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### Dose Monitoring Software: New Tools For Radiology Quality Management

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#### Introduction

In the last decades there has been a significant increase in the number of radiological examinations, resulting in an increase of radiation dose per capita (Schauer and Linton 2009; Frush 2009; Hall and Brenner 2008; Smith- Bindman et al. 2012). The largest part of this growth comes from computed tomography (CT) scans, as this modality underwent important technological developments, and can now give physicians very precise diagnostic information in a very short time (Brenner and Hall 2007; Furlow 2010). This means that nowadays we can save more lives than in the past: we surely have to consider that radiologic examinations are vital for modern medicine. On the other hand, this powerful tool is sometimes used in an inappropriate way, as some of the radiologic procedures are not sufficiently optimised. It is widely known that ionising radiations are a class 1 carcinogenic agent: some recent epidemiological studies showed an increased incidence of cancer in patients who underwent CT scans (Mathews et al. 2013). For this reason, it is important to reduce the radiation dose given to patients in every examination without impairing its diagnostic quality, according to the ALARA (as low as reasonably achievable) principle.

## **The Importance of Dose Monitoring**

Constant and systematic monitoring of radiation dose is indispensable in order to increase the quality of radiological services to patients. This activity can lead to performance control, protocol optimisation and rapid correction of wrong practices. Furthermore, dose monitoring can increase risk awareness among hospital staff members, which is considered by experts one of the best way to improve their dosimetric behaviours (Goske et al. 2012).

Unfortunately, dose monitoring has not been a simple activity until now: first of all, less recent radiological equipment may not measure the amount of delivered dose for each procedure. Secondly, dose reports are often exported to the Picture Archiving and Communication System (PACS) as screen-captured images, so that it is not possible to use these data in an aggregated way, nor simply copy and paste them in worksheets.

Up to now, radiologists, radiographers and medical physicists have obtained dosimetry statistics by long manual work: that has been discouraging them, resulting in a lack of systematic dosimetric control. Moreover, even those who had the possibility and the will to monitor doses had to accept that their statistics were based on small amounts of data, not on the whole database.

## **Legal Changes in the EU**

Lawmakers are interested in monitoring and reducing radiation doses, as shown by the newly published 2013 / 59 / Euratom Directive that contains more stringent radiation protection rules, especially concerning patients' protection (Council Directive (EC) 2013/59/EURATOM). In particular, the European Directive requires that patients are informed about the risk associated with ionising radiation, and that detailed information about radiation dose is included in every procedure's report. EU Member States must transpose the requirements of this Directive in their national laws by 2018.

## **How Technology Can Help**

In the last few years, things have changed in a very positive way: new software tools that can automatically retrieve, store and analyse dosimetric data are now available. These IT resources can be installed on hospital networks, and are in most cases web-based, ensuring easy access to all authorised users.

These software tools recover dosimetric data in two ways: either by communicating directly with the radiological modalities or by retrieving dose information from the PACS, which receives dose reports from the modalities. The second type of communication may be easier to manage, as it does not require the collaboration of device vendors during the set-up phase: in any case, to make statistics reliable it is important that every single device has the ability to measure dose correctly.

## **Dose Monitoring Software for the Radiologic Team Day-to-Day**

Automatic dose monitoring systems can be helpful during all the phases of radiologic procedures.

Before the examination starts, radiologists may include in their appropriateness assessment the dosimetric history of the patients, especially those who need to repeatedly undergo radiologic examinations.

To optimise examinations, radiographers can use another tool of dose monitoring systems, which consists of the visualisation of the technical parameters of the previously performed procedures. This tool allows the radiologic team to decide the appropriate dose for a specific diagnostic task.

In addition, a meticulously monitored CT protocols database can assist the activity of the radiologic team. In fact, it is regrettably common that optimised parameters are modified with no clinical reason. These modifications may cause unjustified increases in patient dose, until someone notices them. A unified protocol database would allow optimal control, as this instrument can issue an alert every time a protocol modification is made.

## **Dose Monitoring Systems as a Quality Management Tool**

Dose monitoring systems allow realtime and multi-parametric performance evaluations. In this way, at the end of the examination, the procedure dose can be compared with the doses delivered by other procedures with the same study description or concerning the same anatomical area. This tool allows rapid detection of outliers, resulting in their fast correction by prompting the change of the wrong acquisition parameters. Appropriate alerts can be automatically produced, so that improvement strategies can be quickly decided. In addition best practices can be found that can be used for staff training and protocol optimisation.

Some of these systems can calculate dose descriptors based on the specific body size of patients, such as Size Specific Dose Estimate (SSDE) for CT scans, which takes into consideration the difference between the real patient size and the standard size of the reference phantom. These descriptors allow better analysis, as dose changes significantly depending on the patient's size. At the same time it is possible to automatically evaluate CT off-centring, which is the gap between the patient's actual position and the CT gantry isocentre; this is crucial, as a patient's positioning mistake of only a few centimetres can increase the dose by up to 40% when automatic exposure control (AEC) is active. Moreover, dose monitoring systems may allow many retrospective analyses: for instance, to evaluate the Diagnostic Reference Levels (DRL) compliance and to analyse the variations of average doses for a single study description, in order to verify that they are solely due to clinical reasons and not to the operators performing the procedure, the day of the week or the hour of the day. Detailed graphs can be automatically produced, showing dose trends and distribution with any desired degree of detail.

### **The Experience of Pisa University Hospital**

We established a multidisciplinary dose team at our hospital, and recently started to evaluate some commercially available dose management systems. The first dataset that we analysed concerned paediatric procedures and CT colonography. It is commonly known that children are more sensitive to radiation damage than adults: because of that, it is important to pay particular attention when performing radiological examinations on them. In particular, it is crucial to tailor the particular anatomical and physiological characteristics, following the recommendations that are available in the literature and that are strongly recommended by international awareness campaigns (Image GentlyR [http:// imagegently.org](http://imagegently.org), EuroSafe <http://www.eurosafeimaging.org>). Thanks to dose monitoring software, our dose team recovered and analysed retrospectively more than 12,000 procedures, 9% of which were CT scans. The original purpose of this work was to reduce average doses. Our analysis showed relevant dosimetric differences between examinations performed on similarly-sized patients and auditing, training and protocol optimisation were used to ensure a better homogeneity of dosimetric values. The improvements could be confirmed by the real-time analysis made possible by dose monitoring systems.

CT colonography or virtual colonoscopy is a low dose CT procedure that can be used as a screening test for colon cancer. Our PACS database contains over 1700 such examinations. As two different scanners were employed for virtual colonoscopy, the dose team analysed data in order to compare their performances. This analysis showed a general compliance with the predefined protocols, but spotted a protocol error that prevented full exploitation of the iterative reconstruction software available on one of the two scanners to reduce the dose. After protocol optimisation, dose values significantly decreased.

### **Conclusion**

Dose monitoring software represents an essential part of radiologic quality management by allowing the systematic control of dose performances, by contributing to the reduction of wrong practices, and by supporting protocol optimisation.

However, a multidisciplinary dose team is at least as important as any dose monitoring software since only expert users (radiologists, medical physicists, radiographers) are able to ascertain which are the dose variations seen in our practices that are clinically justified and to help reduce those variations which are not.

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