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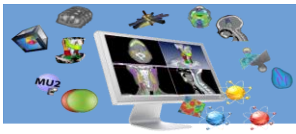

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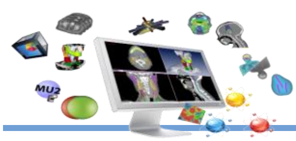

EPIgray in vivo transit dosimetry using Electronic Portal Imaging

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PhD candidate

François Husson, PhD
Scientific Director of DOSIsoft S.A.

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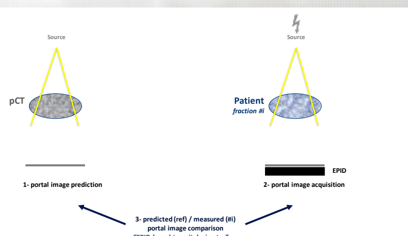
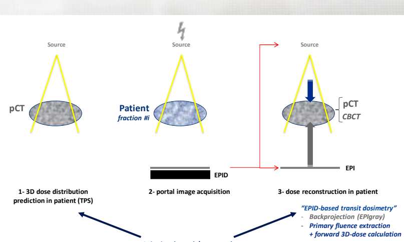
Part 1 EPID-based *in vivo* transit dosimetry characteristics

The advent of IVD EPID dosimetry

On-Line Treatment Verification *1/2*



On-Line Treatment Verification *2/2*



EPID's assets for IVD

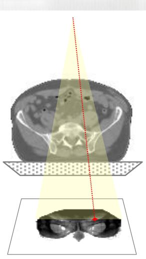
Parameter	Diode	EPID
Dose	0	0
Accumulated dose	+	+
Dose rate	+	0
Energy	+[c]	+[c]
SSD	+[d]	0
Field size	+[d]	+
Linearity	0	0
Reproducibility (1SD)	0(<1%)	0(<1%)
Orientation	+[d]	0
Temperature	+	0
Readout delay	0	0
Intervening with patient setup	+	0
Correction factors	++	++
Estimated dose uncertainty (1SD)[b]	1.5% – 3%[j]	1.5%–3%[j]
Main advantages	Good reproducibility, immediate readout	2D and 3D dose distribution, resolution, immediate readout, permanent record
Main disadvantages	Cumbersome calibration, many corrections, cable	Cost, limited availability of commercial software

adapted from *Mijnheer et al., Med. Phys., Vol. 40, No. 7, 2013*

- the device is in most centers already attached to the linac
- detector accurate and reproducible
- does nor perturb the incident beam
- fast image acquisition
- the image is in digital format with high resolution
- suitable for Conventional as for IMRT beams and VMAT treatment
- compatible with many TPS, R&V systems
- minimal time to process image analysis and review can be done at any workstation (radiotherapists, physicists, radiation oncologists): large scale implementation of *in vivo* dosimetry
- many points of measurement (2D → 3D): more useful information
- available and easy to use for several fractions
- *large field sizes, EPID/couch collision*

EPID-based transit IVD features

Transit portal image characteristics

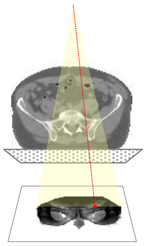


Pixel value depends on the transmitted fluence

.Whole patient (+couch) thickness – *attenuation*

secondly order effects:
.EPID response to irradiation (field size)
.Scatter from the patient

Transit portal image characteristics

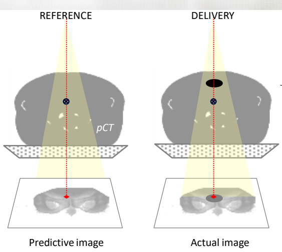


Each PIXEL relates the beam transmission along the corresponding ray in the patient anatomy

Transit dosimetry reports *transmitted fluence error* at *exit of the patient*

- *in case of correct patient anatomy (setup<>pCT):*
  .incident fluence error
- *in case of correct incident fluence (TPS<>linac):*
  .patient anatomy modification
  .patient positioning error

Transit portal image characteristics



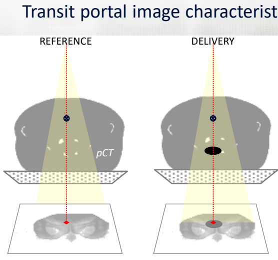
→ **air cavity position**

The radiological thickness (H_2O eq.) along the ray passing by the dose point is reduced: reconstructed dose point is increased and possible alert

> Dose delivery error in the patient

Checkup of the portal image required!

