Justification and optimisation in radiation protection: which one is first?

Michel H. Bourguignon, MD, PhD

Professor of medical physics, Faculty of medicine of Paris
Deputy Director General, Nuclear safety authority (ASN)
France

Radiation protection is based on the application of 3 principles, i.e., justification, optimisation and limitation, which have been established by the International Commission of Radiation Protection (ICRP) in the recommendation n°26 of 1977.

These principles have been successfully applied in the national regulations to protect the workers, the public and the patients from the effects of ionizing radiations. The application of the principles of radiation protection has allowed:

- to suppress the deterministic effects by limiting the doses received by the workers and the public well below the thresholds at which the deterministic effects appear. Thus deterministic effects should appear only in the case of accidental exposures;
- to minimize the occurrence of stochastic effects through the optimization of all individual doses and consequently of the collective dose.

These 3 principles which are cornerstone of radiation protection philosophy are usually cited in the sequential order "justification, optimisation and limitation". This order indicates that :

- a nuclear activity (in this document, a nuclear activity must be understood as any activity or practice or intervention where an exposure to ionizing radiation is possible) must be first justified;
- exposures which occur during a justified nuclear activity are optimised by applying the ALARA principle ;
- in any case, the doses of exposition of the workers and the population are kept well below the regulatory limits.

At first glance, this sequence looks so logic that it cannot be wrong. In fact, this is not so sure and it is quite possible that many nuclear activities are justified because they are somehow optimised and they would not have been justified if they had not been optimized anteriorly. Justification and optimization: which one is first ?

Justification and optimisation

What are we talking about? What is the philosophy covered by these concepts?

- Justification**:** ICRP "recommends that, when practices involving exposure, or potential exposure, to radiation are being considered, the radiation detriment should be explicitly included in the process of choice. The detriment to be considered is not confined to that associated with radiation; it includes other detriments and the costs of the practice. Often, the radiation detriment will be a small part of the total. The justification of a practice thus goes far beyond the scope of radiological protection.... To search for the best of all the available options is usually a task beyond the responsibility of radiological protection agencies".

  This point is expanded in a statement by the Committee on radiation protection and public health of the OECD Nuclear energy agency : "Decisions about the justification of a practice or activity involving radiation exposure usually involve a broad range of social, economical and political issues in addition to those concerning radiological protection....Justification is essentially a political decision-making process, in which the

technical and purely radiation-related advantages or detriments play an important, but relatively limited role."

In simple words, justification means that no nuclear activity should be adopted unless it produces enough benefit to the exposed individuals or to society to offset the radiation detriment it causes. Assessing the likelihood that any practice will produce a net benefit involves many value judgments that are difficult, if not impossible, to quantify.

Thus, it appears that the principle of justification is a difficult concept and its application to a particular nuclear activity is rarely discussed. For example, in the early years of nuclear weapons development, the scientists and administrators involved implicitly assumed that national security justified the risks of the enterprise.

It is worth noticing that nuclear activities were "justified", i.e., being used or practiced, well before the justification principle was set up by ICRP.

- Optimization: Exposures to radiation should be as low as reasonably achievable. Optimization implies that measures will be taken to reduce exposures until the benefits of further reductions do not justify their cost. It is not clear how this principle can be rigorously applied, particularly as it requires some quantitative estimate of the monetary value of a life saved. In practice, optimization is applied in two ways: as an exhortation to use "best available technology" and as a recognition that merely complying with dose limits is not enough. If further dose reductions are practicable at reasonable cost, they should be made. Optimization generally refers to collective rather than individual radiation doses.

Since justification means that no nuclear activity should be adopted unless it produces enough benefit to offset the radiation detriment it causes, it appears that below a threshold of radiation detriment, i.e., when the activity is optimized, it may be adopted. Does this mean that only optimized nuclear activities can be justified?

Examples can be used to make the point (the examples which are analyzed in this document correspond to French situations but it is likely that similar situations can be observed in other countries).

Radioscopy

Radioscopy is probably one of the most interesting example to look at regarding the principles of justification and optimization because of a historical perspective.
At the beginning of the 20th century, the use of X rays in medicine develops considerably because it appeared immediately as a very new, efficient and promising technique.

During World War I, there were considerable needs for searching small shrapnels in the bodies of the soldiers. Radioscopy with fluorescent screens fulfilled the needs of the fast research of these metallic pieces. Since the question was to save lives, the justification of radioscopy was not even a question (the principle of justification was not established anyway!).

Although some pioneers in radiology already knew that ionising radiations could produce some deterministic effects such as skin burns of the hands, very few suspected that some stochastic effects could result from exposure to ionising radiations. Thus, radioscopy with fluorescent screens continued to be widely used without any significant protection for both patients and radiologists. At that time, radioscopy used the simple technique of a fluorescent screen placed in between the patient and the radiologist.

The persons who were mostly exposed to ionizing radiations were the radiologists and they paid the tribute. Because of a large increase in the number of leukaemias among them,

radiologists were the first to pay attention to the issue of radiation protection. Consequently, the International X ray and radium protection committee (the future International commission on radiological protection ICRP) was created during the 2nd congress of the International Society of radiology in 1928, and the first radiation protection unit proposed by the International commission on radiation unit (ICRU created in 1925 during the 1st congress of the Intentional Society of radiology), the Roentgen, was adopted.

Although the risk of using radioscopy with fluorescent screens was known, this not optimized technique continued to be widely used for the examination of the lungs and the bones during these decades of the 20th century where tuberculosis was the number one disease. Indeed, the justification of such investigations was not an issue for pneumologists and experts in tuberculosis.

