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Awareness of radiation protection and dose levels of imaging procedures among medical students, radiography students, and radiology residents:

a comprehensive, single-centre survey

INTRODUCTION

Several radiological examinations expose patients to significant amounts of ionising radiation [1] and the recent evolution and widespread availability of imaging modalities such as multidetector computed tomography (CT) have led to a steady increase in the number of examinations performed and rising concerns in the scientific community about the possible side effects in patients, especially those related to the risk of radiation-induced cancer [2]. While acute effects of radiation exposure (such as erythema or burns after some interventional radiology procedures) usually manifest themselves within a limited time frame, long term effects are more difficult to assess. Recently, some papers published in the scientific literature have demonstrated a small, but significant increase of the incidence of cancer in children and young patients who had undergone CT scans, confirming findings originally observed among survivors of the Japanese atomic bombs [3-4]. Although the debate about how big such risk could be is still open, it is clear that the problem cannot be underestimated.

Procedures involving the use of ionizing radiation must be carried out by professionals with a specific expertise in radiation protection, such as radiologists, physicists and radiographers. In the radiological field, while medical physicists play a controlling role, radiologists and radiographers are responsible for assessing whether, and eventually how, a radiological examination may be carried out so as to minimise patient exposure while retaining diagnostic accuracy. In this setting, a proper awareness of radiation protection issues and a deep knowledge of the radiation doses produced by different modalities are essential for radiologists to make the right decisions by fulfilling appropriateness and optimisation criteria.

In the past decade, several studies have been performed with the aim of estimating the radiation protection background of physicians from various medical specialties, and most of them have yielded disappointing findings.

It has been shown that, overall, physicians underestimate the radiation doses delivered by various imaging modalities, and in some cases they were even unable to differentiate between ionizing and non-ionizing radiation-based modalities [5-9].

This latter scenario has attracted our attention and stimulated us to investigate the actual level of radiation protection culture that medical students currently have — students who will be required to prescribe imaging examinations during their future professional life [10].

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STUDY DESIGN

A questionnaire consisting of 16 multiple choice questions was submitted to 60 radiology residents (RR), 56 medical students (MS), and 43 radiography students (RS) on the occasion of classes and seminars that they attended during their academic training. The questionnaire was divided into three separate sections, namely demographic information on the survey participant, awareness about radiation protection issues, and knowledge about radiation dose levels of common radiological examinations.

The **first section** was focused on the demographic features of the survey participants, e.g. gender, age, and level of training

	Age	Gender	Perceived knowledge (%)				Training (%)		
	(mean, SD)	(% Male)	Excellent	Good	Sufficient	Insufficient	Frequently	Rarely	Never
Radiology residents (n=60)	29.4 (3.3)	43.1	5.0	50.0	43.3	1.7	45.0	38.3	16.7
Medical students (n=94)	23.6 (1.6)	48.2	22.2	72.2	5.6	0	88.7	9.4	1.9
Radiography students (n=42)	22.5 (3.7)	44.2	0	35.7	54.8	9.5	26.8	46.3	26.8
P-value	<0.05*	<0.05**	<0.05***				<0.05***		

Table 1. Sample demographics (age, gender, and level of radiation protection awareness and training). SD = standard deviation. *F-test statistics by ANOVA, **Chi-square test, ***Fisher's exact test. P < 0.05 indicates statistical significance.

The **second section**, radiation protection awareness, was aimed at assessing the following points:
1. Radiation standards.
2. Susceptibility to radiation damage.
3. Regulations.
4. Knowledge concerning healthcare professionals with a higher exposure risk.
5. Tissues more susceptible to injury from ionizing radiation
6. Diseases related to radiation damage,
7. Knowledge of dose optimisation.

The **third section** (knowledge of radiation dose levels) investigated specific aspects of the following points:
1. average dose of a postero-anterior chest X-ray (considered as a common reference unit to compare radiation exposure from different radiological examinations).
2. Background radiation dose received by the general population.
3. Lumbar spine X-ray dose.
4. Mammography dose (bilateral, two projections for each side).
5. Chest CT dose.
6. Pelvic magnetic resonance imaging (MRI) dose.
7. Positron emission tomography (PET) dose.
8. Abdominal ultrasound dose.
9. myocardial scintigraphy dose.

RESULTS

Radiation protection awareness - Subjective Performance

The demographics of the survey participants and their degree of perceived radiation protection knowledge and previous training are shown in Table 1.
As to the perceived knowledge of radiation protection issues, the MS showed the highest value among the three categories of survey participants, claiming to have at least a good knowledge in 94.4% of cases (22.2% excellent, 72.2% good). The RR declared they had at least a good knowledge in 55% of cases (5% excellent, 50% good), whereas the RS had the lowest rating with a perceived good level of knowledge in 35.7% of cases and no cases of perceived excellent knowledge.

