DEBATE:

Has Transit Dosimetry Come Of Age?

NHS Lothian

YES

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A review of Electronic Portal Imaging Devices (EPIDs)

Arthur L.Boyer etal , MedPhys 19(1) **1992**

...during the last few years rather intensive efforts have led to the development of techniques that produce images using high-energy X- rays directly. As a result, electronic portal imaging devices (EPIDs) are becoming available to cancer radiotherapy. In some systems, a small fraction of the radiation dose delivered on a given day can be used to produce a digital on-line image that is displayed in real time or near real time. .....

Purpose of the study:

(1) Examine the limitations of imaging with high-energy radiation beams and
(2) Review the EPIDs that are currently being developed for clinical use.

Summary:

This review has demonstrated the potential for development of advanced imaging devices, image enhancement and evaluation software and clinical applications of EPID technology.

Portal Dose Image I: Quantitative treatment plan verification
John W. Wong etal , IJROBP, Vol 18 , Issue 6, 1990.

Feasibility study with Co-60 irradiation of (1) plastic phantom (2) anthropomorphic Phantom and a patient with lung cancer.
Calculations were made with 3-dimensional scatter ray-trace Delta volume method.
Phantom based study agreed within 3% with ionchamber / TLD / Film measurements.
Concluded ... More work is required for improving the estimation of dose to the patient.

Portal Dose Image II: Quantitative treatment plan verification
Xingren Ying etal, IJROBP, Vol 18 , Issue 6, 1990.

An iterative approach is used to match the calculated DRR with the measured portal dose image and CT data is accordingly modified to represent the Actual dose transient path and new dose calculations are performed on the New CT dataset.

Measurement possibilities using an electronic portal imaging device
M.C. Kirby , P.C. Williams
Radiotherapy and Oncology Vol.29, Issue 2, 1993.

Electronic portal imaging devices are effective at providing this verification, however, these devices are versatile enough to be used in other ways pertinent to the delivery of high quality , high precision radiotherapy....
configured as a dosimeter, the system shows a linear response with good dynamic range... Our preliminary results from this '**exit dosimetry**' technique demonstrate that , under specific conditions, doses can be determined to within 2.5% of that measured using silicon diodes or ion chambers.

Input / Output characteristics of a matrix Ion-chamber electronic portal Imaging device - Fang-Fang Yin, M.C. Schell and Philip Rubin
Med.Phys , Vol.21, No.9, 1994.

Characteristics study of liquid filled ionchamber, focussed on the pixel value changes with f.size, FSD , gantry position and off-axis location .

Portal dose measurement in radiotherapy using an electronic portal imaging Device (EPID) B J M Heijmen, K L Pasma, M Kroonwijk etal
Physics in Medicine and Biology, Vol. 40, No.11, 1995

Physical characteristics of a commercially available EPID , relevant to ***dosimetric applications*** in high-energy photon beams, have been investigated.. A ***point spread function***, derived from measured data and describing the increase in EPID respons at the beam axis due to off-axis irradiation of the fluorescent screen ,has been successfully applied to connect portal doses with grey scale values measured with the EPID.

Accurate portal dose measurement with a fluoroscopic electronic portal imaging Device (EPID) for open and wedged beams and dynamic multileaf collimation
K L Pasma M Kroonwijk, J C J de Boer etal,
Physics in Medicine and Biology Vol. 43, No.8, 1998

An accurate method to measure portal dose images (PDIs) with a commercially available fluoroscopic EPID has been developed. The method accounts for (i) the optical `cross talk' within the EPID structure, (ii) the spatially non-uniform EPID response and (iii) the nonlinearity of the EPID response. The method is based on a deconvolution algorithm.

Portal dosimetry using a liquid ion chamber matrix: Dose response studies , Yunping Zhu, Xun-Qing Jiang and Jake Van Dyk , Med.Phys Vol.22(7) 1995.

Invivo dosimetry (e.g., using diodes or TLD) is well accessible, but is generally limited to a few points. Transmission dosimetry for multiple points using a portal imager represents a practical alternative...

If electron-density information in CT volume scans truly represents the patient in treatment position and the method of dose calculation is accurate, it should then possible to compare the precalculated portal dose images with the real-time measurements for both geometric and dosimetric differences.

The electronic portal imager studied in this work belongs to a special class of EPIDs that are made up of scanning liquid ionization chamber .. In conclusion this liquid ion chamber matrix system has the potential for use in on-line radiotherapy dose verification.

The application of transit dosimetry to precision radiotherapy - V.N. Hansen, P.M. Evans and W. Swindell Med.Phys. 23(5) 1996.

