In profile

PROF. DR. MARIA-HELENA SMET

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In small doses

Reducing dose to improve the long-term health and safety of premature babies and neonatal patients

AGFA HealthCare

To visit UZ Leuven's new, state-of-the-art Neonatal Intensive Care Unit (NICU), you have to go through special measures, from careful hand and arm washing, to wearing gloves and removing rings, to wearing a gown over your clothes. But these are just a few of the precautions to protect the delicate patients, who face elevated health risks in several areas.

Other actions taken for patient safety are not so visible, yet are just as important, including the ongoing efforts of UZ Leuven's pediatric radiology department to reduce to the minimum the amount of radiation neonates (as well as other pediatric patients) receive. Professor Maria-Helena Smet, a Pediatric Radiologist at UZ Leuven, and her colleagues are spearheading efforts and research into dose reduction and image quality optimization. Along with a multi-disciplinary team, including Agfa HealthCare, she is carrying out the testing of CR and DR modalities to determine which allows the greatest dose reduction while still offering the image quality needed for the specialty. She sat down to explain the research, and why dose reduction is so important in pediatric radiology.

How is neonatal and pediatric radiology different from imaging for adults?

Imaging is absolutely crucial for many of our NICU patients, who can have a broad range of pathologies, including the positioning and checking of catheters. One baby can require multiple images during a stay here, and may need additional images in the future.

But the imaging can be quite challenging. Between premature babies and other neonates you can have a huge size and weight difference: anything from an extremely premature baby weighing only 500 grams, to a full-term baby that can weigh from 2500 to 4000 grams. And each individual patient will change and evolve over time, rapidly and significantly.

The chest of a grown man, for instance, will be essentially the same at 20 years, 30 years, 40 years… and the radiation dose will remain the same. This is not at all the case in pediatric imaging! And the smaller the patient, the more significant the changes.

With this smaller size, the structures being imaged are also smaller, as are the catheters. Some of the structures have a high contrast and some have very low contrast. And here in the NICU, we are often dealing with a broad range of pathologies that can be visible in the images. It's a very mixed population.

What's more, their cells are still developing and dividing. DNA repair after radiation is difficult and hence these patients are more susceptible than adults to stochastic effects, such as radiation-induced cancer. Radiation effects are known to appear a long time after the imaging process. The probability of a stochastic effect is proportionate to the dose, but the severity is independent of absorbed dose. And it may occur without a threshold level of dose.

Finally, we must remember that radiation risks are cumulative throughout the patient's life. And while we are very pleased that our NICU and other pediatric patients have ever-greater life expectancies, there is also thus more time for carcinogenic effects to appear.

So we must find ways to lower radiation dose without impacting the quality of the imaging. We have achieved a lot in this area over the 30 years I have been practicing medicine, and I believe there are still dose reductions to be found.

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In this neonatal environment, our Agfa HealthCare DX-D 100 has been ideal. We got this mobile wireless DR solution in early 2014. It has proven very convenient, very smooth in operation, with a short turning circle that is ideal for the individual patient rooms in the new department. The detector fits into the incubator, and we can switch off the batteries when not in use, so battery life is longer. And of course the image quality is very good. In all, it fits right in.

In this context, what does image quality mean to you?

In neonatal and pediatric imaging, the term image quality relates to whether an image allows me, in a clinical situation, to answer the clinician's question. If I can, then the image quality is good or good enough. So image quality isn't really something tangible but certainly has important consequences.

And as we follow the ALARA (As Low As Reasonably Achievable) principle for dose, image quality can even vary for a specific image, depending on what we need it for. An image that is not the 'highest' quality can in a certain case be perfectly suitable for our needs, allowing us to use a lower dose. On the other hand, there are radiologists who prefer to always have 'very high quality' for every image. This attitude does not fit the ALARA principle.

Image quality thus has two aspects: physical quality and clinical image quality. Physical quality is easier to measure: DQE, MTF, SNR, CNR…

But the clinical image quality is more subjective, based on the viewer's preferences and needs. So, despite the physical quality parameters, the radiologist may say: "No, I don't like it, the image quality is not what I want or need." How should we measure that perceived quality? One can make a visual grading analysis, look at statistics, etc., but it's difficult to test on very young patients. We have tested whether we can use the physical quality parameters to predict the clinical perception of image quality. In other words, is there a definable, measurable relationship between them? We found that in the present case, the physical measurements largely predicted the perceived clinical image quality.