Transit portal image characteristics



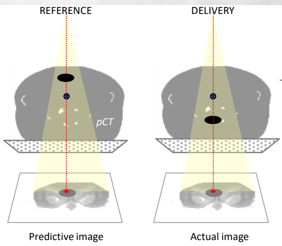
→ **air cavity position**

The radiological thickness (H_2O eq.) along the ray passing by the dose point is reduced: reconstructed dose point is increased and possible alert

> Dose delivery error in the patient?

Checkup of the portal image required!

Transit portal image characteristics



→ **air cavity position**

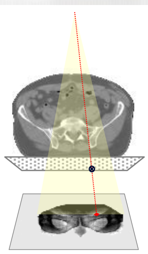
The radiological thickness (H_2O eq.) along the ray passing by the dose point is regular: reconstructed dose point is correct and no alert is emitted

> Dose delivery error in the patient

> False negative test

No portal image modification

Patient dose point reconstruction



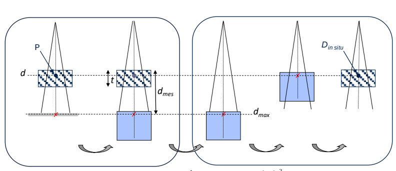
A close correlation exists between the PIXEL VALUE and the delivered dose value at the EXIT point (equivalent transmission).

All other points in the patient (3D) need a dose reconstruction pattern from a 2D information

> additional information required
.anatomical patient modelling
.dose calculation formalism

EPIgray® Dose formalism

Backprojection based on “finite TMR” method



$$pixel\_value \times Calib \times CF \times \frac{1}{fTMR} \times \left(\frac{1}{d}\right)^2 \times TMR$$

sagging

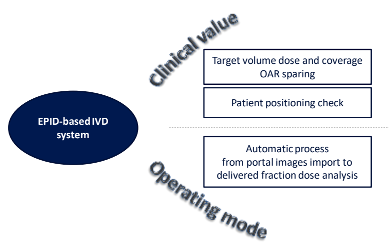
Gy / pixel value
ghosting-lag effect
EPID response *vs* $V_{scatter}$
penumbra & beam profile restoration

field size
d_{mes}, thickness

field size
depth

Essential requirements for EPID-based transit IVD

Essential requirements for EPID-based IVD



Essential requirements for EPID-based IVD

Error detection in dose delivery: First statements

- Equipment related errors
  changes in the dose delivered per monitor unit, incorrectly aligned wedge filter or other accessories, mlc malfunction, beam parameters out of tolerance (e.g. flatness, energy)…
- Errors in the TPS dose calculation
  incorrect beam parameter commissioning, inaccuracies in dose calculation algorithms, misunderstanding of software capabilities and limitations, inappropriate planning practices or result misinterpretation, erroneous patient data, wrong fractionation scheme…
- Data transfer errors
  network corruption or failure, incorrect electronic data exchange compatibility, staff communication deficiency…
- Human errors in treatment set-up
  incorrect setting transcription (MU), missing or incorrect position of beam modifier, wrong selected beam, wrong patient identity, patient positioning discrepancies between planning and delivery (SSD)…
- Discrepancies in the thickness and composition of the patient between planning and treatment
  patient morphological changes for entrance + exit dose measurements only

Essential requirements for EPID-based IVD

Error detection in dose delivery: Additional statements achievable with EPID-based IVD

- Beam per beam analysis and per fraction analysis of dose control points
- Irradiated volume error
- Poor patient positioning
- Inter-fractional patient movement
- Variability of patient's internal anatomy

internal movements, tumor shrinking, weight gain or loss, gas pocket …

Part 2 Assessment tools for *in vivo* transit dosimetry results

Towards an ideal EPID-based IVD solution

Key points

- Portal image *workflow* and *control task manager*
- Dosimetric indicators *for alert system (beam/fraction)*
- Control of *patient positioning*
- Dose distribution in *actual patient*
- Daily control > Cumulative dose (anatomical modification) > *Adaptive Radiotherapy*

