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The Right Dose of Expertise: Best Practices, Best Protection

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Clinicians, physicists, and other experts share their experience and lessons learned about how to implement and carry out a successful CR/DR dose monitoring program.

By Elaine Wilson

When compared to other modalities, radiation dose associated with CT has generated the most media buzz, public concern, and subsequent hospital administration attention. Still, while radiation dose from computed radiography (CR) and digital or direct radiography (DR) is relatively much lower, the percentage of exams coming from these modalities is much higher. Yet, despite their high volume, CR/DR protocols at institutions may be overlooked.

"With CR/DR, for the concerned party, the volume of procedures is really large," said Mythreyi Chatfield, American College of Radiology (ACR) director of data registries. "For any single exam, the dose is lower than the corresponding CT, but there are many more chest X-rays that are done, compared to CTs. Typically, there isn't the same level of concern with regard to X-rays, so a child might get repeated exams."

According to numerous experts, there is significant variation in how patients, especially pediatric patients, get imaged using CR/DR.

Marilyn Goske, MD, chair of the Alliance for Radiation Safety in Pediatric Imaging, said that ideally, the imaging technique that is used should be based on the size of the body part of the patient to be examined. Previously, the amount of radiation administered was based on age, or sometimes body weight.

Furthermore, there are approximately 40 dedicated pediatric hospitals in the country, but these hospitals perform only about 20% of all pediatric emergency department imaging, said Keith Strauss, PhD, medical physicist at Cincinnati Children's Hospital, where Goske also works as a pediatric radiologist. "Adult hospitals may image a small number of children daily, but that's not the majority of the patients that they image," he said. "Therefore, the majority of kids in this country get imaged in nonpediatric hospitals, which may not be focused on the unique needs of pediatric patients."

It is important to acknowledge that one cannot predict the size of a child from their age. The thickness of the belly of the largest 3-year-old is the same size as that of the smallest 18-year-old, Strauss said. "A pediatric technologist who works with children continually knows automatically who is a large, small, or normal sized 5-year-old. But a technologist who normally works with adult-sized patients who is asked to image kids occasionally, may have a difficult time accurately judging the thickness of a child and what technique to use."

Strauss pointed out that an important challenge of CR/DR is how to produce good quality clinical images with a reduced dose of radiation. "It's similar to a photographer—anybody can take a good picture on a sunny day; you find out who is more skilled when it's dark and cloudy," he said. "Obtaining good quality images with less radiation dose is more difficult."

The Early Days of Film

Before the digital era, X-ray images were recorded on film. If the technologist used too much or too little dose in creating the image, there was an immediate feedback. Too much dose produced a dark image; too little dose resulted in a light image. "With digital imaging, that feedback of the brightness of the image is lost," Strauss said. "The digital imaging receptor compensates for differing levels of dose. So if you are not vigilant, your doses can increase.

"If the dose is too high, the image quality will be excellent," Strauss continued. "If the dose is too low, the image will be unacceptable to the radiologist who will object. So low doses get corrected, but high doses may be overlooked."

For these reasons, digital imagers provide relative dose indicators on the images, and are designed to give information on the relative

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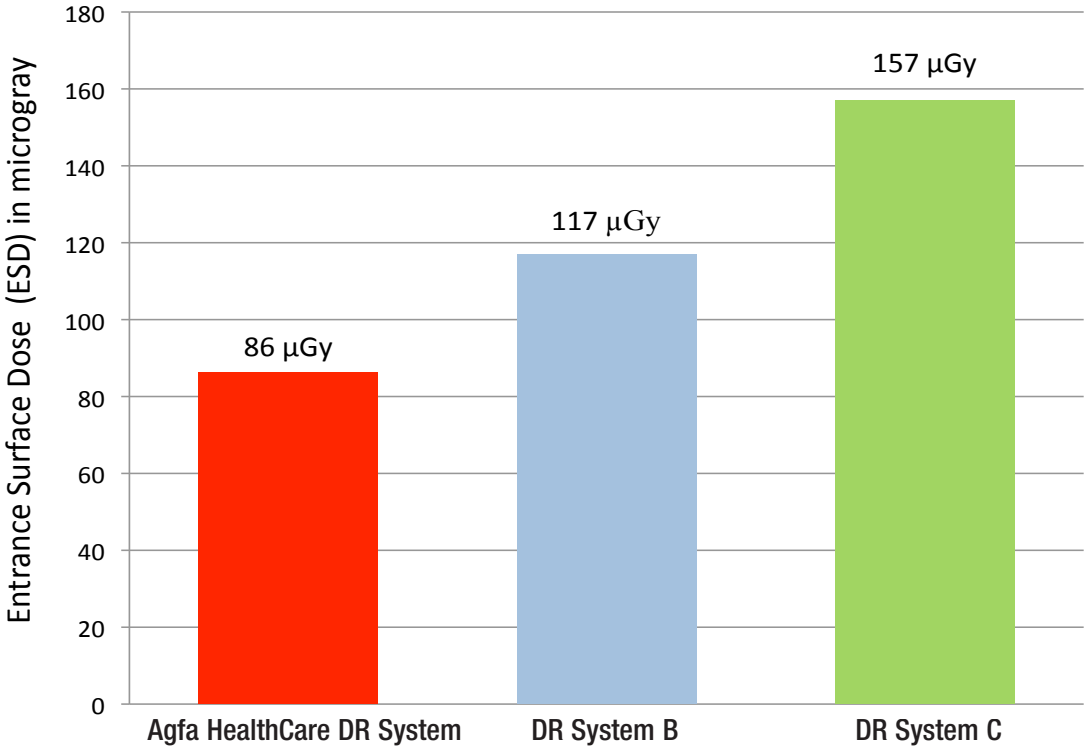

