Radiation dose monitoring software: a Dutch University Hospital's five year experience

The Maastricht University Medical Center (MUMC+) is renowned for its high level of patient care and has a reputation for being equipped with the most up-to-date technology. Since July 2013, the Department of Radiology and Nuclear Medicine at MUMC+ has been using a Radimetrics software system for radiation dose management of their CT scanners. Based on this experience, the department is currently in the process of extending the use of the dose management system to all other x-ray modalities and also to nuclear medicine imaging.

We wanted to find out more about the MUMC+ in general and their experience with the Radimetrics system in particular, so we talked to Dr. Cécile Jeukens, Medical Physicist in the Department of Radiology and Nuclear Medicine.

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Q *Let's start with a bit of background information on MUMC+*

As you said in your introduction as an academic center we have a high reputation based on our recognized expertise, which means that patients are referred to us from the whole southern region of The Netherlands as far as the city of Eindhoven (Maastricht is located in the south east part of the Netherlands). For some specialities we even receive patients from other parts of the country. In addition we occasionally receive patients from the neighboring parts of Germany and Belgium. There are 700 beds in our hospital and we care for more than 26000 in-patients annually and also carry out a total of approximately 21 000 individual treatments on an out-patient basis, including multiple treatments on the same patient. We also provide radiological support for primary care/GPs in the immediate surrounding areas of Maastricht/Heuvelland

Q *Now, what about the radiology and nuclear medicine department?*

As you might expect of a University hospital, we have the whole gamut of imaging modalities, including CT-scanners, MRI scanners, Interventional Angiosuites, Radiography units, Mammography Units, Mobile radiography systems, Mobile C-arms, PET-CT, SPECT-CT, PET-MRI, DXA.

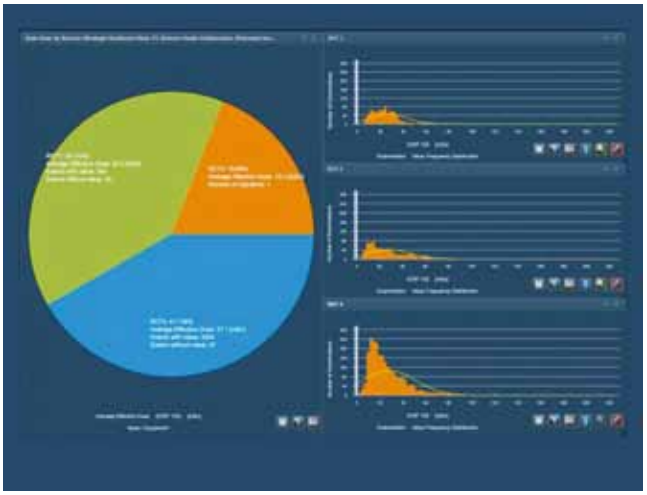
For reasons of operational efficiency all the machines in any one modality are sourced from the same vendor but over all the modalities, all the major vendors are represented: Philips, Siemens, GE, Canon, Hologic, Shimadzu, Ziehm and Oldelft, which is an old Dutch company, now a part of Canon.

Q *Let's turn to the Radimetrics system. Since when have you had the system?*

The system was installed in July 2013 when we hooked up all three of our CT-scanners to it. Back then, and even more so still now, our department already had a commitment to research and development on CT and contrast agent injection protocols, so the acquisition of the dose management system fitted well with our overall R & D strategy. Since 2013 we have built up a significant experience in the field. During this period we have enjoyed a close collaboration with Bayer Healthcare, who developed the Radimetrics system, as well as with Siemens Healthineers.

The patient scorecard enables a review of the patient history with cumulative dose exposure across modalities.

As for the actual installation of the software itself, that went very smoothly, although we did find that one of the scanners was not transmitting the dose data correctly. Once discovered, this problem was quickly resolved. Another issue that we did encounter early on when using the system was that our three CT-scanners had to have different names for what were actually the same or very similar protocols. Also within one scanner, protocol names had slight changes. Even minor changes such as changing a lower-case letter into an upper-case letter or the insertion of a space in the protocol name meant that for the Radimetrics system these were totally different protocols, so we ended up with many individual protocols.
In addition, the Radimetrics system showed us that there were several protocols that had only been used a very few times, and so were basically obsolete.
The result of all these points was that we put a lot of effort into the very useful exercise of tidying up all our protocol names as well as adjusting and making the technical settings of the protocols more uniform.



The system provides several reporting tools which enable data drill down, visualizing and target dose by facilities, equipment and protocols

The system in routine practice
The way we chose to use the system in practice means that only a limited number of radiographers are actively involved in the direct use of the Radimetrics system. Thus, we arrange that one of our radiographers spends four hours each week on 'Radimetrics'. During this period she will typically review the studies carried out over the past week/month to identify those which were the highest in dose; these studies are then be discussed in more detail with the team radiologist. In this way, inconsistencies in protocols between scanners can be identified and corrected.
Another interesting finding that came out of the use of the Radimetrics system to regularly review studies was the discovery that our "obese" protocols were being used in an inconsistent manner. We had been unaware of this inconsistency until then but once we identified the issue, we formulated a much clearer indication for the use of the obese protocols.

"...dose monitoring software opens up opportunities to establish methods based on the patient's individual characteristics..."

In cooperation with our radiation protection officer, who is now also a frequent direct user of Radimetrics, dashboards were made to monitor the dose of several standard head, thorax, abdominal protocols and to check compliance with the national Diagnostic Reference Levels (DRLs) on a regular basis.
It was observed that, as could be expected, our three CT-scanners actually performed differently in terms of the radiation dose used, in the sense that the high- end scanner outperformed the next best scanner and the medium end scanner.

