Errors and incidents associated with IGRT technology and process

Review of literature and lessons learned

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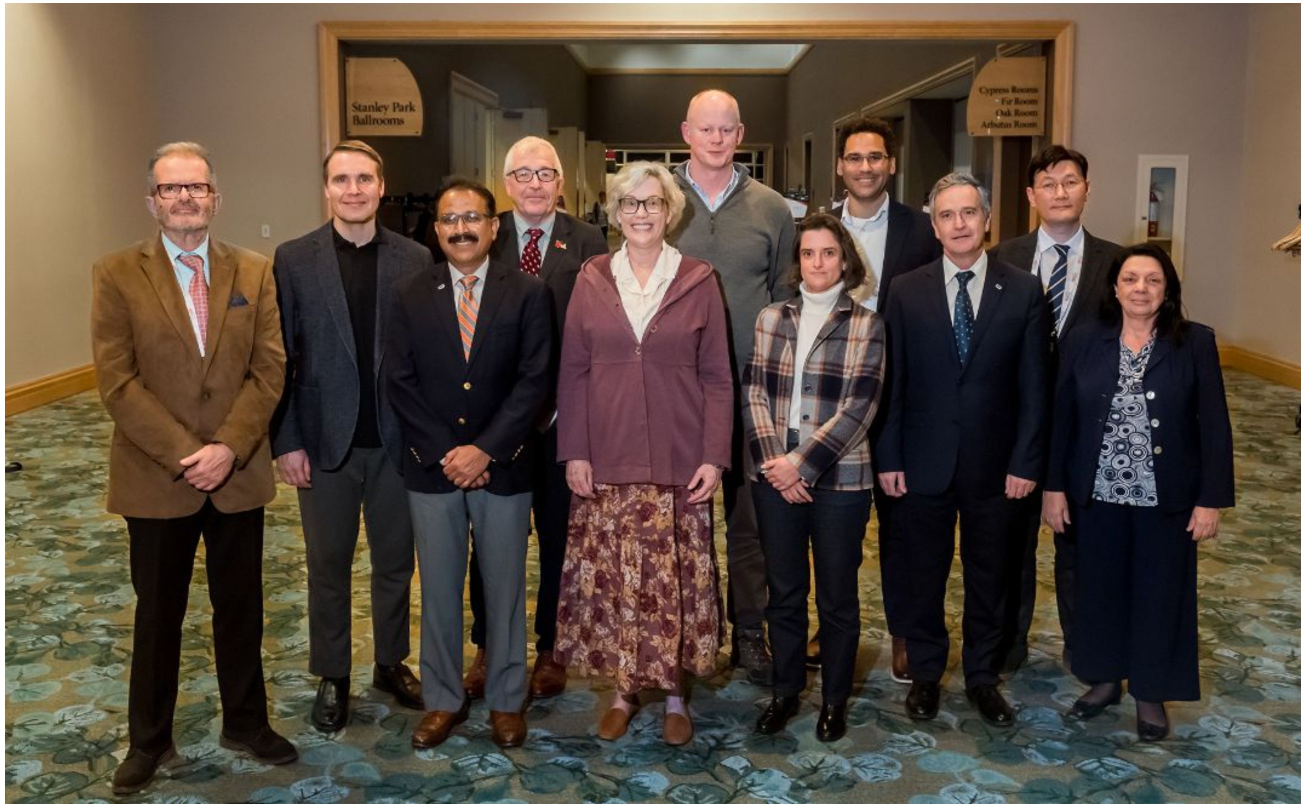
Trieste
October 8, 2024

C3 Radiological Protection in Medicine

Committee 3 addresses protection of persons and unborn children when radiation is used in medical diagnosis, therapy, and biomedical research, as well as protection in veterinary medicine.

Chair :
Kimberly Applegate (USA)

Co chair:
Colin Martin (UK)



C3 Radiological Protection in Medicine

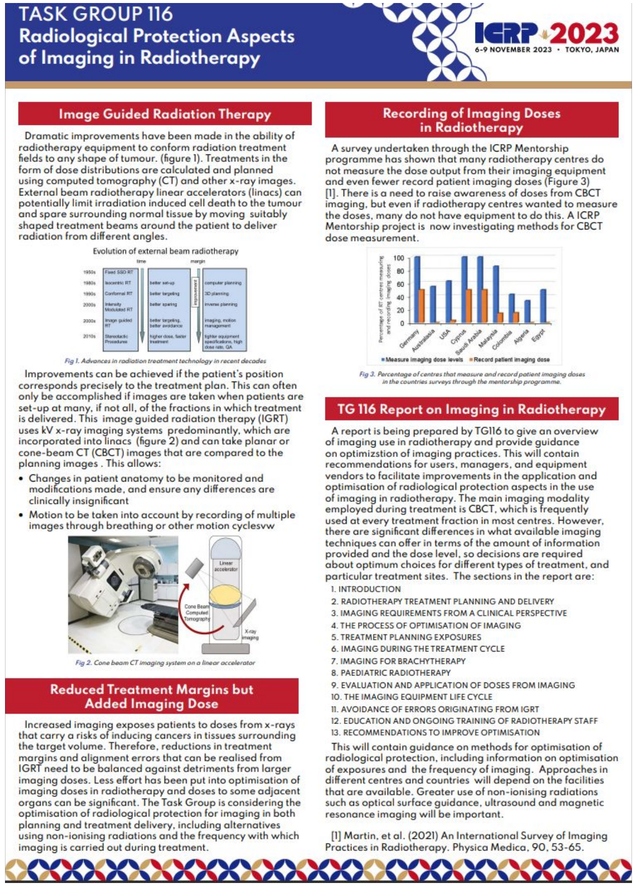
Groups under Committee 3

Task Group 36 Radiation Dose to Patients in Diagnostic Nuclear Medicine	**Task Group 108** Optimisation of Radiological Protection in Digital Radiography, Fluoroscopy, and CT in Medical Imaging	**Task Group 109** Ethics in Radiological Protection for Medical Diagnosis and Treatment	**Task Group 111** Factors Governing the Individual Response of Humans to Ionising Radiation	**Task Group 113** Reference Organ and Effective Dose Coefficients for Common Diagnostic X-ray Imaging Examinations	**Task Group 116** Radiological Protection Aspects of Imaging in Radiotherapy
Task Group 117 Radiological Protection in PET and PET/CT	**Task Group 126** Radiological Protection in Human Biomedical Research	**Task Group 128** Individualisation and Stratification in Radiological Protection: Implications and Areas of Application			

https://www.icrp.org/icrp_group.asp?id=9

TG 116 : Radiological Protection Aspects of Imaging in Radiotherapy

Chair: Colin Martin (UK)
Vice chair: William Small (USA)