Zwanger-Pesiri Radiology based in Long Island, New York is committed to offering patients the "most comfortable exams with the least amount of radiation."

To that end, the practice conducted a study to determine the patient dose exposure of their new Agfa HealthCare DR system versus two other systems in use at their center. They found that the Agfa DR system required, on average, 45% less dose than competitive DR system C and 27% less dose than competitive DR system B.

Zwanger-Pesiri Radiology found that when it comes to lowering dose, not every DR system is the same. The difference lay in the detector and image processing software technology that their chosen system contained.

patient dose. "Unfortunately, these indicators are not as accurate as we would like them to be," Strauss said. "The indicators require some interpretation by the technologist; they are not as foolproof and simple as the old dark/light film was."

Steve Don, MD, pediatric radiologist at St. Louis Children's Hospital, described how in the screen-film radiology days, if an exposure was too high or too low, the image was too dark or light and it was obvious to the radiologist and the technologist. "They would put the under- or overexposed image in the waste bin, the quality assurance technologist could look through the bin to see what exams were being repeated, the technologist who took it, and the reason—did the patient move, was it over/underexposed, appropriately collimated," he continued.

With digital imaging, computers were able to compensate for over- or underexposure. "There's a desire on the part of the radiologist to want the best-looking image as possible," Don said, adding that increasing the dose just a little produces a less noisy or grainy picture, which radiologists prefer. The radiologist may make a comment to the technologist, who may in turn incrementally increase the dose. This results in what is known as exposure or dose creep.

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—Keith Strauss, PhD, Medical Physicist, Cincinnati Children's Hospital

A Little Bit of Knowledge

At Oregon Health and Science University (OHSU), there are approximately 14 DR rooms and nine portables, with one or two portables still using CR technology. Noting that many of its CR systems were reaching end of life, the medical center began its conversion to DR around December 2012. According to Thomas Griglock, PhD, medical physicist, administration needed to determine whether it was going to spend the money on brand new CR equipment or take the plunge to DR. After site visits and market research, it chose the latter.

The conversion from CR to DR resulted in an unknown benefit for OHSU: if too much radiation is placed on the DR plate, users will actually get burnout on images because DR is only linear up until a certain point—unlike CR, where image quality has a linear response with dose. As a result, technologists can more readily minimize or completely avoid dose creep.

Yet, even with DR, dose creep and unnecessary patient dose can occur. At Loma Linda University Medical Center, for example, medical physicist Don Farley, PhD, polled staff to determine if they could distinguish between the four different types of digital receptors used at the facility: CR powder/barium-flouro-bromide, CR cesium, DR gadolinium, and DR cesium. Proper identification can allow the technologist to customize techniques for the different types of receptor and thus optimize patient dose. "DR tends to be more sensitive, requiring less dose than conventional powder CR by approximately a factor of 2, which is similar to what film used to be," Farley said. "In addition, cesium receptors are more sensitive than gadolinium."

Polling results showed that technologists seldom distinguish between the four different types of receptors, and therefore could not optimize patient dose and image quality. "We don't want to throw our technologists under the bus, but when they are in a busy clinical environment, they may grab a cassette and go, then use a technique that will result in a good image regardless of the type of receptor," Farley said. "You may or may not say, 'This is a cesium, not a gadolinium plate, so I'm going to reduce my dose because it's more efficient.' We found that most of our staff just did what almost everyone does, which results in unnecessary dose and dose creep."