The use of a measurement of radiation transmission through the patient, during treatment, to estimate the actual dose distribution administered in known as 'transit dosimetry'.

Pelvic phantom study: EPI corrected for scatter to get the primary fluence striking the detector. This is backprojected through the planning CT data to get the primary fluence within the patient. This distribution is then convolved with dose deposition kernels to get the dose matrix. *Agreed within 2% in relative terms* with treatment planning system and other independent measurements..

New method to obtain the midplane dose using portal *Invivo* dosimetry , Ronald Boellaard, Marion Essers, Marcel Van Herk, and Ben J Mijnheer, IJROBP Vol.41, No.2, 1998.

The method first calculates the 2D contribution of the primary and scattered dose component at the exit side of the patient or phantom from the measured transmission dose (Liquid filled chamber matrix). Then, a correction is applied for the difference in contribution for both dose components between exit side and midplane, yielding the midplane dose.

Concluded as , midplane doses estimated with the new method were either simila or higher accuracy compared with conventional *invivo* dosimetry with the added advantage of calculated dose in a 2-d plane.

Transmission Dosimetry with a Liquid-Filled Electronic Portal Imaging Device

Marion Essers, Ronald Boellaard, Marcel Van Herk , Hugo Lanson and Ben Mijnheer, IJROBP, Vol.34, No.4, **1996.**

Liquid Filled ionchamber array: EPID measured dose-rate agreed about 1% with minphantom measurements in air. Exit dose-rate study results were poorer due to loss of scattered photons. However, EPID measurements can be Used to obtain relative exit dose-rate with a reasonable (2.5%) accuracy.

Two-dimensional exit dosimetry using a liquid-filled electronic portal imaging device and a convolution model

Ronald Boellaard, Marcel van Herk, Hans Uiterwaal, Ben Mijnheer Radiotherapy and Oncology Vol.44, **1997**.

The obtained EPID images analysed with the convolution model can be used to Determine the exit dose distribution with an accuracy of 1.7% (1SD).

First clinical tests using a liquid-filled electronic portal imaging device and a convolution model for the verificatio of the midplane dose

Ronald Boellaard, Marcel van Herk, Hans Uiterwaal , Ben Mijnheer
Radiothrapy and Oncology Vol. 47, 1998.

Midplane 2-d dose calculated using transit image and convolution model agreed within 2.5% w.r.t the treatment planning calculations in most parts of the radiation field for various treatment sites in clinical practice.

With portal device measurements, it is possible not only to measure the midplane Dose but also evaluate the deviation between actual and calculated dose due to differences in the patient anatomy on treatment compare to planning CT data set.

3 D – dose reconstruction from EPID images - development

Three dimensional dose reconstruction of breast cancer treatment using portal imaging , Louwe RJW etal Med Phys 2003;30:2376 – 89

A dose delivery verification method for conventional and intensity-modulated Radiation therapy using measured field fluence distributions, Renner WD etal Med Phys 2003;30:2996 – 3005

Three dimensional IMRT verification with a flat-panel EPID Steciw S, Warkentin B etal , Med Phys 2005;32:600 – 12.

A Monte Carlo based three-dimensional dose reconstruction method derived From portal dose images , Van Elmpt WJC etal , Med Phys 2006;33:2426 – 34

Patient-specific dosimetry of conventional and intensity modulated radiation Therapy using a novel full Monte Carlo phase space reconstruction method From electronic portal images, Jarry G etal, Phys Med Biol 2007;52:2277 – 99

Routine Individualised patient dosimetry using electronic portal imaging devices, Sebastiaan M.J.J.G. Nijsten, Ben J Mijnheer etal Radiotherapy and Oncology 83 , 2007

2511 patients (3146 plans) from radical treatments of pelvic region, breast Lung and H&N region were verified using 37500 images taken from 4 SL15 Linear Accelerators using Theraview CCD camera based EPID system. Transit dose (at the plane of the detector) , In-vivo dose (calculated at 5.0cm Inside the patient) and pre-treat verification at the imager plane – all are Point dose verifications at the central axis.

Conclusion: False positive dose delivery errors due to user errors
Implementation errors in the analysis software
Procedure Limitations
+ True positive dose delivery errors

12% of all treatment sessions imaged, patient relate error sources could be determined that probably affected the 3-D dose distribution locally.

2008 : The next step in patient-specific QA: 3D dose verification of Conformal and intensity-modulated RT based on EPID dosimetry and Monte Carlo dose calculations, Wouter van Elmpt etal, Radiotherapy and Oncology 86 (2008).

EPID dosimetry combined with 3D dose reconstruction is a useful procedure for patient-specific QA of complex treatments.