TASK GROUP 116
Radiological Protection Aspects of Imaging in Radiotherapy

ICRP 2023
6-9 NOVEMBER 2023 • TOKYO, JAPAN

Image Guided Radiation Therapy

Dramatic improvements have been made in the ability of radiotherapy equipment to conform radiation treatment fields to any shape of tumour. (figure 1). Treatments in the form of dose distributions are calculated and planned using computed tomography (CT) and other x-ray images. External beam radiotherapy linear accelerators (linacs) can potentially limit irradiation induced cell death to the tumour and spare surrounding normal tissue by moving suitably shaped treatment beams around the patient to deliver radiation from different angles.

Evolution of external beam radiotherapy

Fig 1. Advances in radiation treatment technology in recent decades

Improvements can be achieved if the patient's position corresponds precisely to the treatment plan. This can often only be accomplished if images are taken when patients are set-up at many, if not all, of the fractions in which treatment is delivered. This image guided radiation therapy (IGRT) uses kV x-ray imaging systems predominantly, which are incorporated into linacs (figure 2) and can take planar or cone-beam CT (CBCT) images that are compared to the planning images . This allows:

- Changes in patient anatomy to be monitored and modifications made, and ensure any differences are clinically insignificant
- Motion to be taken into account by recording of multiple images through breathing or other motion cyclesvw

Fig 2. Cone beam CT imaging system on a linear accelerator

Reduced Treatment Margins but Added Imaging Dose

Increased imaging exposes patients to doses from x-rays that carry a risks of inducing cancers in tissues surrounding the target volume. Therefore, reductions in treatment margins and alignment errors that can be realised from IGRT need to be balanced against detriments from larger imaging doses. Less effort has been put into optimisation of imaging doses in radiotherapy and doses to some adjacent organs can be significant. The Task Group is considering the optimisation of radiological protection for imaging in both planning and treatment delivery, including alternatives using non-ionising radiations and the frequency with which imaging is carried out during treatment.

Recording of Imaging Doses in Radiotherapy

A survey undertaken through the ICRP Mentorship programme has shown that many radiotherapy centres do not measure the dose output from their imaging equipment and even fewer record patient imaging doses (Figure 3) [1]. There is a need to raise awareness of doses from CBCT imaging, but even if radiotherapy centres wanted to measure the doses, many do not have equipment to do this. A ICRP Mentorship project is now investigating methods for CBCT dose measurement.

Fig 3. Percentage of centres that measure and record patient imaging doses in the countries surveys through the mentorship programme.

TG 116 Report on Imaging in Radiotherapy

A report is being prepared by TG116 to give an overview of imaging use in radiotherapy and provide guidance on optimizstion of imaging practices. This will contain recommendations for users, managers, and equipment vendors to facilitate improvements in the application and optimisation of radiological protection aspects in the use of imaging in radiotherapy. The main imaging modality employed during treatment is CBCT, which is frequently used at every treatment fraction in most centres. However, there are significant differences in what available imaging techniques can offer in terms of the amount of information provided and the dose level, so decisions are required about optimum choices for different types of treatment, and particular treatment sites. The sections in the report are:

1. INTRODUCTION
2. RADIOTHERAPY TREATMENT PLANNING AND DELIVERY
3. IMAGING REQUIREMENTS FROM A CLINICAL PERSPECTIVE
4. THE PROCESS OF OPTIMISATION OF IMAGING
5. TREATMENT PLANNING EXPOSURES
6. IMAGING DURING THE TREATMENT CYCLE
7. IMAGING FOR BRACHYTHERAPY
8. PAEDIATRIC RADIOTHERAPY
9. EVALUATION AND APPLICATION OF DOSES FROM IMAGING
10. THE IMAGING EQUIPMENT LIFE CYCLE
11. AVOIDANCE OF ERRORS ORIGINATING FROM IGRT
12. EDUCATION AND ONGOING TRAINING OF RADIOTHERAPY STAFF
13. RECOMMENDATIONS TO IMPROVE OPTIMISATION

This will contain guidance on methods for optimisation of radiological protection, including information on optimisation of exposures and the frequency of imaging. Approaches in different centres and countries will depend on the facilities that are available. Greater use of non-ionising radiations such as optical surface guidance, ultrasound and magnetic resonance imaging will be important.

[1] Martin, et al. (2021) An International Survey of Imaging Practices in Radiotherapy. Physica Medica, 90, 53-65.

2023_Poster_TG-116.pdf (icrp.org)

Current draft report sections

1. INTRODUCTION
2. RADIOTHERAPY TREATMENT PLANNING AND DELIVERY
3. IMAGING REQUIREMENTS FROM A CLINICAL PERSPECTIVE
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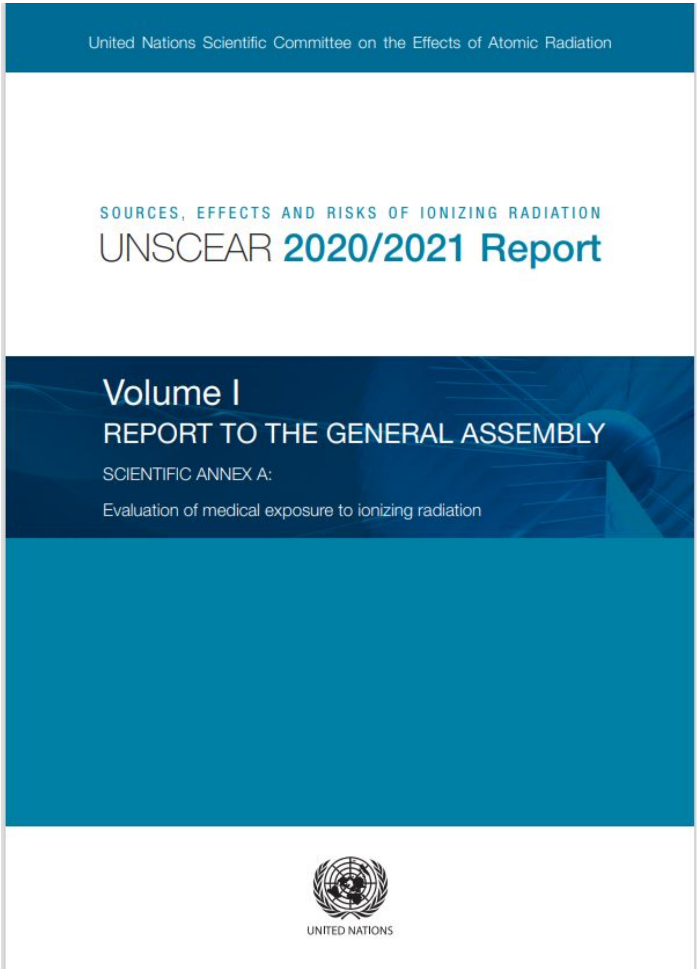
The report should be ready for public consultation S1 2025

