

# Patient safety

*Paving the way for progress*

N°5

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## In Vivo Dosimetry

Newsletter for  
radiotherapy professionals



## > Editorial

In vivo dosimetry (IVD) is an essential tool that contributes to the safety of radiotherapy treatments. This measurement of the dose in the presence of the patient allows errors to be detected so that their possible consequences can be alleviated.

The requirement that centres perform IVD (INCa authorisation criterion) involves “technically measurable beams”. However, the proportion of patients treated using beams of modulated intensity (IMRT or volumetric modulated arc therapy) continues to grow; this raises the question of the inadequacy of the “standard” method of dose measurement at a point.

This bulletin no. 5 invites you to discover the innovative solution of so-called in vivo “transit” dosimetry currently being implemented at the Curie Institute (75), the François Baclesse centre in Caen (14) and the Thiais (94) centre.

You will also find an overview of the practice of standard IVD in France and several European countries, as well as feedback from the La Roche sur Yon (85) and Jean Bernard (72) centres, which have been practicing IVD for 4 and 6 years, respectively.

We hope you find it interesting!

The Editors

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Patient safety – Paving the way for progress is edited by the French Nuclear Safety Authority (ASN) as part of the work of the multidisciplinary working group specially created to provide radiotherapy professionals with feedback.

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## > Background

### In France

The requirement for in vivo dosimetry (IVD) is one of the French National Cancer Institute (INCa) authorisation criteria for practicing external radiotherapy, an integral part of the system of authorisation for cancer treatment (2007 decree). This requirement was implemented in the framework of the French radiotherapy measures specified in 2007.

Approval criterion no. 15 stipulates: "In vivo dosimetry is to be performed for each technically measurable beam during the first or second irradiation session, as well as at each modification in the treatment". In order to assist radiotherapy centres in observing this requirement as soon as possible and under the best possible conditions, the INCa financed equipment for radiotherapy centres in the private or public sector in the amount of € 3.1M in 2008.

The 2013 French radiotherapy observatory indicates that at the end of December 2012, all the centres that had responded (168/172) were equipped with in vivo dosimetry systems.

68% of the centres use IVD for all their treatments in which beams are technically measurable, with the share of non-technically measurable beams estimated at 21% on average. The most widespread equipment is that of direct readout type, 93% of which uses semiconductor diodes. Most centres have defined an action threshold at 5% discrepancy between the measured dose and the calculated dose.

The share of the centres using IVD systematically (100% implementation) has progressed by 41 points in 3 years (from 27% to 68% of the centres between 2009 and 2012).

In application of decision ASN no. 2008-DC-0103 setting quality assurance requirements in radiotherapy, procedures involving IVD must appear in the documentation system. The methods of implementation, monitoring and analysis of the results of these measurements must be described.

### And in Europe?

A survey was conducted by ASN among 30 European countries (the 27 Member States in June 2013, Norway, Switzerland and Iceland). Twelve countries responded.

IVD is not mandatory for all beams in most European countries (Austria, Finland, Belgium, Germany, Greece, United Kingdom, Estonia, and Lithuania).

IVD has been mandatory in Sweden since 2000, in Denmark since 2001, in Norway since 2004, and is mandatory in the Czech Republic.

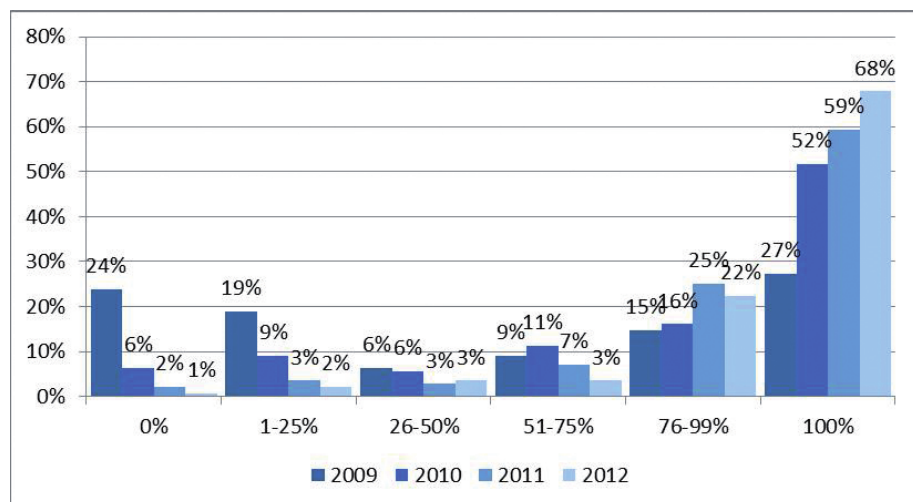
In Austria, IVD is mandatory only for total-body irradiation.