Radiology techniques made progress. In the mid 50s, X ray image intensifiers appeared. In the late 60s, image intensifiers / TV cameras started to be used to be replaced later on by CCD cameras. In the 80s, digital imaging processing techniques started with continuous improvement of image enhancement and automatic imaging assessment. During all these decades, cardiologic and vascular applications successfully developed in combination with catheterization guided radioscopy.

Although the use of radioscopy with fluorescent screens decreased slowly, it is amazing to note that the interdiction of radioscopy without image intensification appeared only with Directive 96/29 Euratom in 1996. Time had come to definitely suppress a non optimized technique and to replace it by a more optimized one.

In fine, it took almost a century for radioscopy with fluorescent screens which was a great and useful technique to become unjustified because it was not optimized and could be replaced by a more optimized technique, i.e., radioscopy with image intensification.

Other examples in the field of medicine.
Virtual coloscopy or coronaro-scanography are techniques developing rapidly on the basis that they are non invasive in comparison with the alternative techniques, i.e, the optical coloscopy and the coronaro-angiography. This is due to the conjunction of spiral CT and of multislice detectors.

But in order to visualise a lesion, either a tumor of the colon or a coronary stenosis, it is mandatory to sample at a resolution twice better than the size of the lesion. Basically, a coronaro-scanography is currently performed with slices of 0.6 mm in order to be able to reconstruct with a resolution of 1.2 mm. The dosimetry, as evaluated by the dose x length product (DLP), is currently in the range of 2000 Gy.cm, that is four times greater than the DLP of an ordinary slice. Thus the equivalent dosimetry is probably in the range of 80 mGy, value high enough to be considered carefully by radiation protectionnists. Indeed, more detailed evaluations are necessary.

Indeed, cardiologists/radiologists are requesting coronaro-scanography with a better resolution because a resolution of 1.2 mm is not sufficient for detecting small lesions due to coronary artery disease. Thinner slices are needed and the dosimetry increases correspondingly.

CT scanners are widely used for coronary investigations because nobody seems to question a priori the justification of such examinations, and because it is economically rewarding to perform such tests when you own a CT scan.

The problem comes when a coronaro-scanography examination is doubtful; what is the percentage of doubtful examinations ? A regular coronary angiogram is then necessary. The whole process is not optimised in terms of doses delivered since 2 examinations are necessary instead of one ; consequently such a process should not be justified.

In order to make progress on this issue, the nuclear safety authority (ASN) of France has created in 2006 a working group with two missions:

- on the one hand to establish standard procedures of realization of a coronaro-scanography examination;
- and on the other hand to establish the clinical indications of a coronaro-scanography examination.

Indeed, these 2 missions will be accomplished in parallel because a specific optimized procedure must be designed to be able to produce a given diagnosis. Justification and optimization are clearly linked in a combined process.

Medicolegal exposures

There are numerous situations where exposure to ionizing radiations results from a medicolegal situation and where the place of the 2 principles of justification and optimization is not so clear.

At time where tuberculosis was the most severe disease, chest X ray was justified as a diagnostic tool and remained as such in many countries although the prevalence of tuberculosis tremendously decreased. The “so much justified” chest X ray became mandatory for any person getting a job or changing position in the French administration. An annual chest X ray was done to all workers as a basis of their annual survey. Prisoners had a chest X ray at the admission to each prison...
In order to perform all these radiographies, community clinics received X ray equipments, or trucks equipped with X ray equipment moved from place to place. Although these equipments were getting out of date after many years, chest X rays (not optimized if they ever were with some of these equipments!) continued to be realized.

In summary, fully justified chest X ray examinations were carried out whatever their optimization. Nowadays the paradigm has changed: only optimized X ray examinations performed on good quality equipments should be carried out only if the situation and/or the clinical status of the person so justifie the practice.

As another example, controls at the frontiers are developing tremendously. Whatever the reason of the control (drug search, antiterrorist measure, undercover entrance in countries...), X ray techniques exposing people to ionizing radiations are widely (mostly) used because of their convenience. The question remains open if these controls are justified par se, and/or if they can be justified if they are performed in a optimized way. Indeed alternative techniques should be developed.

Exposures to NORM

For a long time, exposures to naturally occurring radioactive materials (NORM) were not considered to fall in the scope of radiation protection, mostly because it seemed not possible to prevent such exposures. Thus, there is a priori no question of justification in this domain.

Time has changed and indeed radiation protection authorities cannot ignore one of the first cause of exposure to ionizing radiations of the whole population (the other one being the medical exposures).

Furthermore epidemiologic studies have now established that exposures to radon are the second cause of lung cancer after tobacco. This recent finding probably ends the fruitless battle between those who thought that radon exposure was not responsible for lung cancer (because tobacco was the prominent factor) and those for whom it was necessary to prevent unnecessary exposures to genotoxic radiations emitted by radon.

We have moved from a situation where the justification of exposure to radon was not an issue since radon is a natural gas, to a new situation where a clear justification appears: since it is possible to decrease to some extent the exposure to radon, for example by ventilating the basements of the houses and the buildings, exposure to high levels of radon needs to be justified. In many countries, radiation protection authorities have set up rules to decrease radon exposure when the concentration in radon in air exceeds threshold values; these rules apply to public buildings (such as schools) and sometimes also to private housing.

In fine, the possible optimization of radon exposure paved the way to the justification of radon exposure.

Conclusion

Time has come for a holistic approach of radiation protection where the 2 principles of justification and optimisation are taken together. The goal is certainly not to stop the practice of new medical investigations but to revisit the rationale of the indication of optimised examinations. By extension, it would be certainly desirable to revisit all nuclear activities using ionising radiations and to investigate their justification in the light of their optimisation and vice versa since the 2 principles of justification and optimization are closely linked to each other.