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Dose Management at Ziehm Imaging

An educational paper on general dose definitions and concepts as well as further insights on dose management at Ziehm Imaging

Dose exposure is being increasingly discussed in our industry and in daily communication with customers and healthcare professionals. At the same time, organizations such as the International Commission in Radiology Protection (ICRP), the European ALARA Network, the American Association of Physicists in Medicine (AAPM) and Image Gently are driving a rise in recognizing the importance of dose management and appropriate treatment. Together, these organizations are helping create the awareness needed to minimize dose and prepare guidelines for the medical use of X-raying.

Ziehm Imaging's commitment to support dose management began with our very first products over 40 years ago. This has never stopped and today we continuously improve dose management tools to help our customers overcome the challenge of finding a compromise between sufficient image quality and the lowest possible radiation dose.

The goal of this paper is to help readers understand the basic principles of radiation dose, its benefits and challenges.

What is dose (radiation)?

One way to describe X-ray dose is in terms of radiant energy (radiation): It is part of the electromagnetic spectrum. All visible light comprises a small part of the electromagnetic spectrum, while a specific color relates to an exact frequency within the visible light spectrum. Radio waves, microwaves, infrared, ultraviolet, X-rays, and gamma rays are also part of the electromagnetic spectrum. Some parts of the electromagnetic spectrum contain nonionizing radiation while others contain ionizing radiation. Nonionizing radiation does not contain enough energy to ionize atoms or otherwise cause biological harm. Ionizing radiation does contain enough energy to ionize atoms and can thus cause biological harm. This paper will focus on ionizing radiation that lies in the X-ray portion of the electromagnetic spectrum.

As radiant energy, ionizing radiation consists of X-ray photons, which are characterized by their energy distribution within the spectrum. If these

X-ray photons encounter tissue, they will immediately start to interact. In the process, a part of these photons, emit energy to the transmitted medium, for example human tissue.

The two factors that influence dose the most are the tube current (mA) which is the number of electrons needed to generate photons, and the tube voltage (kV) that accelerates the electrons and give them the needed energy to be converted into X-ray radiation when they hit the surface of the tube anode.

The dose is the result of the tube current, tube voltage and exposure time. The more dose, the higher the harm to the human tissue.

What are the sources of dose (radiation)?

There are naturally occurring forms of radiation in the environment that originate from sources such as terrestrial and cosmic radiation. These sources contribute to what is known as chronic exposure and there is virtually no way to totally eliminate this ionizing radiation from human exposure. Other sources of ionizing radiation derive from such synthetic sources as medical X-ray devices, including computed tomography (CT scanning), radiography, and fluoroscopy. We plan to focus on fluoroscopy as this is the form of X-ray used for medical devices known as "C-arm".

What is fluoroscopy?

Fluoroscopy-based X-ray imaging has been used in the operating room for more than half a century. The main goal of fluoroscopy is to provide live or real-time images to the surgeon to allow for optimum diagnostic evaluation and required interventions. For the surgeon to see the images in real time, the display rates must be over 18 frames per second. For example, the frame rates displayed in a film shown in a movie theater are around 24 frames per second. The higher the frame rate, the more fluent the visualization of the images. Mobile C-arms offer up to 30 frames per second to ensure adequate visualization.

Typically, the mechanics for most fluoroscopic imagers are shaped like a "C" to allow the source and detector access around the patient and table. The shape of the "C" provided the inspiration for the name of the traditional C-arm, with the X-ray source mounted on one end of the "C" profile and the detector mounted on the other. The X-ray source for these early-technology fluoroscopic C-arms employed electronic circuitry (a high-voltage electronics generator and X-ray tube circuits) that continuously produced X-rays for as long as an X-ray switch was pressed, which became known as continuous fluoroscopy.

To display the image in real time, the cameras for these imagers acquired images at 25 to 30 frames per second; to present images to a monitor at these frame rates, a synchronization pulse was embedded in the camera video signal. This synchronization signal allowed image presentation to the monitor without a "rolling" effect. This rolling effect is similar to what can be demonstrated by older technology commercial television sets where pictures roll vertically. In this case, the viewer sometimes had to adjust the synchronization (called vertical synchronization or VSync) to stabilize the image.

During VSync, the camera system was not able to acquire any image and, as a result, there was a short time that X-rays were produced but the camera was not able to acquire the image. Those X-rays were not contributing to the image or any improvement in image quality and only increased patient and staff exposure.

How is dose measured?

Several different radiation quantities are used to express dose. It is important to understand the different quantities to ensure regulatory compliance and to be able to equitably compare different devices. Several quantities can be measured directly during physical inspections and calibrations while others can be calculated and displayed to the user.

