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Patient repositioning imaging: vertebra identification error

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AFQSR

> Editorial

In its "Experience feedback" report of May 2014, the multidisciplinary radiotherapy working group alerted the professionals to the risks of misidentification of the vertebral landmarks on a kilovoltage (kV) image. Five patient positioning errors had been reported in 8 months.

Despite this alert, 40 events relating to vertebra identification errors have been reported to ASN in 3 years (2015-2016-2017). At present this is one of the main causes of significant events in radiotherapy. This is what has prompted us to examine the subject of patient repositioning imaging in greater depth in this issue.

At the centre of the editorial committee's recommendations is the need for each centre to define a comprehensive image acquisition strategy to guarantee correct localisation of the vertebrae, from preparation through to image validation. The University Hospital of Amiens and the cancer center Léon Bérard in Lyon emphasise in their respective testimonials: the correct usage of imaging concerns all radiotherapy professionals, and their training in the acquisition/utilisation of these images is a key factor contributing to treatment safety.

We wish you enjoyable reading.

The Editorial Team

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>Key figures

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
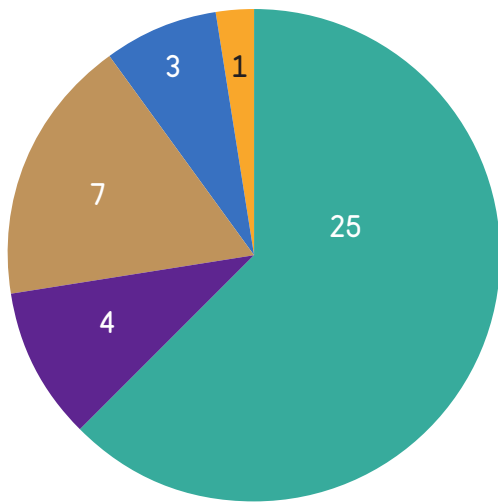
>Decoding

1. Description of the events reported to ASN

Location of target volume:
- The majority of the events concern treatments targeting vertebral (17), pulmonary or thoracic (10), and oesophageal (5) locations.
- The reported events also concern treatments of the mediastinal and retroperitoneal regions, the pancreas, the stomach and the liver.

Who detected the error?
- Radiographer: 22
- Radiation oncologist: 16
- Medical physicist: 2

The radiation oncologist often detected the error when examining the images (at the end of the day or the day after the treatment session concerned).

Number of treatment sessions concerned:
- 23 events concerned 1 session
- 16 events concerned between 2 and 10 sessions
- 1 event concerned more than 10 sessions

Classification on the ASN-SFRO scale:
- All these events led to the delivery of at least one treatment session with a head-foot offset of several centimetres.
- 39 of the 40 events were rated level 1 on the ASN-SFRO scale.
- One event concerning a highly hypofractionated treatment of the lungs was rated level 2.

2. Contributory causes and factors identified by the centres

The main cause identified by the centres lies in the difficulty in differentiating the vertebrae (lumbar and thoracic) from one another.

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).

> Steps for progress

Good practices - Recommendations

Reflect upon a complete strategy to guarantee correct localisation of the vertebrae, from preparation through to image validation

Draw up a detailed procedure for the vertebral and thoracic locations, specifying:
• For the preparation part:
- on the scanner: the rules governing the choice of acquisition range, according to the location of the volume to treat, in order subsequently to have on the DRRs the discriminating landmarks that have been adopted by the department.
- in dosimetry: the desired typical images, the filters to use, the discriminating landmarks to consider, calculation of the imager coordinates that will enable the discriminating landmarks to be seen should the imager be offset from the isocentre.
• For the treatment part: the filter to use, the actions to take and compromises to make according to the registration results, etc.

Adopt the same given procedure independently of the type of treatment (standard, IMRT/VMAT) and the planning software used, and if possible independently of the type of planar imaging (MV or kV).
It is often necessary to have another procedure for the MVCT/CBCT images.

Use the lowest reasonably possible* thresholds for the R&V system tolerance tables. These thresholds will have to be adapted:
- to the treated location,
- to the clinical conditions of the patient,
- to the practices of the department (for example, coupled with immobilisers indexed on the treatment table),
- to the IGRT techniques (daily or weekly image acquisition).

Improving the quality of digitally reconstructed radiographs (DRR)

1. Conduct a reflection on the scanner slice thickness, the need to inject a contrast agent and the elements to contour (trachea, carina, etc..), according to the location.
2. Define models for the creation of a DRR by predefining parameter settings when this is technically possible. It is nevertheless recommended to pay attention to the filters proposed by the software programs: good image quality alone does not guarantee safety. One must avoid having excessive differences between the DRR and the image acquired at the treatment work station (example: pulmonary contrast for one and bony contrast for the other).