Radiation therapy : some figures

- The estimated total **annual number of radiation therapy treatment courses is 6.2 million** (Global estimate of number of radiation therapy treatment courses per annum derived from assessed data (2009–2018)) – UNSCEAR report

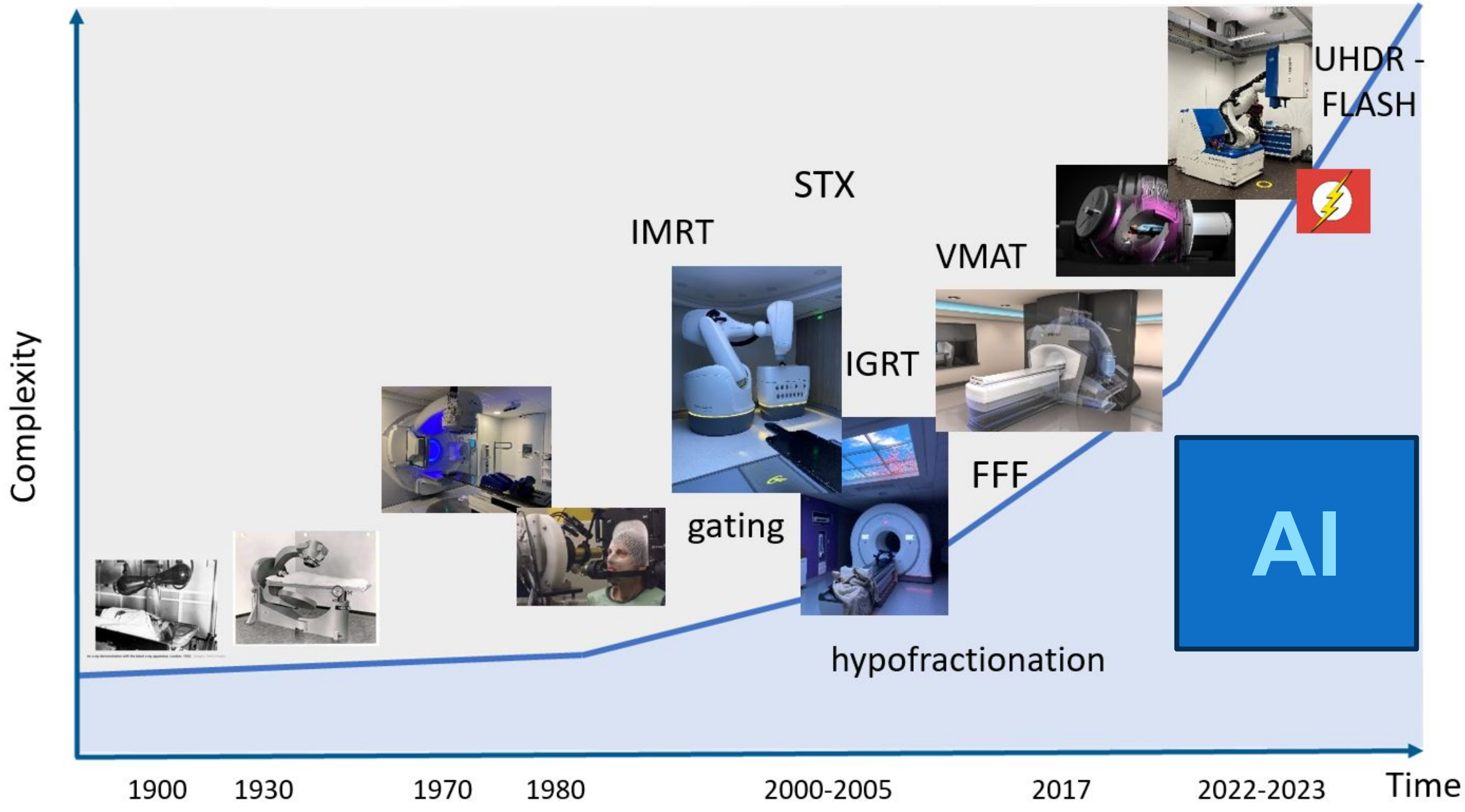
- 5.8 million external beam treatment courses + 0.4 million brachytherapy treatment courses

- by 2025 the number of patients diagnosed with cancer in Europe annually will reach over 4.5 millions, around 50% of whom will need treatment that includes radiation therapy*



**Lievens et al, 2019, Radiation Oncology. Optimal Health for All, Together. ESTRO vision, 2030*

Significant technological developments for the preparation and the delivery of the treatment



IRSN, SER-UEM, 2023

… have resulted in the use of more advanced imaging in radiotherapy.

Radiation oncology is generally safe, with a low rate of adverse events *.