Exposure rate: Exposure rate is described as "the amount of ionization per mass of air due to X-rays" and is traditionally measured in R/minute. Now, however, it is more common to be measured in mGy/minute. Maximum exposure rates are regulated and must be within specified limits for compliance. Currently, there are regulatory requirements in Europe and the US, for 88mGy/minute for fluoro mode and 176 mGy/minute for high-level dose applications. For special applications like e.g. digital substraction angiography (DSA), these values are allowed to be exceeded, as stipulated limits for these applications are measured in dose/image and are not described as the dose rate. For calibrating X-ray devices, specific and defined exposure rates are used to adjust system parameters to maintain consistent image quality and working points for automatic exposure rate control (AERC) algorithms.

Skin entrance dose: Skin entrance dose is another form of a maximum exposure rate measurement for fluoroscopic equipment currently defined as having a fixed X-ray source below a tabletop. It is also described as the measured radiation at the skin entrance point. The measurement point is then defined as one centimeter above the tabletop. There is a trend to implement this form of measurement worldwide as it can better determine the actual dose to the skin entrance of a patient.

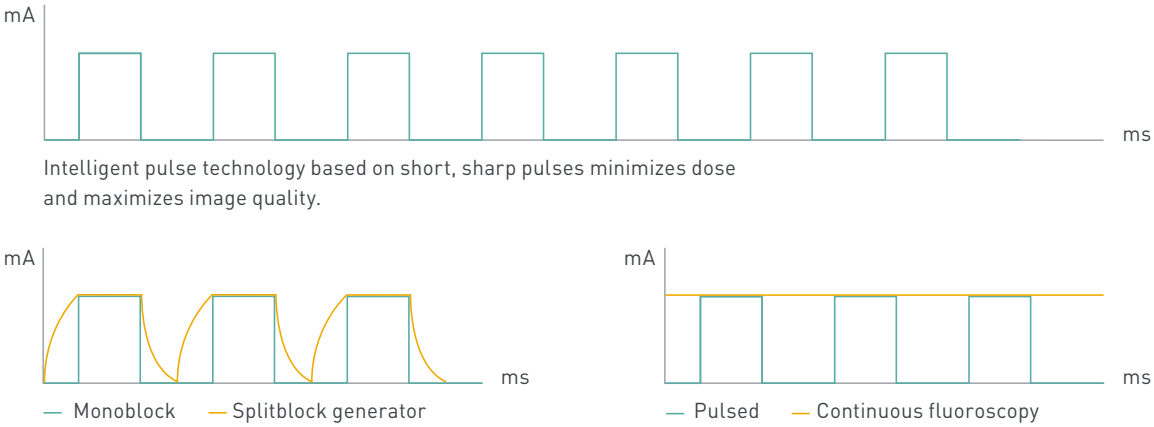
Air kerma: Kinetic energy released per unit mAs. When expressed as a dose rate it is typically mGy/min or for accumulated dose as mGy. Depending on the country, regulatory compliance is maintained by displaying the rate during fluoroscopy and the accumulated amount at the end of fluoroscopy.

DAP: Dose area product is typically measured through an ionization chamber placed directly in the beam path after any form of collimation. Depending on the country, regulatory compliance is maintained by displaying the accumulated dose amount in $mGycm^2$.

What is pulsed fluoroscopy?

Advancements in miniaturization of electrical components along with increased operating ranges and parameters have led to improvements in the technical design for the electronics of the generator and circuitry of the X-ray high-voltage sections. Medical device manufacturers responded with new designs that facilitate pulsed operation of the X-ray sources for fluoroscopic imaging. These new designs had the advantage of allowing the generator and X-ray tube electronics to be turned off during the short VSync interval. As a result, no X-rays were produced during this interval and there was an immediate savings of dose to patient and staff. Pulsed fluoroscopy was first realized in high-end cardiovascular and fixed-room installations and has now been available for decades.

The production of a pulsed X-ray must be synchronized with the image-capture camera. The terms "pulse rate" and "frame rate" essentially mean the same thing when it comes to image acquisition. As a result, pulsed fluoroscopy techniques could be used to better manage and deliver optimum dose levels for procedures.



Intelligent pulse technology based on short, sharp pulses minimizes dose and maximizes image quality.

For example, it was possible to halve the pulse-per-frame rate, thus also cutting the dose levels in half.

There are many other technical implementations that allow for further dose optimization such as "variable pulse widths," the amount of time the X-ray is actually on within a specific pulse-per-frame rate. It is beyond the scope of this paper to discuss these parameters in detail, but it should be understood that a true-pulse fluoroscopy imager allows for very flexible operations and optimizations.