According to Aimee Gallegos, RT, radiology educator at Loma Linda, the learning exercise produced some nerves, in addition to relief. "In being up front about the problem, techs were able to have the time to sit down and say, 'Wait a minute. Am I really paying attention to all the details? Is this something that I'm aware of on a regular basis?' It was a wake-up call."

Assembling a Team

According to Strauss, facilities that have a medical physicist working as a team member with the radiologists and radiologic technologists in the department should be better equipped and positioned to manage their patient doses with respect to image quality. When he arrived at Cincinnati Children's Hospital 3 years ago, Strauss discovered that the department's radiographic techniques were inconsistent. "All technologists were not using the same technique for the same exam on the same size patient," he said. "The department implemented a program to standardize the choices of the technologists when they select radiographic techniques. All the technologists are now delivering similar radiation doses to the patient."

The involvement of all staff members is crucial to the success of the program, Strauss points out. "My job in consultation with the radiologists and radiologic technologists was to help define what should be done from a technical standpoint," he explained. "But once the program was established, the department turned to its excellent Quality Improvement (QI) group, whose focus was to help implement the program and make sure it was consistently followed."

Cincinatti Children's QI group has another role in contributing to the digital radiography

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CHARTING A BETTER WAY

As part of an Image Gently, FDA, and Medical Imaging and Technology Alliance (MITA) children's hospital survey presented at the Society for Pediatric Radiology Annual Meeting in 2012, children's hospitals sent in their technique charts for selected exams. According to Steve Don, MD, the goal was to produce pocket-sized cards that would give reasonable exposure factors and techniques that technologists could use as a reference. "We found variation in their recommended technique chart for an exam," Don added. "This survey wasn't looking at individual patient exposure." Ultimately, the group was unable to produce those pocket cards because there was too much variation among the survey participants.

Results from the survey led to the formation of an ACR subcommittee of the pediatric quality and safety committee (which is under the ACR Commission on Pediatric Radiology) that is seeking to establish reasonable starting point technique charts for common examinations. AAPM Task Group 252, chaired by MacDougall, was formed in July 2013, and is charged with developing the scientific methodology for pediatric techniques for CR and DR. These committees will gather input from all stakeholders—including MITA, the ACR, physicists, radiologists, technologists, and manufacturers. "While children's hospitals may be adept at [building charts based on the selected detector], a community hospital may not have the experience, so it gives them a place to fall back to or start with what people recommend. We hope this kind of a chart will be modifiable for local preference," Don said. "A center that is more tolerant of noise, and we can lower the exposure a little bit; some other centers maybe are a little bit less tolerant, and may need to raise the exposure a little."

program at the hospital: continual monitoring of radiation exposure. "They actually look at the doses that are being delivered to the patient on a continual basis, to make sure that each of the technologists is succeeding in following the program, because if they're not following the program, their doses will be different than everybody else's," Strauss said.

"So number one, you need to have an action plan," Strauss said. "Number two, you need to have a group of people who can work cooperatively together to implement the action plan. Finally, you need to monitor the program over time to make sure the action plan continues to be effective."

At OHSU, there is no formal committee that discusses issues of dose monitoring, but Griglock doesn't see that as a negative. "I don't know that a formal committee is necessary," he said. "One of the things that ends up happening, especially at large or medium-sized hospitals, is inertia because the committees become too big and too numerous." Nevertheless, the department does have a core group of users and experts who weigh in on various issues, whether it's purchasing a new piece of equipment or optimizing protocols. This informal team normally includes administrators, clinical supervisors, radiologists, and medical physicists.

Launching a Dose-Cautious Program

Robert MacDougall, PhD, medical physicist at Boston Children's Hospital, cautions that the goal of a CR/DR program shouldn't be strictly that of dose reduction. "Dose reduction, on its own, is not an appropriate goal for any department. If you are producing images that don't provide the diagnostic quality for accurate interpretation, that is the least safe situation to be in because any dose to the patient is 100% wasted," he pointed out.

Agreeing with MacDougall, Griglock says when people use the term "low dose," it may be a misnomer. "When you say 'low,' it automatically implies you had 'high' before," he said. "What we have here is what I would refer to as a dose monitoring or, better yet, an exposure monitoring program."