Focus attention on the discriminating landmarks

For all spinal and thoracic locations, carry out the contouring of significant discriminating elements which, combined with the use of a DRR/imaging moving window tool at the treatment work station to analyse the image, will guarantee correct positioning of the patient in the head-feet direction. Be careful to remain cautious with regard to the use of the vertebrae and ribs because they are not necessarily discriminating elements.

Example of discriminating elements
- Vertebral edges with a singular shape
- For the upper thoracic locations, the external thoracic cage drawn by hand on the DRRs by the radiographers (in the zone corresponding to the image that will be acquired at the treatment work station).

- For the lower thoracic locations, the iliac crests drawn by hand on the DRRs by the radiographers.

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* Compromise to be found to maximise the safeguard provided by the table tolerances

Improving the repositioning images

Open the X-ray collimation or offset the imager in order to obtain a wider field of view on the image so that the chosen discriminating landmarks are displayed.

The production of an MV image at J0 in addition to the kV images can be useful. This image will have a pulmonary contrast, unlike the kV images which have a bony contrast. The pulmonary contrast will enable the radiographers to locate the carina.

Just before starting the treatment, work on the registered images in dynamic mode

Zoom out the images and rapidly scan the cursor between the DRR and the image acquired at the treatment work station for an overall verification of the position. Poor registration will result in a "jerky" image (no continuity) and will alert the radiographers.

Improving proficiency in the use of the tools

- Consider organising training courses/practical workshops for the medical physicists, radiographers and radiation oncologists to practise using the registration tools available at the treatment work station.
- Set up two-person teams with one experienced person in each team,
- Regularly assess the practices.

Adapting the treatment strategy

Reflect upon the treatment technique that is appropriate for the condition of the patient, in the case of a patient suffering significant pain, for example.
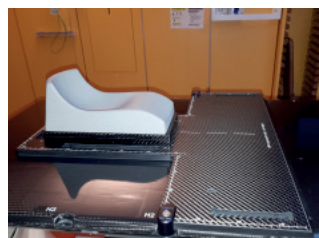Adapt the complexity of the treatment plan.
It is preferable to cancel or postpone a treatment session if the patient is not in a fit state to receive it.

>The experience of the radiotherapy centres

- Léon Berard Cancer Centre in Lyon (Rhône département)
- Amiens University Hospital (Somme département)

Events: patient positioning errors associated with incorrect identification of vertebrae in 2016.

You have defined an image acquisition strategy. What are its underlying principles?

Amiens University Hospital
Further to several incidents concerning patient repositioning resulting from incorrect identification of vertebrae, a multidisciplinary internal IGRT (image-guided radiotherapy) group was created in 2016.

This permanent group, comprising an expert physician, the operational quality manager, two radiographers and a medical physicist, establishes, assesses and adapts the image acquisition procedures for each treatment site (2D kV and /or CBCT).
The group checks the training of the radiographers and the professional practice assessments (PPA).
The Amiens University Hospital has progressed from a reference system based on the acquisition of one image per week to daily imaging for the large majority of its patients, with the exception of breast treatments. This increases the chances of detecting an error.

Léon Bérard Centre
All the image acquisitions (2D or CBCT) have been the subject of a protocol that depends on the irradiation techniques and/or the treatment locations.
Rules have been formalised for arbitrating between 2D and 3D based on technical criteria:
- *3D: acquisition of daily or weekly CBCT images according to criteria such as the significance of the dose to deliver or risk (re-irradiations with risk of overlapping, difficulty in repositioning).*
With children, acquisition is carried out at a reduced angle to decrease the acquisition time and the irradiation dose while maintaining satisfactory image quality.
- *Faster image acquisition in 2D (MV), depending on the indications, for the irradiation of metastatic vertebrae or the treatment of patients suffering pain.*

These arbitration rules can be relaxed, to solve a problem of poor image quality, for example. However, it is mandatory for such a decision to be approved by the technical platform physician before the patient is treated.

What technical solutions have you found to improve image registration?

Amiens University Hospital

The thoracic region is the most complex location for radiographers: *nothing looks more like a rib than a neighbouring rib, and the same goes for the vertebrae. It is difficult to not make a mistake!*

For the vertebrae, we have opted for **the systematic use of a mask holder that is always indexed to the same point on the treatment table** *(photo)*.