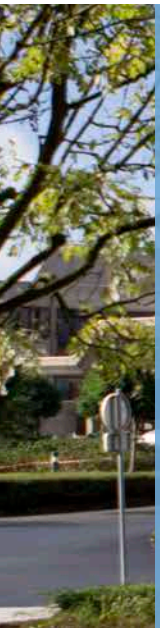
There is an additional complication with digital imaging because the clinician is aware when dose is too low, but not when dose is too high. Low dose results in image noise but high dose just gives you very nice images, which can lead to something called 'dose creep' – slowly increasing dose to have ever 'better' images, when in fact images acquired at a lower dose would be sufficient to perform the clinical task. We need to eliminate this. Of course, you can't push dose reduction too far either. Sometimes it is a question of trial and error.

What tools help you to control and reduce dose?

First of all, we try to take only images that are necessary. For example, we might do an en face spine image but not a profile image, which increases lumbar dose, because we often have enough information from the first image.

Post processing is very important. I worked with Agfa HealthCare to adapt the second-generation MUSICA image processing software for neonatal use, and now I am working with them on the next generation, MUSICA 3. As I said, with these very small children you can have small structures with high or low contrast. MUSICA offers a proper balance between the contrasts, with a better preservation of low contrast details next to high contrast structures. You also need a very stable image processing to ensure standardized images. Collimation is key, too. Consider an adult chest versus an infant chest. If the technician increases the field by 1 cm on top and bottom, this makes little difference for the adult. But for the infant, the proportional increase is huge! This can account for as much as 70% of the radiation dose.

We have to keep track of the dose each patient has received. For our fixed imaging modalities, we have integrated software that automatically records the technician, the dose, the parameters and the patient. So that information becomes part of the patient's file. For our DX-D 100, we do the calculations ourselves, but we will add the software soon.



UZ LEUVEN'S NEW NEONATAL ICU

Early in 2014, UZ Leuven opened the doors of its new NICU. This state-of-the-art facility is designed to be family-centered, yet still provide maximum safety and care for the patients. All rooms are now private (32 single rooms and 4 twin rooms), offering better family-infant interaction. The rooms encircle three central bays, from which care staff can monitor each patient and quickly respond to their needs. Family and visitors enter the rooms through the comfortable and welcoming corridor area that runs along the outside of the room, so caregiver and family streams don't cross.

How are you carrying out the modality testing?
We have been testing three Agfa HealthCare detector systems: a CR system using powder phosphor, a CR needle-based phosphor system and a DR needle-based phosphor system. Our goal is to find the optimal parameter settings – the right mAs, the right kV, the right filtration – to allow us to use the lowest acceptable dose for diagnosis.

The testing is quite complex, and we have already acquired a total of 66 phantom images. These images were scored with image quality criteria during three sessions, with every session taking about an hour. As a next step, we performed a comparative scoring test. I work on this in between my clinical responsibilities, and I see it as a necessary and logical part of my job. This makes my job very busy, yet rewarding in terms of scientific insights and quality improvement.

We do have some preliminary results. For example, our results indicate that we may be able to reduce dose with the fine needle phosphor detector compared to the general powder phosphor detector, while still generating acceptable image quality. But we still have a lot of testing to do. For example, we need to subdivide the effect of filtration on image quality.

What's key here is that, like in so much of patient care today, a multi-disciplinary approach will get the best results. To find ways to reduce dose, we can't work in isolation, nor can manufacturers. So our team includes radiologists, clinicians, technicians, engineers, physicists, the manufacturer of the system – even statisticians! We need them all, and we keep in regular contact – that's the best framework for this type of testing.

While the awareness of the importance of dose reduction has increased in the past years, it has always been an issue. In fact, it was one of the reasons I was attracted to the specialty of pediatric radiology 30 years ago. And we have made a lot of progress, thanks to better parameter settings, digital detectors, better training… Here at UZ Leuven, we already use a quite low dose. The high image quality we get from the needle-based CR and DR indicates that there is still further room to reduce dose. In other types of imaging, we see for example that the speed of CT is increasing, allowing less sedation or anesthesia, and greater throughput. I would also like to see greater availability and increased speed in MRIs – with small children, speed is key!

We have to always remember – the smallest patients are also the most sensitive. We must find the balance between quality and dose.

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