A literature review of electronic portal imaging for radiotherpay dosimetry Wouter van Elmpt etal, Radiotherapy and Oncology 88 (2008) 289 – 309.

Reference : Table 3

Point dose verification
2D transit dose verification at EPID level
2D transit dose verification at patient level
3D dose verification either on CT / Cone beam CT

A simple backprojection algorithm for 3D invivo EPID dosimetry of IMRT treatments , Markus Wendling etal, Med Phys(36), 2009.

Dose reconstruction within the patient volume in multiple planes Parallel to the EPID for each gantry angle. By summing the 3D dose grids of all beams, the 3D dose distribution for the total treatment fraction is obtained.

Planned and in-vivo measured dose distributions were within 2% at the dose prescription point. Within 50% isodose surface of the prescribed dose, atleas 97% of points were in agreement, evaluated with a 3D γ method with 3%,3mm criteria.

Portal dose image prediction for in vivo treatment verification completely based on EPID measurements, Mathilda van Zijtveld etal MedPhys, 36,2009.

A limited set of EPID measurements is required to derive the input parameters of this model. The accuracy of the in vivo PDI prediction was verified using measurements behind phantoms and four prostate cancer patients treated with IMRT.

Behind homogeneous slab phantoms, the local differences between measured and predicated PDI s were within 2% inside the field, while behind a lun

And a pelvic phantom, the agreement was within 3% or within 3mm in regions With steep gradients. Outside the fields, the PDIs agreed within 2% of the global dose maximum.

Evaluation of the in vivo PDI measurements behind patients showed that,on averag 87% of the pixels inside the field fulfilled the 3% local dose and 3mm DTA .

Replacing pretreatment verification with invivo EPID Dosimetry for Prostate IMRT, Leah N. McDermott etal.
IJROBP, Vol.67, No.5, 2007.

75 IMRT Prostate Plans – Pre_treat VS Transit -compared using gamma analysis

In vivo EPID dosimetry is a viable alternative to pretreatment verification for Prostate IMRT. For our patients, combining information from three fractions invivo is the best way to distinguish systematic errors from non-clinically relevant discrepancies, save hours of quality assurance time per patient plan and enable verification of the actual patient treatment.

3D in vivo dose verification of entire hypo-fractionated IMRT treatments Using an EPID and cone-beam CT
Leah N. McDermott etal, Radiotherapy and Oncology 86 , 2008.

Back projected EPID based3D in vivo dosimetry and cone-beam CT to obtain a complete account of the entire treatment for 9 hypo-fractionated rectum IMRT patient plans.

Average planned and measured isocentre dose ratios were 0.98 ± 0.01SD
3D gamma analysis (3%; 3mm) : Mean =0.35 ± 0.03SD ;
Maximum = 1.02 ± 0.14SD

Over dosage of upto 4.5% in one fraction was measured in the presence of gas pockets.

Advantages: Safety net for advanced treatments involving dose escalation
Possibility for dose adaptive radiation therapy.

SUMMARY

Electronic Portal Imaging Devices – Hardware & Associated Software

Camera based systems to modern aSi based high resolution systems

Dosimetric characteristic studies

Energy response, MU linearity, Dose-rate response
Ghost Effect, Scatter effects, Response stability etc.

Calculation Algorithms

Back projection, Pencil Beam, Monte Carlo etc.

Transit / Exit dosimetry commercial products

(1) Dosimetry Check, Math Resolutions , U.S.A

(2) EPIgray , DOSISoft, France

Clinical Advantages

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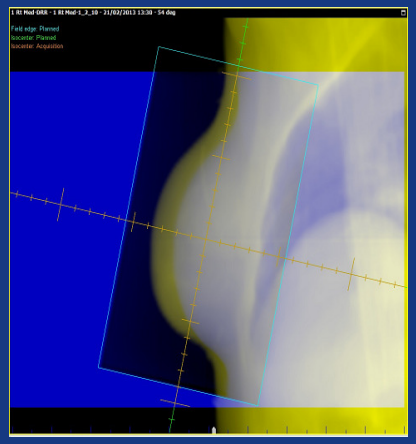
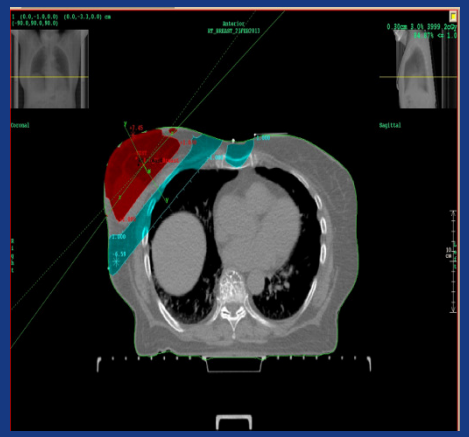
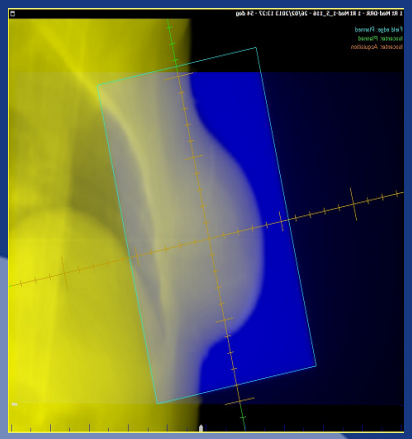