Image Gently is an international campaign that raises awareness, provides educational tools, and advocates for radiation protection for pediatric patients. "One of our goals is to provide educational materials through our website (www.imagegently.org) that are free and open-sourced, and can be used by medical imaging professionals at the point of patient care," Goske said. The Alliance for Radiation Safety, sponsors of the Image Gently campaign since 2007, has a specific initiative in each of the imaging modalities.

"What we try to do through Image Gently is share our learning tools with other centers around the country and around the world," Goske said. For example, Cincinnati Children's Department of Radiology launched an in-hospital campaign called "Right Size, Right Dose," based on an Image Gently-produced online module entitled Enhancing Radiation Protection in Pediatric Fluoroscopy. "While we used the Web-based module on pediatric fluoroscopy as a basis for the campaign, it was a group effort, led by radiologic technologists and a radiology assistant interested in quality improvement," she said, adding that the campaign was augmented with lectures to teach the practical aspect of operating fluoroscopic equipment. "The technologists developed a safety checklist, posters, T-shirts, and other promotional materials to bring the safety message to the department." The hospital hopes to launch a similar campaign for CR/DR.

"We know that DR has up to a 50% dose savings, and that it provides us with an increased efficiency, so we're saying that's a twofer. Getting administration to understand that we need new equipment to help us reduce dose can be a challenge. It is especially difficult when they're trying to figure out how to budget for new beds and other basic needs in our changing financial environment."

—Roland Rhynus, Executive Director of Radiology, Loma Linda University Medical Center

Adapting to Change, Getting Staff Buy-in

According to Strauss, radiologists at his institution value the consistency of the images that they interpret. A rapport was developed during the development of the program to make sure their needs (image quality) were being met. "As the radiographic techniques were developed, there was constant dialogue with the radiologists starting with, 'Is the image quality still clinically good?'" he said. "At some point, further

reductions in patient dose reduce image quality below clinically useful levels. Care is required to make sure this mistake is not made."

In Cincinatti Children's case, the radiologic technologists represented the group that faced the biggest challenge. In recent years, features have been added to X-ray equipment to reduce the patient dose, but these features are difficult to implement into practice because they require significantly different radiographic technique factors. When the department elected to implement these features, the radiologic technologists were asked to abandon the standard radiographic techniques they were comfortable using. "Basically, the new program voided some of what they had been taught in their training programs," Strauss said. "Innovation requires change, and if you think about it, many people have difficulty adapting to change."

"Now, a year later, the radiologic technologists understand the new system," Strauss said. "While they didn't care for it initially, they now understand that it helps them improve patient care."

Meanwhile, pediatric radiologists at OHSU were consulted extensively to ensure that dose was optimized for its dedicated X-ray and RF rooms for pediatric patients. "It's really optimizing the amount of radiation you use versus image quality for the specific diagnostic task, and the only way you're going to do that is to get their buy-in and their willingness," Griglock said. "We're definitely lucky to have three dedicated pediatric radiologists who were willing to help with this, but the most important thing is just keeping lines of communication open." Every time the department seeks to change its techniques or lower its automatic exposure control (AEC) settings, an e-mail goes out to these three radiologists, encouraging them to contact Griglock if there is a single image that is too noisy.

Choosing the Right Equipment

In Roland Rhynus' view, one of the biggest challenges in healthcare today, from a radiology perspective, is the scarcity of capital resources. "It's very challenging for us to go and ask for a quarter of a million dollars for one digital portable," said Rhynus, executive director of radiology at Loma Linda University Medical Center.

Loma Linda is an 800-bed university teaching hospital that is part of a larger campus system including a children's hospital, an orthopedic hospital, and a surgical hospital. The institution currently houses 21 portable X-ray units, which were equipped with CR technology for approximately a decade. "We know that DR has up to a 50% dose savings, and that it provides us with an increased efficiency, so we're saying that's a twofer," he said. "Getting administration to understand that we need new equipment to help us reduce dose can be a challenge. It is especially difficult when they're trying to figure out how to budget for new beds and other basic needs in our changing financial environment."

Because it didn't have the money in the existing plan to install DR plates everywhere and totally replace CR, Loma Linda worked with its PACS and Imaging partner to implement a partial evolution from CR to DR for the vast majority of imaging procedures. Currently, there is a combination of medical film, CR, and DR. (The medical center has replaced film for 99.8% of its cases.)