ABBREVIATIONS
RR - Radiology Residents
MS - Medical Students
RS - Radiography Students

Radiation protection awareness - Objective Performance

Total questionnaire scores are reported in Figure 1. All RR and RS (96.7% and 100%) and the majority of MS (89.1%) were aware of the need to inform patients about the risks of radiation exposure. Conversely, only 54.5% of MS knew that female children are

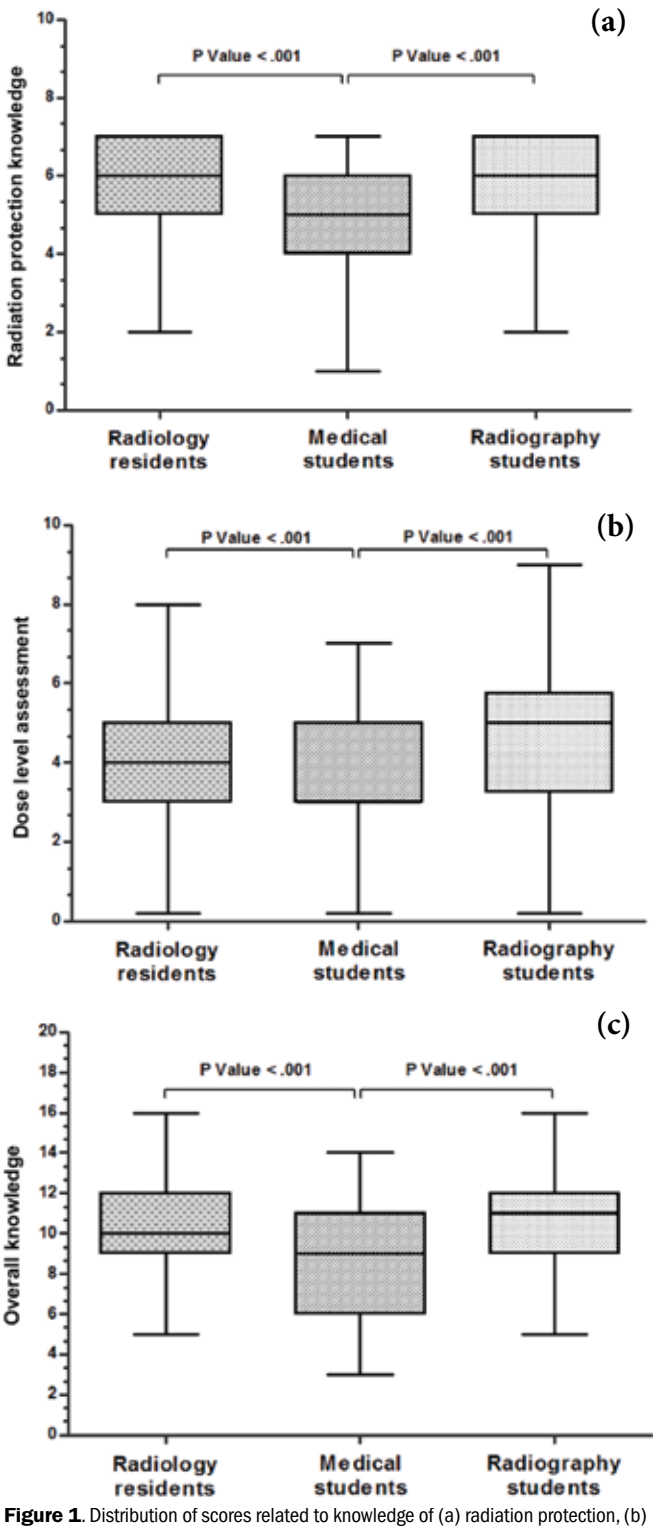

Figure 1. Distribution of scores related to knowledge of (a) radiation protection, (b) dose level assessment, and (c) overall knowledge (i.e. radiation protection and dose level assessment) among radiology residents, medical students, and radiography students. P-values indicate statistical significance.