In Finland, quality assurance for treatment planning must include verification of each individual treatment plan using a procedure optimally independent of the treatment planning system. In addition, every total-body irradiation must include an in vivo dose measurement. Use of in vivo dosimetry is also recommended for other types of radiotherapy.

IVD is considered good practice:

- in Belgium: the National Institute for Health and Disability Insurance (INAMI) reimburses four IVD sessions per patient;
- in the United Kingdom: in 2007, the Chief Medical Officer<sup>1</sup> of England wrote in his report that IVD should be progressively introduced.

<sup>1</sup> Chief Medical Officer (CMO) is the title used in several countries for the senior official designated as the head of medical services, most often at the national level. The position is occupied by a physician who serves as an adviser and directs a team of medical experts on questions of importance for public health.

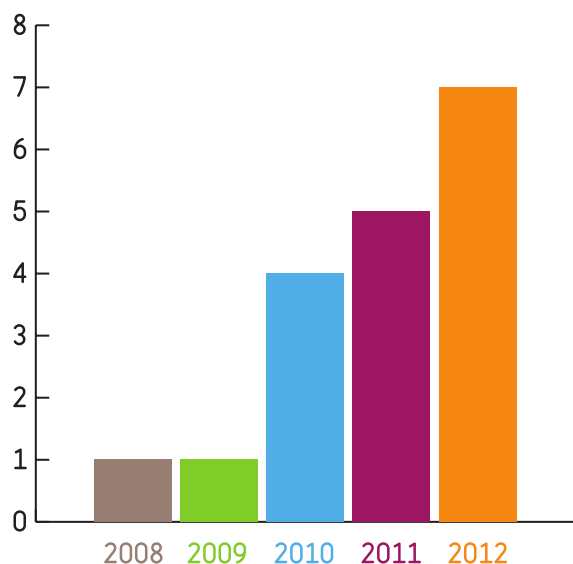


**Figure 1. Variation of the percentage of centres that have implemented IVD as a function of the level of implementation (for technically measurable beams)** (143 centres responding over four years; source, 2013 French Radiotherapy Observatory (to appear))

## > Key figures

In the course of the five years 2008 to 2012, ASN received 1187 notifications of external radiotherapy events involving a patient. The error was detected using in vivo dosimetry in 18 of these. These significant radiation protection events (SRPE) were classified as level 0 or level 1 on the ASN-SFRO scale<sup>2</sup>.

### Distribution of notifications by year:



#### Note:

An error detected using in vivo dosimetry does not necessarily meet a criterion for notification as a significant radiation protection event.

If the error is detected sufficiently early, it can be quickly corrected and is not routinely subject to notification to ASN.

However, a notification of errors of interest on the initiative of a centre according to criterion 6 (see ASN guide no. 11) is relevant from the perspective of sharing experience.

<sup>2</sup> <http://www.french-nuclear-safety.fr/index.php/content/download/22275/123578/file/INES-SFRO+2013-UK.pdf>

## > Decoding

### 1. Description of the notified events detected using IVD

#### Treatment technique

Of the eighteen external radiotherapy events considered, only one involved total-body irradiation.

#### Number of sessions involved

For each significant radiation protection event, the error identified involved at most four external radiotherapy sessions, with IVD measurement having been performed only in the fourth session for one of the treatments involved. For some SRPE, only part of a session was involved (error detected during the session, corrected immediately).