Some "errors" can happen while using imaging **

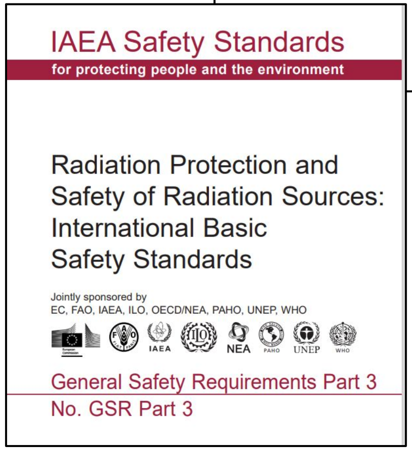
**Arnold et al, Incident review in radiation oncology (2022)*

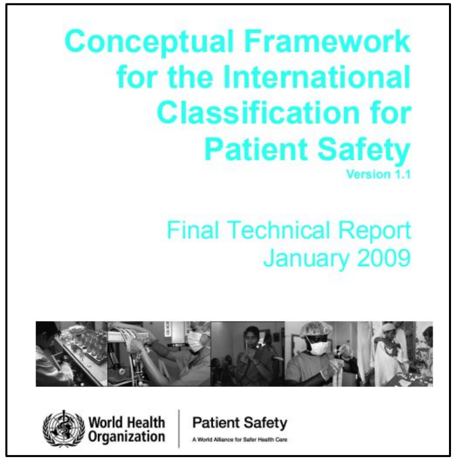
*** Smith et al. / Quality management in radiation therapy: A 15 year review of incident reporting in two integrated cancer centres (2020)*

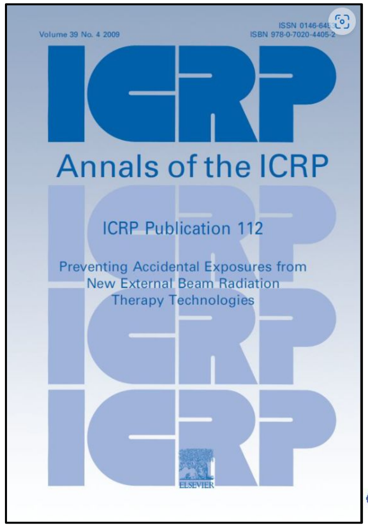
Definitions

Among the various recommendations for risk management and reporting systems, there is **little uniformity in the terminology** used (EC, 2015).

In this presentation, **«errors»** = events that can lead **to unintended and accidental medical exposures** (IAEA and Euratom BSS 2013) + **near misses** (incidents which did not reach the patient) (WHO, 2009).



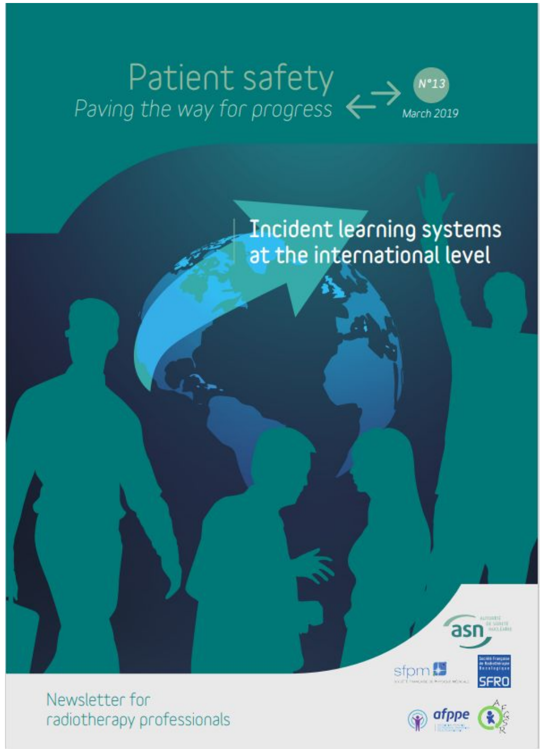




The study of near misses is powerful in identifying work process problems that can lead to an incident (ASTRO, 2019). Focusing on major events with catastrophic consequences and very low probability of occurrence may result in overlooking other types of error that can occur with a higher probability and have lower, but still significant, consequences (ICRP, 2009)

COMMISSION ON RADIOLOGICAL PROTECTION

Learning systems worldwide: examples



https://www.french-nuclear-safety.fr/Media/Files/00-Publications/13-Incident-learning-systems-at-the-international-level

ESTRO
ROSEIS

RO-ILS RADIATION ONCOLOGY® INCIDENT LEARNING SYSTEM
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SAFety in Radiation ONcology
SAFRON

-> See next speaker

FANC

Incident description

PRISMA-RT.be

Sources of case reports

Most examples are extracted from the Radiation Oncology Incident Learning System® (RO-ILS, ASTRO) quarterly reports or from ROSEIS of ESTRO, reports from the French and Belgian periodic newsletters for experience feedback issued by the two nuclear safety authorities (ASN and FANC), ARPANSA reports and SAFRON.

- RO-ILS Education - American Society for Radiation Oncology (ASTRO) - American Society for Radiation Oncology (ASTRO)
- Radiation Oncology Safety Education Information System (estro.org)
- Publications (french-nuclear-safety.fr)
- Notification d'incidents (radiothérapie) | AFCN - Agence fédérale de Contrôle nucléaire (fgov.be)
- https://www.arpansa.gov.au/regulation-and-licensing/safety-security-transport/australian-radiation-incidents-register/annual-summary-reports

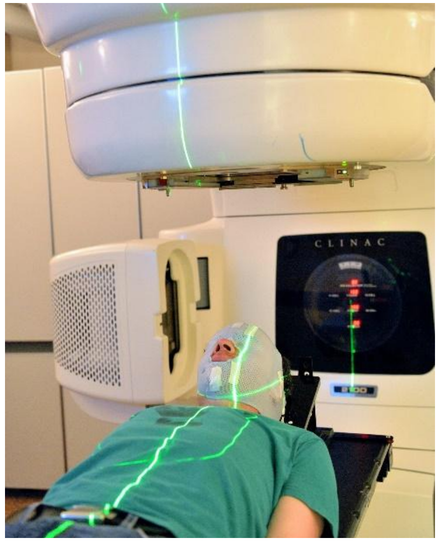
Errors resulting from imaging

… can occur during :

1. the treatment plan preparation

2. the treatment delivery

Philippe Dureuil/Médiathèque IRSN



Laurent Zylberman/Graphix-Images/Médiathèque IRSN

Errors resulting from imaging: 1.plan preparation

- Incorrect target volume delineation
- Wrong set of images
- Errors from processing of image data
- Differences in patient positioning between imaging and treatment