Benefits and insights in pulsed fluoroscopy

In the early years of the technology, Ziehm Imaging as well as most other medical-device manufacturers of C-arms implemented continuous fluoroscopy X-ray generators and X-ray tube electronics. In some cases, there were attempts to emulate pulsed fluoroscopy, but there were always limitations. These included such restrictions as the production of an X-ray during the VSync and not being able to pulse at a rate that allowed synchronization with the VSync. Due to the missing synchronization, there was a tremendous lag effect in the image. As a result, only a limited amount of noise filtering could be added, resulting in a very noisy image.

These older designs and inherent limitations prevented manufacturers from implementing specialized anatomical programs and program modifiers that could be used to further optimize dose for a specific anatomy. These specialized programs could implement various pulse rates and pulse widths to optimize imaging results. Reductions in pulse rate provided for a linear reduction in dose.

In continuous X-ray fluoroscopy, simulated pulse operation often doesn't provide a linear reduction in dose for reduced pulse rates. Pulsed fluoroscopy, with the proper selection of the anatomical program, program modifier, and pulse rate can, in many cases, provide a less accumulated dose than a continuous X-ray system in a low-dose setting.

Dose management

The medical field is always pushing for better imaging at lower X-ray doses whether it is to meet current regulatory requirements or to comply with hospital administrations calling to further push the dose to lower levels. The US Federal Code of Regulations (10 CFR 20.1003) defines the ALARA principle as: "as low as reasonable achievable" and the European ALARA Network also has a commission for research and optimization of occupational exposure. Globally, the idea is to move to a low-dose practice.

In addition to a pulsed fluoroscopy mode in imaging devices, there are also several real-time processing features that provide a great solution to enhance image quality while reducing dose to lower levels. Filters in the generator housing are made from various elements such as cooper or aluminum. Much like the visible light of a specific color, these filters help filter out those photons that have energy at a lower end of the spectrum and are insufficient for imaging and only contribute to an absorbed and scattered dose.

Medical device manufacturers spend a considerable amount of time and money on research and development to create device designs that include features and functions to allow the end user to select the best and most reasonable approach to image for the procedure. The ultimate decision for selecting the appropriate dose for a procedure is the responsibility of the end user. Ziehm Imaging provides the tools and training to raise users' awareness and help them use these tools to minimize dose.

Ziehm Imaging's comprehensive SmartDose concept

As part of its commitment to improving patient care, Ziehm Imaging has incorporated SmartDose in their mobile C-arms. With innovative technology ranging from pulsed fluoroscopy technology to various features for real-time and post-processing, Ziehm Imaging is helping set the benchmark in the user-friendly adjustment of dose exposure that benefits patients and staff.

SmartDose enables physicians to obtain optimal fluoroscopic examination results with minimized radiation by using dose-reduction features such as anatomical programs, virtual collimators and the removable grid that reduces the working dose required.

The innovative features of SmartDose reduce dose to patients of all ages. Ziehm Imaging encourages technicians and members of the imaging team to become familiar with the dose-saving functions of the Ziehm Imaging C-arm as well as situations in which these functions can be applied most effectively. Knowledge of pulsed fluoroscopy, the exposure rate of equipment, and the appropriate timing for specific dose-saving features can enable physicians and staff to reduce dose significantly.

Please visit our website at www.ziehm.com/SmartDose to discover more about current initiatives of Ziehm Imaging to drive the topic of high-image quality by minimizing dose even further and explore our post-processing features to help you in your daily routines.

Conclusion

There are many different sources of radiation, some natural and some human-made for the purpose of medical imaging. The concepts of ionizing radiation, specifically as it relates to fluoroscopic X-ray imaging with medical devices called C-arms, were presented in this paper. Medical fluoroscopic X-ray sources are important to control and manage dose at the lowest possible levels. Various measurement methods come into play and caution must be exercised to ensure equitable comparisons among devices.

As seen with fixed-room installations, implementing technology to transition from continuous to pulsed fluoroscopy provides for potential dose reductions. For those manufacturers who attempt to fulfill the needs of the market by only offering equipment with outdated continuous fluoroscopy technology, the ability to satisfy market demands will become increasingly difficult.

Mobile C-arms are being used more and more to perform complicated, demanding procedures. It is therefore becoming more important to educate users about employing dose management techniques such as those made possible through the use of tools provided through Ziehm Imaging's SmartDose concept. This will help reduce dose exposure to patients, staff and surgeons alike.

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