#### Who detected the error?

In analysis of the IVD results, the error was identified by:

- A radiation therapy technician: 12
- A medical physicist: 5
- An assistant physicist: 1

#### Which step of the clinical radiotherapy process caused the significant event?

The error that caused the event occurred during:

- Constitution of the file: 1
- Dosimetry: 4
- TPS to R&V transfer: 1
- Initiation of treatment (verification session): 3
- The treatment process: 9

### 2. What type of error did IVD allow to be detected?

#### • Identification of the patient or the data: 3

Use of an incorrect identity photograph in the patient file

Use of another patient's beams

Wrong DRR incorporated in the R&V (that of another patient)

#### • Positioning of the patient: 7

Table displacement incorrect or not performed

Wrong table height (SSD incorrect)

Confusion between two tattoo points

#### • Missing contention: 1

#### • Incorrect monitor units (MUs): 3

Confusion between MUs involving a beam with wedge filter and without wedge filter

Manual error in recording the MUs transmitted between TPS and R&V

Calculation of a MU number on the basis of an incorrect dose per session

#### • Wedge filters: 3

Inadvertent removal of the wedge filter of one of the beams on the R&V

Software incompatibility: erroneous transfer between the TPS and R&V leading to transformation of static filters into dynamic filters

Omission of a wedge filter on one of the beams

#### • Energy used for the treatment not compliant with the prescription (indirect detection) : 1

#### IVD thus allowed detection of errors of the type:

- Random : 5
- Systematic : 13

For the latter, IVD thus allowed repetition of the error throughout the treatment to be avoided.

## > Centre experience

### In which session is IVD performed?

*H. Luttiau: In the second session, and, exceptionally, in the first session for short treatments. The first session is centred more on verification of the beams and positioning of the patient.*

*S Estivalet: IVD is also performed in the second session for long curative and palliative treatments. On the other hand, IVD is performed in the first session for hypofractionated treatments. For very high doses per session, the beams can even be split in half to allow verification of the dose in the course of treatment.*

### How are the IVD results analysed and used?

*H. Luttiau: A 5% threshold is set for most treatments, except for breasts (7%). If the measurements comply with this threshold, the technicians validate the measurement. In all cases, the physicists re-verify the results obtained.*

*S Estivalet: The IVD result is validated by the technicians if the measurement AND the source-skin distance (SSD) comply with the specified tolerance thresholds. Otherwise, the physicist intervenes.*

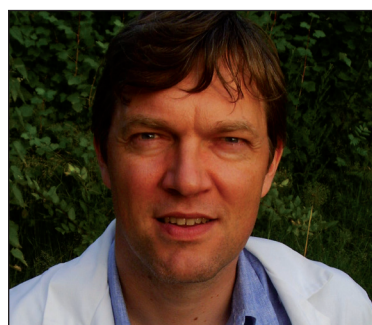
### What obstacles or difficulties have been encountered?

*H. Luttiau: On the technical level, the difficulties are related in particular to positioning of the detector in the case of the breasts (obliqueness of the beams and mobility of the breast).*

*S Estivalet: At the organisational level, proper implementation of the IVD technique requires a progressive approach and establishment of a dialogue between the radiation therapy technician and the physicist. At the Centre Jean Bernard, a physicist and a technician have been named contact persons for IVD.*



**Hélène LUTTIAU**,  
a radiation therapy technician at the Centre Hospitalier Départemental of La Roche sur Yon (85). The centre has been practicing IVD since June 2009.



**Stéphane Estivalet**,  
medical physicist in radiotherapy at the Centre Jean Bernard (72). The centre has been practicing IVD since 2007.

### What are the advantages of using IVD?

*H. Luttiau: The impact is very positive. IVD greatly reassures patients during the diagnostic announcement consultation, especially in the current media context. It demonstrates the measures taken to ensure that the treatment delivered is correct, and the traceability in their file.*

*S Estivalet: I have been convinced of the importance of verification of the patient dose for a number of years. Thanks to IVD, we have detected two systematic errors, including one involving the MU number for a beam.*

## > Steps for progress

### 1. Good practices

*Recommendations of the working group with the contribution of Isabelle Buchheit, manager of medical physics at the Lorraine Institut de Cancérologie (The centre has been practicing IVD for 25 years).*

#### Recommendations:

- Choose IVD tools and specify measurement protocols sufficiently simple and robust that they can be incorporated into a clinical routine.
- If the use of different types of irradiation beams justifies it, don't rule out having several co-existing in vivo measurement systems in the department.
- Stay aware of the available technical solutions and plan for the investments necessary for acquisition of a new solution, subject to having the resources necessary for incorporating it into the department.

- When implementing new external radiotherapy techniques, consider ahead of time the technical solutions that can be envisaged for in vivo dosimetry.



- In vivo dosimetry is a tool allowing an error to be detected, thus preventing it being reproduced systematically due to the Record and Verify systems. It is not a measurement of the absolute dose delivered to the patient.
- Quality controls of modulated beams before treatment using matrix detectors do not constitute in vivo dosimetry, as they are conducted in the absence of the patient.