Analysis criteria

Basic **dose-point approach**

Action Level / Tolerance

per beam – per fraction

Relative Difference

$$Rel.\ Diff.\ (P) = \frac{D_{epigray}(P) - D_{TPS}(P)}{D_{TPS}(P)} * 100 \quad (\%)$$

≈ 5%

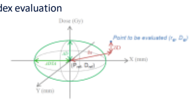
Absolute Difference

$$Abs.\ Diff.\ (P) = D_{epigray}(P) - DTP_S(P) \quad (cGy)$$

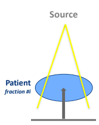
≈ 2.5cGy

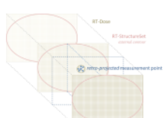
Analysis criteria

γ-index evaluation



$$\Gamma(r_e, D_e) = \sqrt{(\frac{\delta r}{\Delta DTA})^2 + (\frac{\delta D}{\Delta D})^2}$$





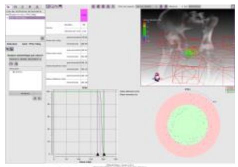
γ < 1:
reconstructed dose value likely in the vicinity of the RT-dose matrix (DTA acts as an additionnal tolerance for IMRT beams)

Note:
Gamma Agreement Index (GAI): percentage of points in a given volume with γ value <1

In vivo transit dosimetry analysis
Dose-volume relationship

EPIgray®

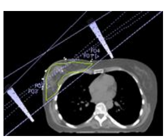
Web-based interface
(from any computer)



Expert interface
(EPIgray® workstation)

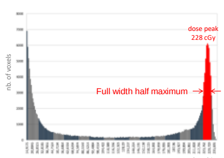
Automatic control points target volumes

Dose peak identification



Homogeneous dose area: 223 – 229 cGy

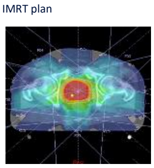
Average TPS dose value
with a low standard deviation

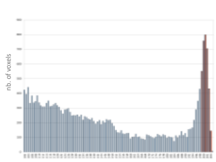


Automatic definition and contouring
of the « prescribed dose area »
from the RT_dose file

Automatic control points target volumes

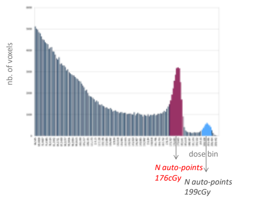
IMRT plan





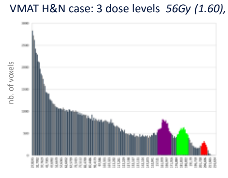
Automatic control points target volumes

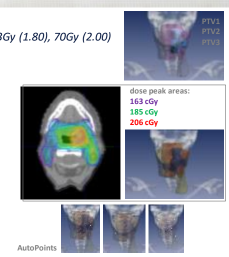
VMAT prostate case: 2 dose levels (180 & 200 cGy)



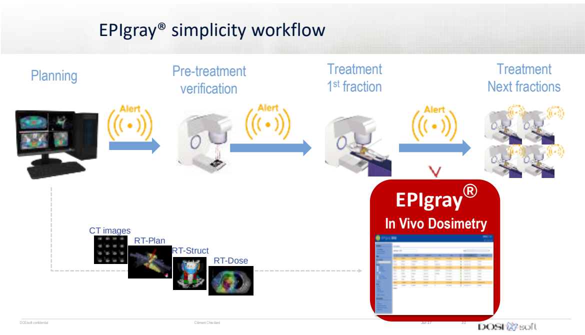
Automatic control points target volumes

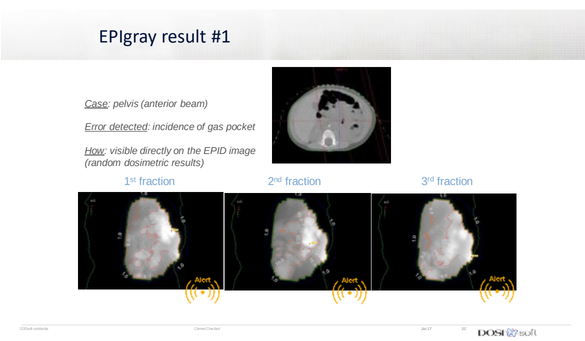
VMAT H&N case: 3 dose levels *56Gy (1.60), 63Gy (1.80), 70Gy (2.00)*