Plan preparation: incorrect target volume delineation

Incorrect delineation of the target can result when there is **doubt about the location** of a lesion to be treated:

- when there is uncertainty about the **side of the body (laterality)**

or

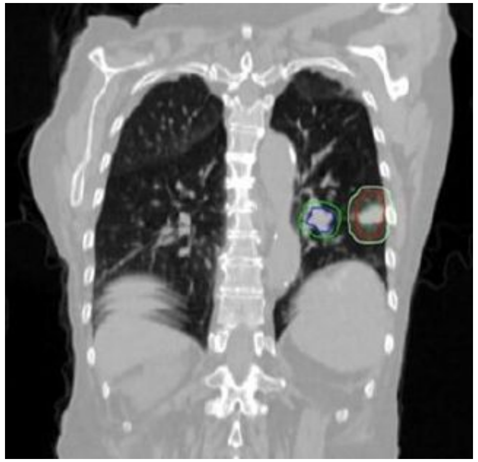
- when **multiple lesions** are present, such as an **additional benign target** or a **target that has been treated previously**.

These types of situations can be exacerbated if:

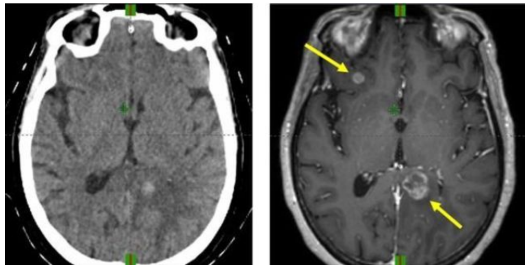
- the **quality of the images** being used is **poor**

or

- multiple image sets are **incorrectly registered** with respect to each other



Images used with permission from Loyola University Medical Center, Maywood, U.S.A.



Plan preparation: incorrect target volume delineation

Case report : Delineation of the wrong side

FANC

REX 1 - YEAR 2023

Incident description

A patient is to be treated with external radiation therapy (DIBH) on the left thoracic wall (with expander) and glandular regions. The treatment scheme prescribed is 15 * 2,670 Gy = 40,05 Gy.

Due to the contouring of the wrong breast by the attending radiation oncologist, an incorrect treatment plan was created and the patient was irradiated for 2 of the planned 15 fractions on the right breast instead of the left.

On the day of the third fraction, the incident was discovered by the RTT whilst checking the scar of the surgery. It was noticed then that the scar was on the left side while according to the treatment plan, the right side should be treated. The patient was removed from the table without administering fraction 3.

The attending physician was informed and the treatment plan was adjusted. The patient was informed of the incident and started the day after with a correct irradiation plan on the left side.

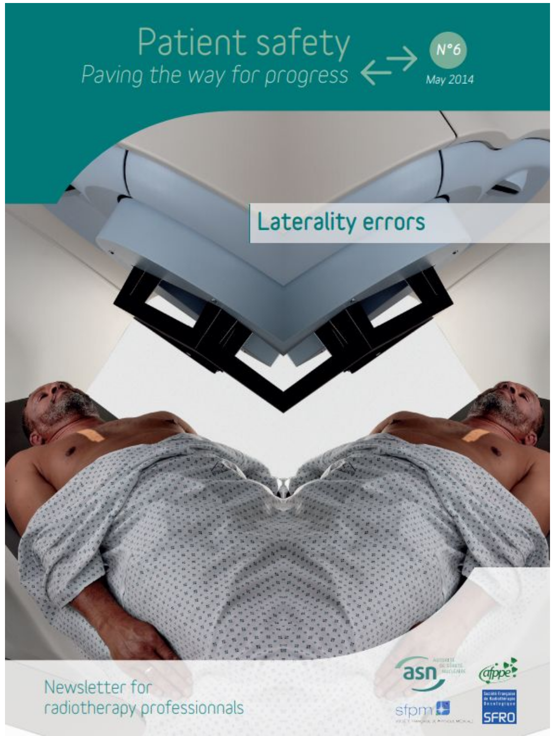
Corrective actions:

A time out procedure has been worked out: in addition to the existing procedure already applied as part of patient identification before each treatment, the RTT must ask the patient some extra data (the injury for which he or she will be treated, the laterality, ...). There will also be a check of the injury (scar control).

https://afcn.fgov.be/fr/system/files/2023-rex-1_0.pdf

Plan preparation: incorrect target volume delineation

Delineation of the wrong side : steps for progress



[Publications (french-nuclear-safety.fr)](french-nuclear-safety.fr)

> Steps for progress

1. Good practices

Prevention measures:

- take all necessary measures so that a radiotherapy cannot begin without first having the patient's complete medical file, including the surgical report, the pathological report and the imaging file,
- ensure, for paired organs, that the information from these different documents is consistent with that supplied by the patient or their family and the multidisciplinary team meeting report,
- inform the patient (and their family) about the treatment to be carried out and get the patient involved in their care.

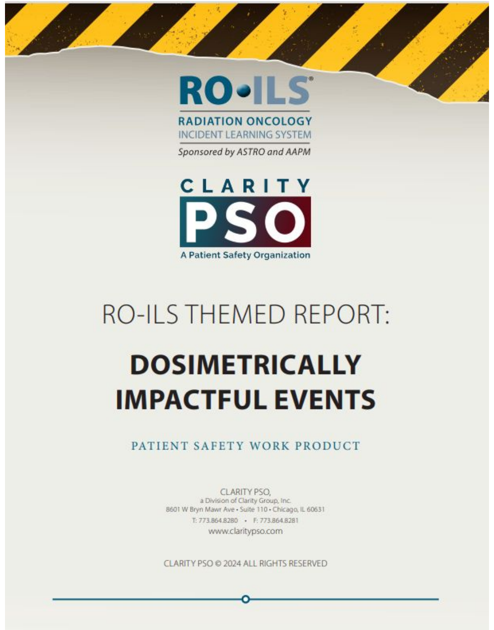
Detection measures (radiation oncologist):

- review the file in detail during the first follow-up appointment (particularly for files identified as at risk – cf. Decoding),
- review the positioning images regularly.