## (...) Steps for progress •

### 2. Innovative initiatives

At the end of 2012, 25 dedicated accelerators (Cyberknife®, Novalis®, Tomotherapy®) were in use in France, as well as four Gammaknives®. The rapidly increasing number of treatments performed using this apparatus use beams previously considered “not technically measurable”<sup>3</sup>. The innovative approach of so-called in-vivo “transit” dosimetry allows in vivo dosimetry to be extended to IMRT and volumetric modulated arc therapy. Studies are also underway on the same principle for tomotherapy.

Transit dosimetry is in particular being implemented at the Curie Institute (75), the François Baclesse centre in Caen (14) and the Thiais oncology centre (94).

#### Transit dosimetry

Usually used to check patient positioning, portal imagers (EPID) allow two-dimensional acquisition of the signal transmitted through the patient throughout the entire duration of irradiation. It is then possible to arrive at an estimate of the dose in the patient. The dose thus reconstructed can then be compared to the planned dose to validate the quality of the treatment delivered. This method has a certain number of advantages compared to the “standard” method (measurement of the dose at a point by placing a detector on the skin) and opens up a number of prospects with regard to strategies for validation of the dose delivered to the patient:

- Ease of implementation.
- No additional time required at the treatment station, allowing measurements to be repeated over several sessions.
- Enrichment of the information obtained through analysis of transmission images, on which the patient’s anatomical information can very often be used.
- Possibility of analyses at several checkpoints inside and outside the target volume.
- Compatibility with comparison tools such as the Gamma Index.

#### In volumetric modulated arc therapy

The Thiais (94) oncology centre has used transit dosimetry since July 2013 for treatments with the 3D conformal technique, with IMRT or by volumetric modulated arc therapy. Between July and September 2013, 1523 in vivo checks of the dose were performed using the portal imager. The results show good agreement between the dose calculated by TPS (DTPS) and the dose actually delivered to the patient (Dportal).

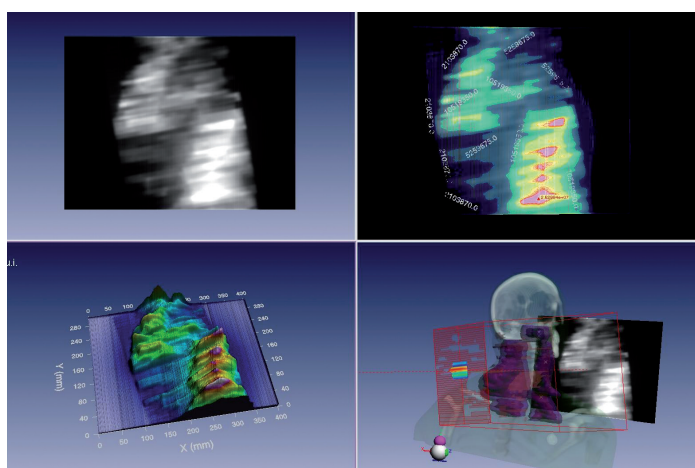
- Of 1250 checks of treatments with the 3D conformal technique, the average discrepancy between DTPS and Dportal was 0.6%, with a standard deviation (1 sigma) of 3.8% for calculation points located in the target volume and in organs at risk.

- Of 249 treatments with volumetric modulated arc therapy, the average discrepancy between DTPS and Dportal was 1.3%, with a standard deviation (1 sigma) of 3.0%, for all locations combined.
- 24 IMRT give an average discrepancy between DTPS and Dportal of 0.3%, with a standard deviation (1 sigma) of 2.4%.

The greatest discrepancies (> 10%) were due to movements of the patient during irradiation, easily visible on the transit portal image.

These results are very encouraging, and show that use of portal images for IVD with reconstruction of the dose actually delivered to the patient is applicable for all techniques of irradiation with high-energy photons.

Figure 2. Distribution of the “dose” measured by the portal imager for a patient treated by volumetric modulated arc therapy for a H&N cancer (Thiais oncology centre)



#### In tomotherapy

The François Baclesse centre in Caen (14) is currently testing a software that, starting from the signal collected by the detectors used for tomotherapy imaging, allows the dose to be reconstructed in a phantom, for pre-treatment verification of dosimetric plans, or in a patient, for 3D in vivo dosimetry.