Besides checking DRLs with the system, the Radimetrics software is also employed as a database to gain insight into the usage of CT-scanners in terms of typical dose-length-product per protocol for each of the protocols selected.
This information is used to carry out risk analysis of imaging procedures (which is in fact required by Dutch law) based on actual usage instead of estimates from literature.
Dose estimates are also needed to quantitate and justify the use of radiation to which study subjects may be exposed in any research proposals that are submitted to our local medical ethics committee. To obtain reliable dose estimates for such purposes we use the CT-dose data from the Radimetrics system.

Research Projects
As I said before, we are actively involved in several development programs so, in addition to the use of the Radimetrics system for our routine clinical work, we also carry out several research projects with it.
• For example in CT angiography, we wanted to establish local diagnostic reference levels. We knew that the dose-related parameter CT Dose Index (CTDI) depends strongly on the size of the patient — for slim patients a lower radiation dose can be used whereas for more bulky patients a higher radiation dose is necessary to obtain a diagnostic image of acceptable quality. For this reason a fixed DRL is not adequate to identify and monitor dose outliers in CT angio applications. To solve this we developed and introduced a size-dependent local DRL.
In general I believe that dose monitoring software opens up opportunities to establish methods, based on the patient's individual characteristics, such as girth, for assessing or monitoring the radiation doses to which the patient is exposed.
In this way what might be considered to be an outlier does not necessarily need to be identified by comparison with the whole group but can be more individualized and considered in its own right. In addition, this approach also enables the adjustment of CT protocols as a function of the individual patient's size, or in the case of CT angiography as a function of cardiac output. The results of this work have now been published (*Boere H et al. Implementation of Size-Dependent*

Local Diagnostic Reference Levels for CT Angiography. AJR Am J Roentgenol. 2018; 210: W226. doi: 10.2214/AJR.17.18566).

• Bench marking of the CT protocols and comparison dose parameters of CT examinations now becomes possible on a large, even international, scale. In this context, we have participated in the multicenter, multinational CT Dose Benchmarking project headed by Prof R Smith-Bindman of UCSF, in California in the United States. All the participants in this project had Radimetrics software, so sharing and comparison of data was easy. Thus, in the study, data from our Radimetrics database were shared with the other participants. As feed-back we obtained audit reports and participated in collaborative conference calls to optimize the protocols.
The results of this study have recently been published (*Smith-Bindman R, et al. International variation in radiation dose for computed tomography examinations: prospective cohort study BMJ. 2019 Jan 2;364:k4931)*. The significant conclusion of the study was that "*CT protocols and radiation doses vary greatly across countries and are primarily attributable to local choices regarding technical parameters, rather than patient, institution, or machine characteristics. These findings suggest that the optimization of doses to a consistent standard should be possible*". Such findings encourage us to pay continuous attention to the issue of dose optimization and lead to more awareness of the issue by all concerned
• In another project, this time concerning pregnant women, we used the Monte Carlo dose calculation module incorporated in the Radimetrics software to study how much radiation dose could be reduced in such cases — not just for the woman but also for the foetus — by optimizing the scan range during CT scans for suspected pulmonary embolism. The results of this study have just been published (*Hendriks BMF et al. Computed Tomography Pulmonary Angiography during Pregnancy: Radiation Dose of Commonly Used Protocols and the Effect of Scan Length Optimization. Korean J Radiol. 2019 Feb;20(2):313-322*). The study showed large variations in the CTPA radiation dose between several CT scanners and scan protocols. By evaluating the effect of an optimized scan length, it was found that the scan range could be reduced by 30 -33%. In this way, the patient could be spared about 25% of the usual radiation dose and the foetus could be spared approximately 80% of the dose that would otherwise have been used before optimization, while still maintaining diagnostic confidence.
These results are being used to encourage and instruct the CT technicians and to make them again aware of the importance of avoiding scan ranges that are longer than strictly needed.

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Q *So after a total of approximately five years' experience with the Radimetrics system for CT how do you summarize your opinion of the usefulness and potential of the system?*

I hope that from the above you have already got a feel for the use we make of the system and our impression of it. In short, I think that it is extremely useful to have a database of accumulated CT dose-related data together with an easy method of accessing the data so as to be able to analyze and learn from the valuable information contained in the database

The Radimetrics system allows dashboard reports to be run to efficiently identify and investigate exams that exceed established Dose Reference Levels

Our belief in the value of the system can be seen from the fact that recently we have purchased additional monitoring software so that we can connect not just to our CTs but to all X-ray modalities as well as to nuclear medicine imaging systems. In addition we intend to make use of the module in the Radimetrics system which monitors the parameters involved in the administration of contrast media and the associated contrast injectors. We plan to use this also for the monitoring of MRI contrast media.

Different aspects of the system are appreciated by different members of our team, but one feature in particular that I personally find very useful is the fact that the database can be accessed in so many different ways, Thus the database can be interrogated by looking up a specific examination type, or a particular series within an examination, or an individual patient, or by making dashboards that are updated automatically. The fact that email-alerts can be send, makes it a versatile program that can be used not just by technicians physicians and radiation protection officers but also by medical physicists such as myself.
This strength is however also partly a weakness, since the very many possibilities can make it difficult for new or infrequent users to find their way around the program. It would be nice to have a slimmed-down version, which would hopefully make the program more accessible and easy to use for inexperienced users.
As for the future, my personal desire is to see more technicians and physicians becoming much more closely involved and interested in the radiation doses used so routinely in daily routine. Such involvement can only increase awareness of the subject on the part of all the personnel, which is a vital step in the optimal use of imaging modalities which rely on ionizing radiation.