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SPOTLIGHT

Dose optimization: a major challenge for acceptability of nuclear medicine

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In real life, the perception of a risk depends not only on its reality and severity, but also on subjective external factors. The fear of potential health risks of ionizing radiation is very present in collective unconscious of our society, most probably because of their military use, which preceded their civil and medical use. This, as well as the principle of the risk/benefit balance optimization inherent to any good medical practice, makes this topic of major importance for the diffusion of nuclear medicine. The therapeutic field uses high doses were the risk is always present, but with a large expected benefit. In contrast, imaging field is in the range of very low doses where the risk is still unknown. But for both applications, major improvements have been and still can be done, and this supposes for each nuclear physician or physicist to be aware and well trained in the field.

Potential health risks of ionizing radiation were identified soon after the discovery of x-rays in 1895. In the field of Nuclear Medicine, functional and molecular imaging as well as therapy demonstrated their benefits in terms of medical usefulness. Medical diagnostic exposure is nowadays the first cause of radiation exposure, raising some concerns regarding potential side effects, which are to be weighed against the specific risk of the disease(s) that are taken in charge, mainly in elderly patients. However, optimization continuously aims to decrease these side effects for the same or extended benefit [1].

Injuries to highly exposed tissues, such as encountered in therapeutic applications of Nuclear Medicine, are classified as deterministic effects because they will always occur once a particular threshold dose has been exceeded. Tissue reactions are caused by cell death and increase in severity as radiation dose increases. Deterministic effects can impair the tissue integrity, and compromise the function of non-target organs. A threshold dose is needed for damage to become clinically observable, and the extent of damage depends upon the absorbed dose, dose rate, and radiation quality. Thus, the severity of the effect increases with increasing absorbed dose. Apart from the case of accidental irradiation with early clinical reaction, these deterministic effects are usually delayed, occurring years or sometimes decades later and include tissue reactions such as cataracts, cardiovascular disorders, and necrosis.

The risk of stochastic effects increases with dose, in theory with no threshold. In addition to hereditary effects, which originate in germline mutations, cancer is classified as a stochastic effect since it originates in somatic mutations. Even if the reality of this risk is still uncertain in the domain of very low doses such as used in the field of imaging, this has led to the adoption of international rules in the field. Cancer risk increases after exposure to moderate and high doses of radiation (more than 0.1–0.2 Gy); however, whether cancer risk is increased below this level is unclear and is the object of extensive research. Currently, one in three women and one in two men will develop cancer in his or her lifetime. Since this is so much higher than any estimated effect of medical radiation, and since medical exposure is in the same range than natural exposure, the potential increase in cancer due to radiation is extremely difficult to detect. In addition, no prospective

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trial focusing on the adverse effects of radiation with doses used in diagnostic procedures has ever been performed, since such studies would require a tremendous patient's population and a very long follow-up. Research founded by the European Community will facilitate such trials.

Therefore, the risk is not of the same nature for therapy, which implies high dose, and for imaging, which is in the field of low doses. However, for both activities, lowering the radiation exposure is mandatory in order to comply with the principle of optimization, which means the lowest exposure for the same benefit. This is even more crucial for some specific populations such as children, or patients with chronic disease who are likely to have repeated scans all along their life. Based on results from various epidemiological studies, the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) concluded that children are generally more sensitive than adults to radiation for 25 % of cancer types, including leukemia and cancers of the thyroid, skin, breast, and brain. Results of studies suggest that children who undergo several CT examinations (which involve high-dose-rate, but low-dose x-ray exposure) are at increased risk of leukemia and solid cancers, although interpretation of these studies has some problems. Also, exposure in utero to low doses at high dose rates can increase risks of leukemia and solid cancers in childhood and pregnancy represents a condition of caution if not contra indication. At the other side, elderly patients are the subjects of the vast majority of diagnostic and interventional procedures, at an age where the probability to develop a radiation induced disease is largely outbalanced by the diseases they are exposed to.

Risks are different depending whether internal exposure or external exposure is concerned. More and more often, procedures imply both kind of exposure, for example using multimodality imaging with PET-CT or SPECT-CT.

For targeted radiation therapies, the absorbed dose that can be delivered to tumoral lesions is limited by the toxicities for organs at risk (OARs). The activity prescription is thus conditioned to the irradiation of OARs which has to be kept to an acceptable level to avoid adverse side effects. Therefore, an accurate and personalized evaluation of absorbed dose to OARs and tumoral lesions must be performed to guide decisions on the activity prescription. The treatment planning is a real challenge and will be performed from 3D personalized dosimetry, based on Monte Carlo calculations [2] or faster methods compatible with clinical constraints.

Optimization should not only be technical, a better definition of adequate indications is also an important step in this global process, and this implies to weight all risks, and not only one specific risk- i.e. radiation exposure. Every medical procedure presents with risks, as emphasized in a recent publication about cardiac imaging: stressors, contrast agents, invasiveness, radiation, etc. Even more important, each test must be weighed against the benefit of "performing or not performing", with the risk and drawbacks associated with the disease remaining undetected [3]. This balance between different relative risks for the best benefit is inherent to our medical practice.

Patients are nowadays more and more concerned by all kind of risks related to medical care, and radiation exposure is—only—one of them. Recent research, as well as software and hardware implementation, has led to sometime dramatic decrease in patient exposure, while significantly improving diagnostic/therapeutic quality, resulting in a better quality/risk balance for the patient. It is mandatory for physicians and physicists, but also technologists who are performing the scans on a daily basis, to be aware of the topic, to be sure to have the best practice for dose optimization, and to adapt their practice as often as necessary to be at the state of the art.

This represents a challenge for the continuing success of our specialty. In all fields of our practice, this special issue will contribute to a better recognition of this important topic.

Compliance with ethical standards

Conflict of interest Dominique Le Guludec and Jocelyne Aigueperse declare that they have no conflict of interest.

Human and animal studies This article does not contain any studies with human or animal subjects performed by any of the authors.

References

1. Kamiya K, Ozasa K, Akiba S, Niwa O, Kodama K, Takamura N, Zaharieva EK, Kimura Y, Wakeford R (2015) Long-term effects of radiation exposure on health. Lancet 386(9992):469–478
2. Petitguillaume A, Bernadini M, Broggio D, de Labriolle Vaylet C, Franck D, Desbrée A (2014) ŒDIPE, a software for personalized Monte Carlo dosimetry and treatment planning optimization in nuclear medicine: absorbed dose and biological effective dose considerations. Radioprotection 49(4):275–281
3. Knuuti J, Bengel F, Bax JJ, Kaufmann PA, Le Guludec D, Perrone Filardi P, Marcassa C, Ajmone Marsan N, Achenbach S, Kitsiou A, Flotats A, Eeckhout E, Minn H, Hesse B (2014) Risks and benefits of cardiac imaging: an analysis of risks related to imaging for coronary artery disease. Eur Heart J 35(10):633–638