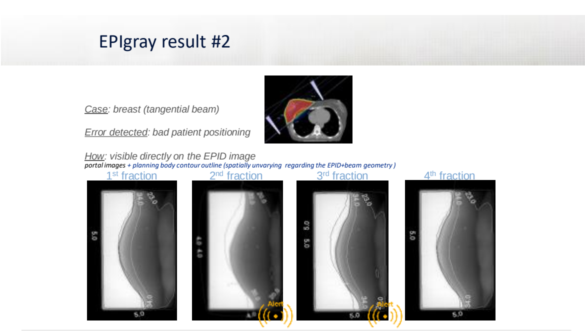




Part 3 *Clinical use and error detection examples*


EPIgray® simplicity workflow
Planning
Pre-treatment verification
Treatment 1st fraction
Treatment Next fractions
Alert
Alert
Alert
EPIgray®
In Vivo Dosimetry
CT images
RT-Plan
RT-Struct
RT-Dose
DOSIsoft


EPIgray result #1
Case: pelvis (anterior beam)
Error detected: incidence of gas pocket
How: visible directly on the EPID image (random dosimetric results)
1st fraction
2nd fraction
3rd fraction
Alert
Alert
Alert
DOSIsoft

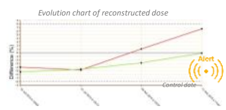

EPIgray result #2
Case: breast (tangential beam)
Error detected: bad patient positioning
How: visible directly on the EPID image
portal images + planning body contour outline (spatially unvarying regarding the EPID+beam geometry)
1st fraction
2nd fraction
3rd fraction
4th fraction
DOSIsoft

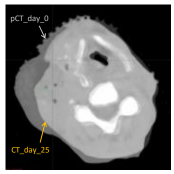
EPIgray result #3

Case: head-&-neck

Detection: tumor shrinkage

How: inter-fraction dosimetric deviations and new CT





Study

Patient case

USE OF IN VIVO TRANSIT DOSIMETRY AS A WARNING SYSTEM FOR ADAPTIVE RADIOTHERAPY

F. Husson, F. Vincent[1], H. Tournat[1]

[1]Oncology and Radiotherapy Center. Chambray-lès-Tours. France
Presenting at the French annual meeting of Medical Physicist , Lille, France 2015

Clinical case

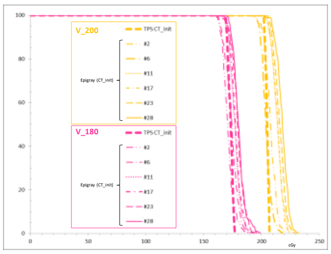
Pelvic irradiation

↓

Patient with serious slimming down during the treatment course

↓

Which indicators for in vivo transit dosimetry for a relevant warning?



DVH Epigray # vs TPS

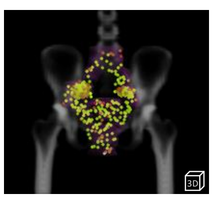
#2

Control points with color-coded relative deviation (Epigray/TPS):
● in tolerance ±5% and out-of-tolerance : ● under -5%, ● over +5%

#6

#11

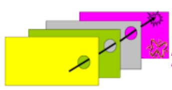
#17



#23

#28

EPIgray results: conclusion



Error detection verified about

- field aperture (MLC default), beam energy, MU default
- wedge (in/out, angle, orientation), block
- wrong plan protocol or planning error (volume naming and segmentation mistake)
- TPS dose calculation error
- plan transfer error
- delivered dose level (prescription mode, dose fraction value, site location, bolus material…)
- delivery conditions (not radio-transparent accessory in the beam…)
- in many situations reported by published radiation accident review
- bad and wrong *patient positioning* (±SSD)
- *patient anatomy* modification (internal movements, gas pocket, tumor shrinking, patient slimming down, …)

Thank you

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