For pulmonary tumours, we use an inclined plane which is always indexed to the same place, except in certain particular cases. This limits the situations where radiographers override table positioning value warnings in the head-feet direction and makes such actions more the exception.

In addition, we materialise the patients' anatomical particularities (osteophytes for example) on the DRRs. When there are no anatomical particularities, the kV imager is offset to include reliable anatomic landmarks in the image, such as the first or last rib (front view) and the sternal angle or the xiphoid (side view).

Léon Bérard Centre

To ensure correct fusion of the dosimetry CT images and the CBCT images, we proceed in 3 steps:

1. *Automatic registration using a zone that is sufficiently large to contain discriminating bony landmarks;*
2. *Verification on the zoomed-out image of automatic fusion in green/purple mode by the radiographers;*
3. *Verification of fusion with the grey levels on a zoomed-in image centred on the volume to treat (checkerboard aid for example).*

This fusion is validated by cross-checking by two radiographers. They are regularly reminded that *the automatic registration system can make mistakes*, particularly with the registration of vertebrae, and *one must always maintain a critical attitude.*

What training measures have you organised?

Amiens University Hospital

As of 2016, the Amiens University Hospital has organised practical workshops which include the reading of images and registrations led by the IGRT group team. The radiographers have fully embraced this initiative, and today they are the first to ask for it. These workshops are being held again in 2018, enabling the new radiographers to take part.

Léon Bérard Centre

Several IGRT courses with different working groups (head and neck, thorax and pelvis), have provided the radiographers and radiation oncologists with initial - and now refresher - training in the various rules associated with the acquisition of repositioning images. Each newcomer has dedicated time with the working group experts and can have access to all the corresponding protocols.

Since 2015 the center has put in place on-line course material on the themes of 2D and 3D matching. These modules were developed in-house by the department's expert radiographers, on the university teaching platform of the Lyon1 University.

This module is used as a complement to face-to-face training, on the initiative of each radiographer and at the request of the manager, in the event of a change of treatment work station for example. It includes reminders of the procedures, videos and quizzes for assessing what has been learned.

What message would you like to pass on to our readers?

Amiens University Hospital

The acquisition, quality and utilisation of images concern all radiotherapy professionals, not just radiographers. *Every radiotherapy department should have a multidisciplinary IGRT group*, given the development of practices and the increase in the number of images acquired.

Léon Bérard Centre

Training and maintaining the knowledge of all the actors (radiographers, physicians, medical physicists and dosimetrists) through various tools (face-to-face training, in groups, individually, etc.) is vital to guarantee treatment safety.

Experts in each treatment technique must be identified in each discipline.

If there is any doubt about the identification of the vertebra to treat, it is preferable to postpone the session.

Léon Bérard Cancer Center (from left to right)
- Séverine RACADOT, *radiation oncologist*
- Magali SANDT, *medical physicist*
- Emilie CARTAL, *radiographer*
- Peggy DUBS, *radiotherapy quality and risk management coordinator*

Amiens University Hospital
- Doctor Alexandre Coutte, *head of the radiotherapy department (picture)*
- Aldo Fanelli, health manager, *operational quality manager*

> Further reading

"Experience Feedback" Sheet No. 1 – Avoid a positioning error in kV-kV imaging
May 2014
https://www.asn.fr/Professionnels/Activites-medicales/Radio-therapie/Fiches-Retour-d-experience/N-1-Eviter-une-erreur-de-positionnement-lors-d-une-imagerie-kV-kV

Radiation safety oversight and experience feedback

Unintended overexposure of a patient during radiotherapy treatment at the Edinburgh Cancer Centre, in
September 2015
http://www.gov.scot/Publications/2016/07/8854

Safer radiotherapy: summary of error data analysis
January 2018, issue 24

Safer radiotherapy: summary of error data analysis
September 2017, issue 23

Safer radiotherapy: supplementary error data analysis
April to July 2017, issue 23
https://www.gov.uk/government/publications/safer-radiothe-rapy-error-data-analysis-report

SAFRON newsletter
December 2017
https://www.iaea.org/sites/default/files/18/01/17-12-safron-update.pdf

Prospective risk analysis

The report of Task Group 100 of the AAPM: Application of risk analysis methods to radiation therapy quality management
Medical physics Volume 43, Issue 7, July 2016

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https://www.asn.fr/Professionnels/Activites-medicales/Ra-diotherapie/Bulletin-La-securite-du-patient

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http://www.french-nuclear-safety.fr/Information/Publica-tions/Publications-for-the-professionals

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