> ! Note: certain recommendations arise from coordination between departments (e.g. with the surgical department to obtain the surgical report sufficiently early).

Plan preparation: incorrect target volume delineation

Case report : Re-Irradiation – Wrong Lesion Retreated (RO.ILS, 2024)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CASE 2: Re-Irradiation – Wrong Lesion Retreated

A patient had multiple brain lesions treated at an outside clinic. When planning the current course of treatment, the radiation oncologist contoured a lesion that was previously irradiated, instead of the intended, new lesion. This resulted in excessive radiation dose to a critical area of the brain.

Prior radiation treatment adds increased complexity to the treatment planning workflow. With the increasing use of radiosurgery (SRS/SBRT) in patients with metastatic cancer to repeatedly treat new metastatic lesions in the same organ (e.g., brain, lung, liver metastases), it is critical to collect all of the prior radiation plans, including Digital Imaging and Communications in Medicine data when available, to delineate the areas of prior radiation. This is important both to make sure the correct lesion is targeted, and to ensure the new treatment course is safe (i.e., accounts for the prior radiation). Prospective peer review and generation of a composite plan could help decrease the error rate in this complex process. Vendor partners can continue to help improve this complex process by further streamlining transfer of calculated dose between planning systems for a more effective composite plan review.

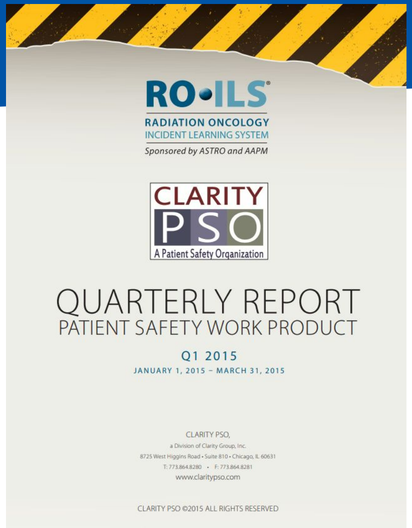
https://www.astro.org/ASTRO/media/ASTRO/Patient%20Care%20and%20Research/PDFs/ROILS_TR_Dosi.pdf

Plan preparation: Wrong set of images

Errors can result from the use of:

- Images from the **wrong patient**
- Images from **previous treatment**

For patients receiving successive treatments, several cases have been reported of patient plans being developed on old CT simulation data sets (for the same patients)



Case report (RO.ILS, 2015)

Problem: Patient plan being developed on an old CT Simulation data set

> "The patient had previously been treated to his T spine in May 2014. We scanned a TPCT then and named it 'ct_1 c t sp.' The two scans were registered to assess the overlap/abutment of his current and previous T spine treatments. We accidentally planned the new plan on the previous scan which we were using currently to establish the vertebral levels."

This case was found at the time of the first treatment because the shifts were clearly incorrect.

Planning scans could be given names that clearly identify the date of the scan and the site being treated. It would also be useful to have planning systems warn that a new plan is being created on an old scan and ask for confirmation

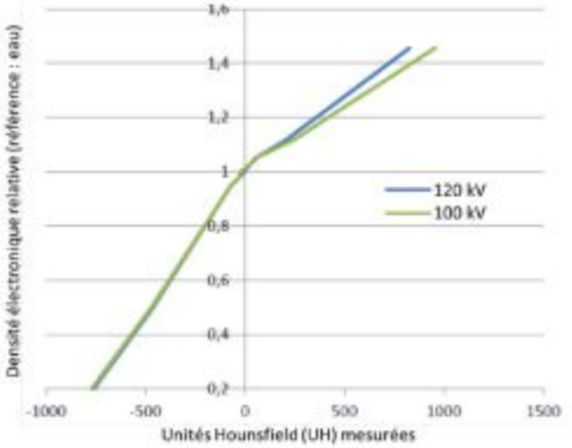
https://www.astro.org/ASTRO/media/ASTRO/Patient%20Care%20and%20Research/PDFs/ROILS-Q1_2015_-Report.pdf

Plan preparation: Errors from processing of image data

Errors can result from :

- **Improper image registration**, for instance due to the use of deformable registration algorithms, and automatic registration
- **Incorrect calibration curve** to establish the relationship between CT numbers and tissue density used for dose calculation

Case report (ASN, 2019)




›Retour d'expérience

Focus sur un événement déclaré à l'ASN

Décembre 2019

Cohérence entre haute tension du scanner de préparation et courbe d'étalonnage du TPS

Une erreur dans les paramètres du scanner lors des examens de préparation a entrainé un écart sur la prise en compte des densités des tissus des patients, avec un impact sur les doses calculées et délivrées.

Un centre partage son analyse et ses pistes pour éviter des discordances entre les paramètres d'étalonnage du scanner de préparation dans le système de planification de traitement (TPS) et les paramètres de réalisation des scanners des patients.

A 4D stereotactic radiotherapy treatment technique was set up for which CT images were acquired with a voltage of 100 kV, whereas a value of 120 kV had been used to establish the calibration curve recorded in the TPS. Dosimetric consequence was <1% on the delivered doses.

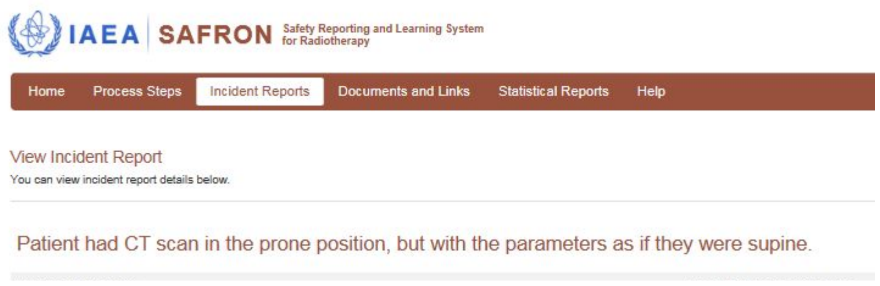
https://www.asn.fr/espace-professionnels/retour-d-experience/fiches-retour-d-experience-radiotherapie/n-6-coherence-entre-haute-tension-du-scanner-de-preparation-et-courbe-d-etalonnage-du-tps

Plan preparation: Differences in patient positioning between imaging and treatment

Errors can result from :

- **differences in patient orientation** for imaging with different modalities and at **different stages** of preparation and treatment
- **issue in motion management**

Case report (SAFRON, courtesy J. Vassileva)



Patient had CT scan in the prone position, but the parameters as if they were supine.