The dose is retroprojected onto the tomodesitometric images to display the treatment plan dose distribution and then compared to the dose distribution measured at the output of the detectors. Currently available evaluation tools such as dose profiles, gamma index, and histograms allow the results to be analysed. One of the priorities in development of the software being tested is to be able to compare the patient output measurements for different sessions in order to monitor the progress of the treatment and decide whether it should be re-planned.

<sup>3</sup> The concept of “not technically measurable” beams (see guide INCa 2008) designates beams or irradiation techniques for which point dose measurement is not suitable and not sufficiently representative of the dose delivered to the target volume. This is the case for example with IMRT, robotised treatments, helical tomotherapy and arc therapy treatments, and also beams for which the detector size is not suitable (stereotactic irradiations).

## > Further reading

### In vivo dosimetry:

#### Authorisation criteria for the practice of external radiotherapy

[http://www.e-cancer.fr/component/docman/doc\\_download/1994-criteres-radiotherapie](http://www.e-cancer.fr/component/docman/doc_download/1994-criteres-radiotherapie)

#### Guide for the routine practice of in vivo dosimetry in external radiotherapy

written under the auspices of the National Cancer Institute (INCa) with the collaboration of the French Society of Medical Physics (SFPM) and the French Nuclear Safety Authority (ASN). October 2008.

[http://www.sfpm.fr/download/fichiers/docs\\_sfpm/200810\\_guide\\_dosi\\_in\\_vivo.pdf](http://www.sfpm.fr/download/fichiers/docs_sfpm/200810_guide_dosi_in_vivo.pdf)

#### In vivo electron beam dosimetry: recommendation of the SFPM (2010)

In August 2010, the ASN consulted the SFPM on the difficulties encountered in conducting in vivo electron beam dosimetry.

[http://www.sfpm.fr/download/fichiers/docs\\_sfpm/sfpm\\_2011-position-sfpm-sur-dosi-in-vivo-electrons\\_avis-a-asn.pdf](http://www.sfpm.fr/download/fichiers/docs_sfpm/sfpm_2011-position-sfpm-sur-dosi-in-vivo-electrons_avis-a-asn.pdf)

#### National Radiotherapy Observatory – end of 2012 survey report and progress since 2007 – to appear

## > Previously published bulletins

- N°1** Identification du patient [Patient identification] (March 2011),
- N°2** La première séance “à blanc” [The verification session] (Nov. 2011),
- N°3** Comment analyser vos événements significatifs de radioprotection? [How to analyse your significant radiation protection events?] (July 2012)
- N°4** Quels événements déclarer à l’ASN? [Which events are to be declared to ASN? Available in French only] (April 2013)

<http://www.french-nuclear-safety.fr/index.php/English-version/ASN-s-publications/Publications-for-the-professionals>

To receive the bulletin by e-mail when it appears, register at:

<http://www.asn.fr/index.php/bulletinradiotherapie/inscription>

**Mijnheer B. et al.** In vivo dosimetry in external beam radiotherapy. Med. Phys. 40 (7), July 2013.

**Tanderup K. et al.** In vivo dosimetry in brachytherapy. Med. Phys. 40 (7), July 2013.

**François P. et al.** In vivo dose verification from back projection of a transit dose measurement on the central axis of photon beams. Physica Medica, 27:1-10, 2011.

**Boissard P. et al.** Evaluation et mise en œuvre de la dosimétrie in vivo de transmission par imageurs portaux [Evaluation and implementation of in vivo transit dosimetry with EPID]. Cancer Radiothérapie 17 (2013) 656-663.

**Buzurovic et al.** Commissioning and implementation of an implantable dosimeter for radiation therapy. Journal of applied clinical medical physics, vol 14, n° 2, 2013.

<http://www.jacmp.org/index.php/jacmp/article/view/3989/2820>

### Other topics:

**Ford et al.** Consensus recommendations for incident learning database structures in radiation oncology. Med. Phys. 39 (12), December 2012

**Reitz et al.** Démarche systématique d’analyse dysfonctionnelle en radiothérapie [Systematic approach for dysfunctional analysis in radiotherapy]. Cancer Radiothérapie 16 (2012) 667-673.

**Meyrieux et al.** Analyse des risques a priori du processus de prise en charge des patients en radiothérapie: exemple d’utilisation de la méthode Amdec [FMEA applied to the radiotherapy patient care process]. Cancer Radiothérapie 16 (2012) 613-618.

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