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The danger of radiation exposure in the young

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Radiation is energy travelling through space. The most familiar form of radiation is sunshine with its visible light and heat. Beyond ultraviolet light are higher energy kinds of radiation, referred to as ionising radiation because of their ability to penetrate and interact with matter, thereby causing secondary emission of detectable energy which can be used for diagnostic purposes in medicine. Much as we know from sunlight, there are good and bad effects with any kind of radiation.

THE GOOD
Wilhelm Conrad Röntgen’s detection of diagnostic radiation in 1895 has revolutionised medical diagnosis. 1 Even today when cardiac imaging with sophisticated tools such as magnetic resonance and 3D echocardiography is available, plain chest roentgenograms retain a place in the daily routine as they show cardiac size and silhouette, large vessels, surrounding lung tissue and pulmonary vasculature. Moreover, fluoroscopy requires ionising radiation to guide catheters and instruments into the heart, thus enabling diagnostic and therapeutic interventions. Both, chest roentgenograms and fluoroscopy provide imaging with excellent spatial resolution but no true 3D information.

Much progress has been made since Röntgen’s discovery, and image quality has been continuously improved. With the introduction of CT by Hounsfield in the 1970s, a true 3D modality became available for medical imaging. After further evolution of this technique, including spiral acquisition, ECG gating and multidetector technology, we can now reconstruct images in any desired cardiac phase and anatomical plane with submillimetre spatial resolution and excellent tissue contrast. The speed of the CT procedure has been increased to such an extent that a time-resolved 3D dataset, also referred to as 4D imaging, can be imaged within a breath hold of <20 s. This is particularly important in patients who are unable to cooperate, such as children or young adults with congenital heart disease. 2 Morphological and functional data are analysed after the acquisition, allowing depiction of the anatomy and physiology even in complex congenital heart disease. 3

THE BAD
These imaging methods have the disadvantage of using ionising radiation which has harmful biological effects at any dose level. 4 Admittedly, the dangers of diagnostic radiation as it is commonly used in adults are low. However, young patients are more susceptible to radiation damage for many reasons. First, cells of younger people have a higher mitosis rate and are therefore more susceptible to radiation damage. 5 Second, children and adolescents may accumulate higher radiation doses during an expected long lifespan, especially if repeated imaging is required. 5 Third, in the case of CT scanning, the radiation exposure from a fixed set of CT parameters results in a dose that is relatively higher for a child’s smaller cross-sectional area than for an adult. 5 Moreover, organs of children and infants are much smaller, therefore a given amount of energy will result in a substantially higher effective dose. 6

In order to fully appreciate the risks involved with radiological imaging some understanding of physics is helpful. Radiation doses for any given radiological test can be measured and calculated by various methods. 7 8 Usually, the effective dose in mSv (milliSievert) is used, which allows a comparison of the biological effects in various tissues.

Compared with papers praising the diagnostic capabilities of radiological imaging, there are surprisingly few reports dealing with its potential harm. A paper of one of the groups constantly providing valuable information in this respect is included in this issue of Heart (see page 269). 9 Their work shows that in children with congenital heart disease considerable cumulative radiation doses are achieved already during the first year of life. Furthermore, the harmful effect of this exposure is underlined by their finding of an elevated biomarker of DNA damage. This is especially helpful since the judgment of tests using radiation technology is thus based on dose calculations and also on empirical findings. As the authors themselves state, when considering average doses in this field one has always to bear in mind that there may be wide variation in radiation according to the length of procedures and the protocols used. 10

Doctors ordering radiological tests must be aware of these issues, especially cardiologists who generally lack in-depth knowledge of radiology and physics. This report also sheds some light on the speed of development in the field, as the doses used for calculations by these authors are lower than those found in other publications. 11 In addition, modern imaging methods seem somewhat underused in comparison with cardiac catheterisation procedures in the cohort of this study. This might be owing to a selection bias in the referral of patients included in their study.

TOO MUCH OF A GOOD THING?
In contrast to the increasing use of fluoroscopy-guided procedures in adults, these investigations in children, with the exception of electrophysiology studies, are mostly non-repetitive and have a relatively high threshold for indication, making their overuse unlikely. 12 However, as they do convey a substantial effective radiation dose, they should be used with caution and if possible not repeatedly in children. The described advantages—the non-invasive nature and the immense diagnostic potential of CT—present the danger that this method may be used inappropriately. It is estimated that since 1992 the number of CT scans has quadrupled, which seems hardly justified by disease rates or results from definitive trials. 11 In the European Heart Survey on congenital heart disease the predominant radiation exposure in young patients with cardiovascular disease indeed came from angiography and other fluoroscopy-guided catheter procedures, as well as from CT scans, whereas radionuclide imaging is rarely used in this patient group. 13

As examples, angiography and nuclear studies may result in an effective radiation dose which is 200–300 times the dose of a simple chest x-ray examination. For multidetector CT scans this figure may have to be increased by a factor of 2–5, depending on the protocols used. This should be considered, especially when used...
in children and adolescents. It is estimated that as many as 2% of cancers may be attributable to radiation exposure. Alternative imaging techniques without ionising radiation should be critically reviewed and weighed against alternative non-radiation imaging such as echocardiography and magnetic resonance, especially when multiple follow-up studies are to be expected. Even with the judicious use of radiation much thought has to be given in each case to optimising the protocol to achieve the lowest possible radiation exposure of any given test procedure by (a) scaling the radiation dose to the patient’s weight and height; (b) use of proper tube modulation and shielding; (c) ensuring low heart rates (if necessary and possible by the use of β blockers) and using a prospectively gated sequential mode when performing a CT scan.

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SPECIFIC RECOMMENDATIONS AND PRECAUTIONS FOR THE USE OF RADIOTHERAPY TESTING IN YOUNG CARDIOVASCULAR PATIENTS

Any indication for diagnostic tests using ionising radiation should be critically reviewed and weighed against alternative non-radiation imaging such as echocardiography and magnetic resonance, especially when multiple follow-up studies are to be expected. Even with the judicious use of radiation much thought has to be given in each case to optimising the protocol to achieve the lowest possible radiation exposure of any given test procedure by (a) scaling the radiation dose to the patient’s weight and height; (b) use of proper tube modulation and shielding; (c) ensuring low heart rates (if necessary and possible by the use of β blockers) and using a prospectively gated sequential mode when performing a CT scan.

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