What safety barrier identified the incident? Image-based position verification.

<u>Near miss</u>
Was any part of the treatment delivered incorrectly? NO

Errors resulting from imaging: 2. during treatment

In a recent paper, Crouch et al* (Australia) identified « verification imaging » as the 2nd source (about 20%) of incident reports in their ILS (Learning In Radiation ONcology (LIRON))

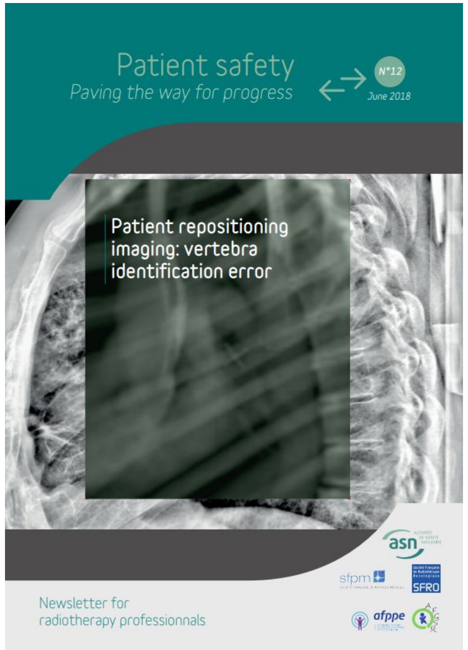
Review of the litterature :

- Incorrect vertebral body localisation
- Differences in motion management techniques

**Crouch K, et al. 2024. Learning in radiation oncology: 12-month experience with a new incident learning system. J Med Radiat Sci.*

During treatment: Incorrect vertebral body localisation

Case report 1 (ASN, France, 2018) "one of the main causes of significant events in radiotherapy"

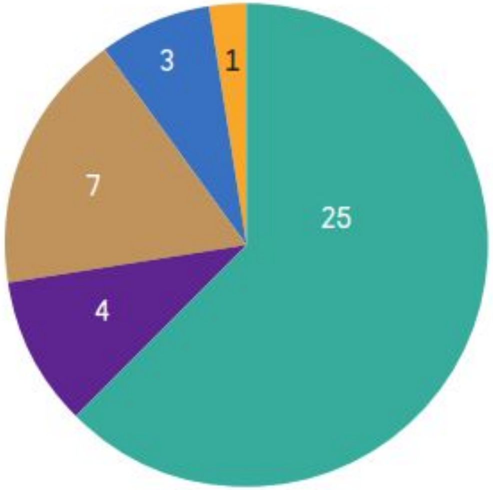


https://www.french-nuclear-safety.fr/Media/Files/00-Publications/Patient-safety-12.-Patient-repositioning-imaging-vertebra-identification-error

Between January 2015 and January 2018, 40 significant radiation exposure events associated with vertebra identification errors on repositioning images were reported to ASN.

Events reported according to image acquisition method:

- 2D kV on-board imaging: 25
- 2D kV imaging in room associated with the accelerator (peripheral system): 4
- 2D MV imaging (portal imaging): 7
- 3D kV CBCT imaging: 3
- 3D MVCT imaging: 1



Contributory factors identified by the centres

- Associated with practices and training:
  - Excessive collimation of the control image with an image field of view that is too small to formally identify the discriminating bony landmarks, with no possibility of counting the vertebrae;
  - Longitudinal matching using the vertebral bodies, which are non-discriminating landmarks;
  - Confidence in the system for automatic registration of the 3D images acquired at the treatment work station;
  - The registration tools are not all mastered and used by all the personnel.
- Associated with the equipment:
  - Poor quality of the portal images;
  - Difference in quality between the digitally reconstructed radiographs (DRR) and the repositioning images at the treatment work station;
  - For lung locations, the quality of the kV/kV images, which do not provide satisfactory contrast and landmarks.
- Associated with the patient:
  - Patient suffering pain, difficult to reposition, necessitating rapid validation of the images to minimise the time spent on the table;
  - Patient with severe scoliosis, difficult to reposition;
  - Patient overweight (patient landmarks unreliable).

During treatment: Incorrect vertebral body localisation

https://www.arpansa.gov.au/sites/default/files/arir_-_annual_summary_report_2020.pdf

Case report 2 (ARPANSA, Australia, 2020)

Example case: Incorrect treatment site (spine)
Treatment prescribed is 20 Gy in 5 fractions to T10-T12. Fraction 2 was matched incorrectly due to poor image quality and treatment delivered to T9- T11 for that fraction only. Incident was discovered on weekly chart check.
(Unintended dose to T9, 4 Gy)

"Misalignment or targeting the wrong site can occur for a variety of reasons.
Mismatching using the spine was a factor in more than half (7) of these types of incidents."

During treatment: Incorrect vertebral body localisation

Case report 3 (FANC, Belgium, 2024)

FANC REX 7 - YEAR 2024

Incident description

A patient is to be irradiated with VMAT for antalgic purposes at two localisations, more specifically on the dorsal vertebrae D11-D12 and on the os ileum. The prescribed dose is 20 Gy in 5 fractions for both localisations. The patient is set up routinely with body-surface scanning and daily CBCT to check the treatment position. The CBCT is taken by 2 RTTs and images are matched online. If necessary, the patient's position is corrected before irradiation starts. After the first session, a task is automatically generated for the radiation oncologist to review the matching result offline and approve the matching or give advice for the next fractions.