DC – Gamma Analysis





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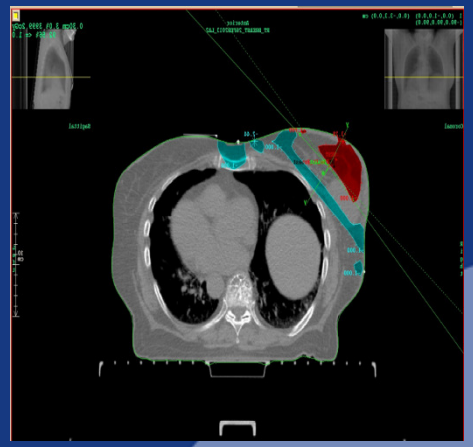
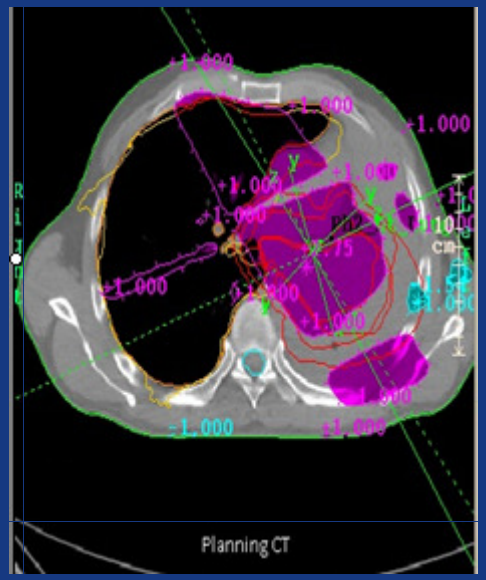
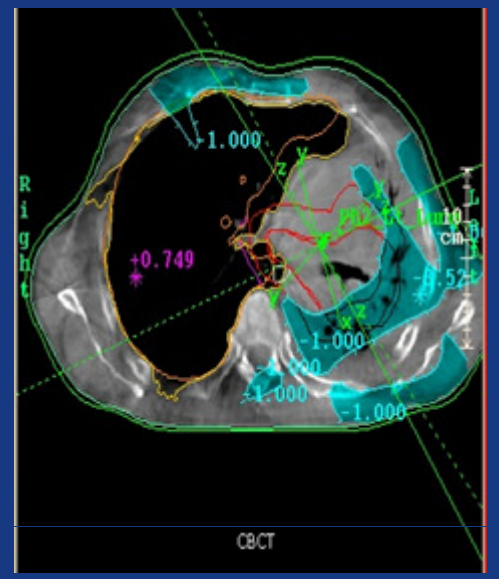
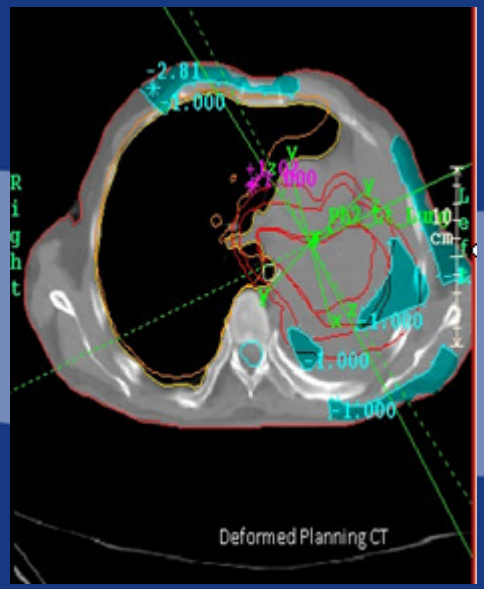


DC – Gamma Analysis

Ca.Lung – 3Fld Gamma Analysis







EPID based Transit / Exit / In-vivo Dosimetry