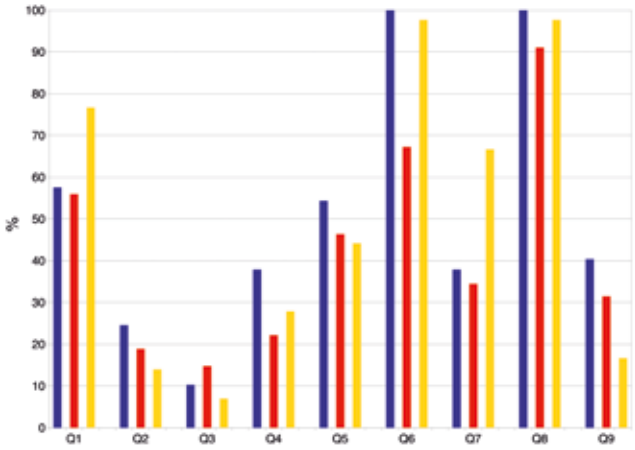

Figure 2. Overall distribution of correct answers to questions (expressed in percentage) about the dose of natural background radiation and commonly performed imaging examinations given by radiology residents (blue), medical students (red) , and radiography students (yellow).

most sensitive to ionising radiation; better results were obtained by RS and RR, who gave correct answers on 82.1% and 76.3% of cases, respectively. The majority of RR and RS (83.3% and 83.6%) correctly answered that referring physicians, radiologists and radiographers are all responsible for unnecessary patient exposure and lack of optimization, whereas MS performance in this respect was significantly worse (73.2%). Interventional radiologists and cardiologists were properly considered as the most exposed category by 88.3% of radiology residents and 76.2% of RS, whereas fewer than 50% of MS gave the correct answer (43.6%). Almost all RR (97.7%) and the majority of RS (87.5%) knew that the breast is the tissue with the highest radiation sensitivity, whereas just about three quarters of MS (75.5%) gave the correct answer. The question about stochastic radiation damage was answered correctly by as few as 69.8% of RS, 62.7% of RR, and only 57.1% of MS. Overall, almost all survey participants knew the concept of dose optimisation, yet the rate of correct answers by MS was slightly, but significantly, worse compared with the other groups (MS 87.3% vs RS 95.0% and RR 95.3%, $p<0.05$).

KNOWLEDGE OF DOSE RADIATION LEVELS

As to the questionnaire section related to main radiation protection issues [Figure 2], the radiation dose from a standard chest X-ray examination was correctly estimated by 77.6% of RS versus only 57.6 of RR and 56.0% of MS. The radiation dose delivered by a lumbar X-ray examination was known by only 10.3% of RR, 14.8% of MS, and 7.0% of RS, respectively. Mammography dose was known by 37.9% of RR, 22.2% of MS and 27.9%of RS. Surprisingly, 3.4% of RR, 1.9% of MS, and 4.7% of RS considered mammography as a radiation-free procedure. The dose figure best known by all participants was that of a chest CT examination (RR 54.4%, MS 46.4%, RS 44.2%). Strikingly, 1.8% of both RS and MS believed that CT does not involve the use of ionizing radiation. Moreover, MRI and US were correctly identified as radiation-free by all RR (100%) and almost all RS (97.7%), whereas 9.1% and 32.7% of MS, respectively did not even know that US and MRI are radiation-free.
As to nuclear medicine procedures, RS correctly estimated the radiation dose of ^{18}F-FDG PET-CT examinations more than RR and MS (66.7% vs 37.9% and 34.5%, respectively), whereas the radiation dose delivered by myocardial scintigraphy was known more by RR (40.4%) than by MS (31.5%) and RS (16.7%). Finally, a small, but significantly higher percentage of RR and MS thought that PET-CT (3.4% and 5.5%, respectively) amd myocardial scintigraphy (9% and 3.7%, respectively) were radiation-free procedures, as compared with RS.
Overall, the performance of medical students was significantly worse than that of RR and RS ($P<0.05$), and these latter had a better knowledge of radiation protection issues than RR ($P<0.01$). Fewer than 50% of survey respondents correctly answered all questions of the survey.

4. CONCLUSIONS AND FUTURE PERSPECTIVES

Our findings show that radiology residents, radiography students and medical students have a limited awareness about radiation protection, with a particular gap of knowledge concerning real radiation doses of daily radiological examinations.

More specifically, medical students tend to overestimate their own knowledge of radiation protection issues, though their radiation protection skills are significantly worse compared with radiology residents and radiography students. On the other hand, these latter believe that their radiation protection background and training is not enough for their future professional needs, and their objective radiation protection knowledge actually reveals significant flaws.

To overcome these shortcomings, specific initiatives should promptly be taken with the endorsement of academic institutions and scientific societies, including radiation safety courses in medical schools and radiography courses, systematic auditing of the degree of radiation protection knowledge at teaching hospitals, and update courses for the working staff.

To this purpose, we believe that a larger study involving multiple institutions would be warranted to gain a broader, more solid insight about the actual radiation protection knowledge of medical students, potentially allowing to spot and tackle deficiencies of current educational programs at a higher level.

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