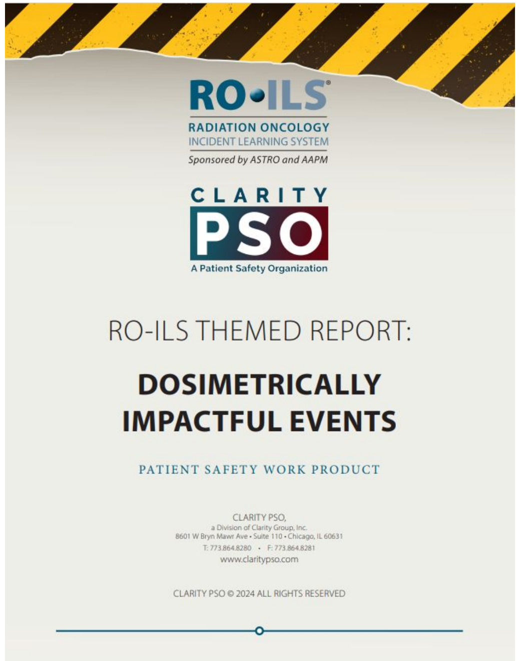
At the start of treatment, the online matching procedure is performed by a student together with a RTT. The student is quite confident about the online matching, but the RTT doubts and wants to seek advice from the second RTT working at the treatment unit. As this RTT is very busy with urgent administrative tasks, the advice is finally not sought. No doctor is called in either. The shift of 3.88 cm in the longitudinal direction, -0.31 cm in the vertical direction and -0.42 cm in the lateral direction is performed and treatment is started.

Considering this was the first radiation session, the CBCT is reviewed offline by the doctor. It is noted that vertebrae D12-L1 were treated instead of D11-D12, leaving vertebra D11 almost completely out of the irradiation field.

https://afcn.fgov.be/fr/system/files/2024-09-09-REX-7.pdf

During treatment: Incorrect vertebral body localisation

Case report 4 (RO.ILS, USA, 2024)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https://www.astro.org/ASTRO/media/ASTRO/Patient%20Care%20and%20Research/PDFs/ROILS_TR_Dosi.pdf

CASE 5: Patient Aligned to Incorrect Anatomical Landmarks

The patient came in for treatment to an abdominal target but was not aligned to the correct anatomical landmarks during setup imaging with kV orthogonal views. The therapists reviewed the images and were confident that the portal image matched the digitally reconstructed radiograph and that they were targeting the correct thoracic region. However, the treatment was administered with a 3.1 cm superior and 0.5 cm posterior deviation from the target position. A treatment plan was re-created with one out of five fractions delivered at the misaligned location for evaluation. The patient's liver and bowel received a higher dose than planned. In addition, about 3 cm of the inferior portion of the planning target volume (PTV) was outside the field for the misaligned fraction, significantly affecting gross tumor volume and PTV coverage at the prescribed dose.

Radiation therapists face several challenges when aligning patients using the T-spine. Unlike other treatment sites on the body, the T-spine lacks distinct external landmarks that can be easily visualized and aligned to. This makes it more challenging to position patients correctly. Incorrect **vertebral body alignment issues were shared in previous RO-ILS education as single events (2015 Report Case 1) and as a featured theme (2018 Report).**

During treatment: motion management

Case report

FANC

REX 2 - YEAR 2022

Incident description

A patient is treated with external radiotherapy (12 * 2 Gy = 24 Gy) for gastric lymphoma. Given the significant mobility of the stomach due to respiratory movement, it was decided to simulate and treat the patient using the Breath Hold (BH) inspiration technique. This technique has been in use at the radiation department for several years.

A CBCT was carried out with the patient holding their breath (BH) at one fraction, but the 2nd fraction was performed while the patient was able to breathe freely

https://afcn.fgov.be/fr/system/files/2022-rex-2.pdf

Errors resulting from imaging can occur :

- **during the treatment plan preparation**: incorrect target volume delineation, differences in patient positioning during the preparatory scan and the treatment, use of the wrong sets of CT images, use of improper DRR, incorrect CT calibration curve, confusion between old and new targets, …

And

- **during the treatment delivery:** incorrect vertebral body localization, wrong matching protocol, incorrect alignment of the CBCT images, motion management…

Safety gaps still present within the patient alignment process

Luximon et al, 2024, performed a **retrospective analysis of 17610 registrations** between planning scans and pretreatment CBCT scans (2414 patients) throught an AI based image review algorithm

They highlighted the **reliability and safety of IGRT**, with an absolute gross patient misalignment error rate of 0.04% per delivered fraction.

They stressed that the **incidents that occured expose safety gaps still present within the patient alignment process**

Luximon DC, et al, 2024. Results of an Artificial Intelligence-Based Image Review System to Detect Patient Misalignment Errors in a Multi-institutional Database of Cone Beam Computed Tomography-Guided Radiation Therapy. IJROB

Key messages (1/2)

- Incidents and errors are an important opportunity to learn and improve processes. This also applies to imaging in radiotherapy.

- All necessary measures should be taken so that a treatment cannot proceed until the **patient's complete medical file is available to confirm the consistency of information from different documents**. This is particularly important for bilateral organs and when several lesions are visible on images.
- The patient should be **positioned in a similar orientation** (prone/supine or feet first/head first) for the preparatory scans, the planning and the treatment, **whenever possible** in order to reduce the risk of tumour localisation errors.
- **Procedures** should be developed for importing images into the TPS to **lower the risk of using the wrong set of CT images**. These may include setting up planning systems to recognise CT image information relating to patient IDs and use of names for planning scans that include the date and site to be treated.

Key messages (2/2)

- The **same unique identifying fields** (e.g. name, age, unique ID) should be used across all systems that acquire, store and handle patient image information, if at all possible.
- A systematic approach should be adopted to reduce the risk of incorrect vertebral body localisation by **matching at multiple anatomic points**. This can be facilitated by increasing the length of the FOV. **Maximum tolerances should be set on the shifts** allowed between set-up and treatment.
- A complete reliance on automatic contouring and identification of fiducials should be avoided at present by **including human confirmation checks** to reduce the risk of incorrect target identification. This is **particularly important in the context of re-treatment**.
- **Multi-disciplinary team meetings** and peer review of procedures and **check lists** are effective measures for reducing errors.

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Current Consultations

ICRP routinely solicits comments on most draft documents prior to publication, with the exception of those that are basically compilations of computed values such as specific absorbed fraction values or dose conversion factors.

The first public consultation launched by ICRP took place in the late 1980's, concerning what became Publication 60, the 1990 Recommendations of ICRP. From 1999 and the early 2000's, when the internet provided a technically feasible method, public consultations became a regular feature. Today, public consultation for all ICRP reports published in Annals of the ICRP is a required part of the process.

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Thank you !