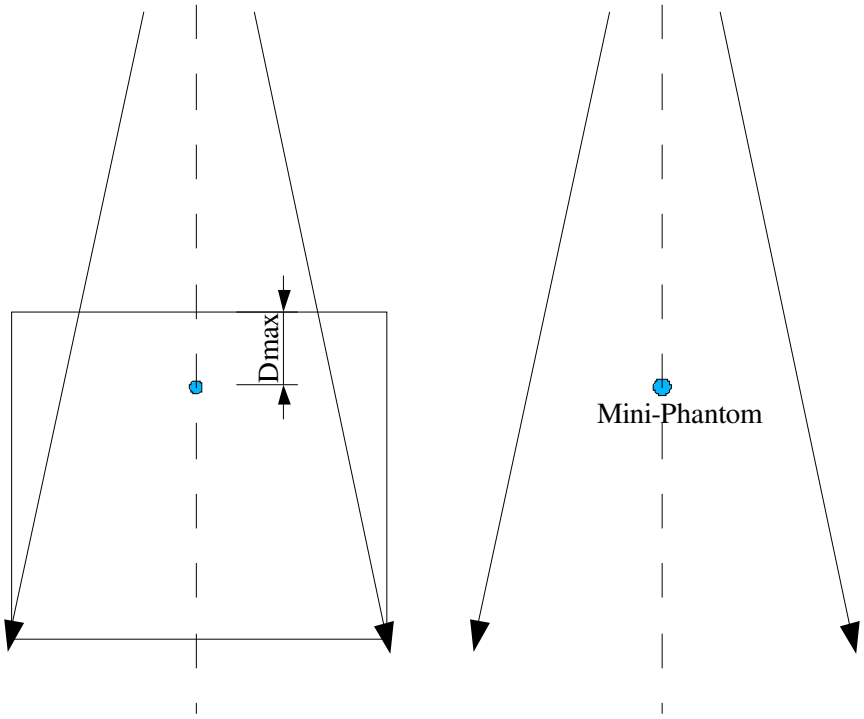

Figure 0-2: PSF Measurement setup

TMR: Ratio of the dose at depth z to the dose at Dmax

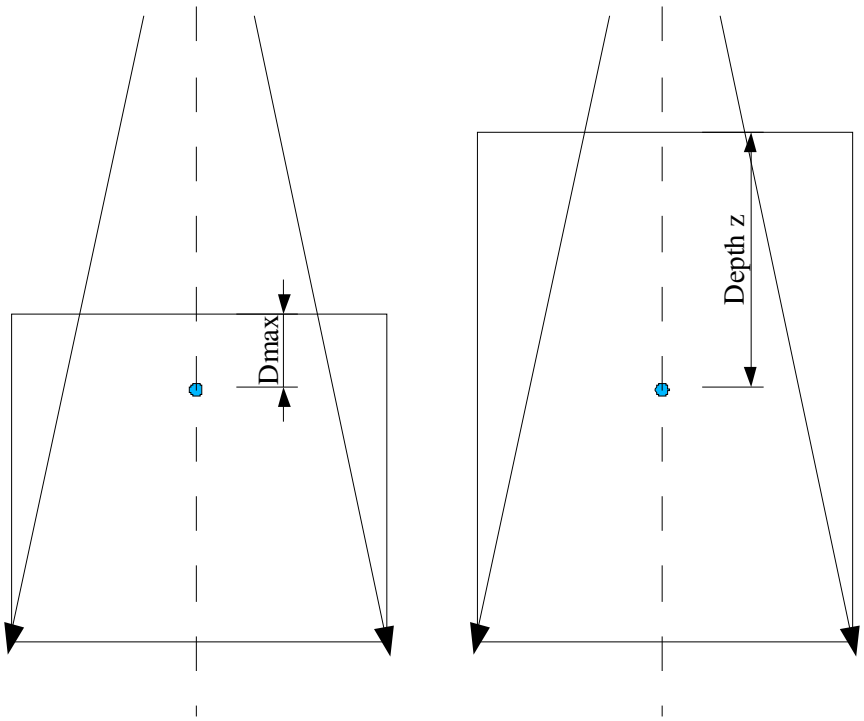

Figure 0-3: Setup for measuring TMR

Total scatter correction factor $S_{c,p}(A)$ **:** The scatter contribution to the dose at depth originating from the collimating system and the phantom for field size *r* (Khan et al. 1980).

Collimator scatter correction factor $S_c(A)$ **:** The ratio of the effective primary dose for a given collimator field size *r* (Khan et al. 1980).

Effective primary dose $P_c(A)$: Dose due to the primary beam as well as photons scattered from the collimating system (including source, target, flattening filter, collimator and other scatterers in the beam) (Khan et al. 1980).

Back Scatter Factor *BSF(A)*: see **Peak Scatter Factor** PSF*(A)*.

Off Axis Ratio (OAR): The ratio of the dose off the central axis to the dose on the central axis at a given depth.

Expression of Uncertainties

Error: An error is the difference between a measured value and the true value (IAEA TRS 398 2000). If errors were known exactly the true value could be determined by correcting the errors. Errors can be the result of calculation, transcription or setup errors in in vivo dosimetry.

Uncertainty: the uncertainty associated with a measurement is a parameter that characterizes the dispersion of the values 'that could reasonably be attributed to the measurand' (IAEA TRS 398 2000). Uncertainties may also be referred to as random errors. This is normally an estimated standard deviation and is assumed to be symmetrical. It has no sign. There are 2 types of uncertainty, type A and type B. Type A are based on means of measurements and statistical observations, while type B are based on means other than statistical observations (TRS 398). Because type A and type B uncertainties are both estimated standard deviations, they are combined using the statistical rules for combining variances (which are squares of standard deviations).