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THE IMPORTANCE OF IMAGE PROCESSING

Image processing software should not be overlooked when considering DR or CR systems to help achieve lower radiation dose. Certain image processing offerings provide multi scale contrast level and noise reduction resulting in more image information, even at lower dose. In addition, the software allows radiologists to modify their techniques by increasing the kilovoltage (kVp) and decreasing the milliampere seconds (mAs), thus lowering the effective radiation dose and reducing dose by at least one third without any noticeable difference in image quality.

tion products that we're giving to our staff to use, and we're asking our staff to take the time to be alert and aware of which device they are using in order to reduce dose," Rhynus said.

Loma Linda has employed a strategy of placing DR in its most utilized radiography equipment, while CR is used in the older equipment that is rarely used. Pediatric imaging has been totally converted to DR.

In the early '90s, the digital imaging marketplace only had a few players. Fast forward to the 21st century, and there has been an explosion of companies entering the market, each with its own proprietary way of measuring plate exposure. One company might use a logarithmic exposure scale, another a linear exposure scale, and a third, an inverse exposure scale. Technologists need to be mindful of different indicators from different vendors currently in use. "This can cause confusion among the technologists and radiologists," Don said.

In 2010, Image Gently along with the Mallinckrodt Institute of Radiology sponsored a vendor summit that brought in radiologists, technologists, manufacturer representatives, physicists, and the FDA. During this daylong meeting, attendees discussed the American Association of Physicists in Medicine (AAPM) and the International Electrotechnical Commission (IEC) exposure indicator standards that had recently been published. "Through understanding and talking among ourselves at the summit, the manufacturers agreed to adopt the IEC standard as the format in which they will present exposure data," Don said. "That information is very useful because instead of having proprietary data that varies from the vendors, we'll eventually have a single set of exposure indicators so that radiologists and technologists will only have to learn one set of values regardless of the vendor."

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—Steve Don, MD, Pediatric Radiologist, St. Louis Children's Hospital

Other Ways to Lower Dose

Eliminating unnecessary exposures

According to Goske, the biggest point of emphasis with children is that clinicians should justify every single imaging exam they order. "Bite-wing X-rays are extremely low dose, but we still don't want a child to have a single X-ray if they don't need it," she said, referencing a current Image Gently dental campaign.

Reducing repeat rates through environmental modifications

For pediatric patients, distraction is key to avoiding repeat exams. For example at Cincinnati Children's Hospital, figures on the wall are strategically placed to divert children's attention from the procedure. "It is effective for gaining the cooperation of many kids because they forget they are in a hospital and just become kids again," Strauss said.

Concurring with Strauss, Griglock noted, "Kids who come in here for imaging generally aren't going to be in the best health, and hospitals can be a very scary place when you're that age," adding that the OHSU has worked with the Portland Art Institute to paint each of its pediatric X-ray rooms. Each room has a different theme: a jungle room, an "under the sea" room, and an "outer space" room. Meanwhile, in the waiting room, Disney and Pixar characters are shown with their radiographs; children can see that Buzz Lightyear is doing just fine after getting his X-ray. "We track repeats, especially for pediatrics, and our repeat rate has dropped significantly since we've started to do all this," Griglock said.

Quantifying Results

The ACR Dose Index Registry for CT took between 4 and 5 years of development to get to the point where it is today, with more than 9 million data points. Based on the type of detector and type of exam, individual hospitals are able to get a sense of where they fall in the range of other hospitals that do similar exams.

The ACR is now in the process of building an ACR Dose Index Registry for digital radiography. Chatfield shared that the prototype for the original Dose Index Registry was in fact CR/DR, "but pretty soon after we started thinking about the design, the news stories about CT started to come out, and so we shifted our focus," she said. "So far, manufacturers are still in the process of adopting the DICOM structured report for CR/DR," Don said. "The accumulation of quality assurance data is much easier than other methods, such as looking at spreadsheets or recording all these exposure factors. Having a standard in which to record exposure and having a structured report that allows the data to be acquired automatically and then anonymized, allow for a collection of data from both a point of ease of collection and quickly analyzing the data in one format regardless of vendor."

According to Chatfield, the CR/DR registry is still in the prepilot stage and progress has been delayed after it was discovered that many scanner manufacturers were not populating data in accordance with standards and were producing incomplete records for analysis.

Don confesses that the endeavor is a long-term proposition that will not be solved overnight. However, he hopes that radiologists will be able to "document to the public that we are doing a good job across the board so that a parent can feel comfortable taking their child to any hospital and get an appropriate exposure examination," Don said. ■

The right dose of expertise

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