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ORIGINAL PAPER

Radioprotection (un)awareness in cardiologists, and how to improve it

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Abstract In 2010 the International Atomic Energy Agency launched the "3 A's campaign": Audit, Appropriateness and Awareness for radiological justification, which is an effective tool for cancer prevention. Cardiologists prescribe the majority of radiological testing, but their awareness of doses and risks of ionizing cardiac imaging test is low. To assess radioprotection awareness of prescribing and practicing physicians (mainly cardiologists) before and after a radioprotection course. We held a 1-day 6-h primer of radioprotection for a limited number (20–35) of physicians. The course offered 8 continuing education credits from the Italian Health Ministry and was held 9 times over 3 years. We had 425 attendees, but full data sets (with complete questionnaires) were available for 403 physicians (55% women, age 45 ± 6 years), including 55% cardiologists, 40% general practitioners, 5% others (mainly cardiology fellows). For each attendee, a radiological awareness score was obtained before and after the course, with a survey containing 10 multiple-choice questions (5 answers) on radioprotection basics (doses of common examinations in multiples of chest x-rays; associated cancer risk, etc.). Each answer was scored from 0 ("don't know"), 1 ("strongly disagree") to 4 ("strongly agree"). The radiological awareness score of the 403 attendees improved from 31 ± 3 (before) to 37 ± 2 (after training, $P < 0.001$ vs. pre-training). As an example, before training, 25% of attendees believed that radiation-induced cancer risk disappears after 6 months (10% of respondents), 12 months (8%) or 5 years (7%), whereas 75% (becoming 98% after training) correctly estimated that radiological damage is cumulative over one's lifetime. Awareness of radiological doses and risks, albeit essential for risk–benefit assessment of radiological testing, is suboptimal among cardiologists, but can dramatically improve with a limited teaching effort through targeted training.

Keywords Cancer · Imaging · Learning · Radiation

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Introduction

Medical use of radiation is the largest man-made source of radiation exposure [1]. In developed countries, irradiation from medical ionizing tests

results in a mean effective dose per year per head corresponding to about 150 chest x-rays—an amount comparable to that of 1 year of natural background radiation [2, 3]. This radiation exposure may elevate a person's lifetime risk of developing cancer [4–6]. A balanced public health approach seeks to support the benefits of these medical imaging exams while minimizing the risks [1].

In 2010, the FDA started a campaign to reduce unnecessary medical radiation exposure [1], and the International Atomic Energy Agency launched the "3A's campaign" (Audit, Appropriateness and Awareness) to improve radiological justification, which is an effective tool for primary prevention of cancer [7]. This is especially important in cardiology, since cardiologists prescribe the majority of radiological testing [8, 9] and as interventional cardiologists, are the most exposed among exposed professionals [10, 11]—however, their awareness of doses and risks of ionizing testing is low [12]. The study's hypothesis is that radioprotection unawareness is not a law of nature but can be modified with a brief, targeted teaching effort. Aim of this study was to assess radioprotection awareness of physicians (mainly cardiologists, but also general practitioners) before and after a 1-day intensive radioprotection primer course, as a part of the SUIT-Heart (Stop Useless Imaging Testing in Heart disease) project.

Methods

We held 14 extra-mural 1-day, 6-h primer courses on radioprotection over a 3-year period (2008–2011). The course consisted in 6 classroom lessons on: (1) clinical criteria for appropriateness in diagnostic imaging; (2) biological basis of radiation risk; (3) radiological doses of common examinations; (4) professional exposure of cardiologists; (5) medico-legal implications of inappropriate prescriptions; (6) computer programs to increase radiological responsibility.

The faculty comprised a cardiologist, a radiologist, a radiology technician, a legal physician, a biologist and a computer scientist. Teaching material also included a software program for user-friendly lifetime dose reconstruction and risk calculation (http://suit-heart.ifc.cnr.it Download section: Installazione + esempi) developed in our Institute and distributed to the participants, a syllabus with slide collection, 10 key articles from recent literature, and a poster summarizing doses and risks of the main radiological, nuclear medicine, CT and invasive cardiology tests. All supportive material was illustrated and discussed during the course. We had 425 attendees, but full data sets (with complete questionnaires) were available from 403 physicians (55% women, age 45 ± 6 years), including 55% cardiologists, 40% general practitioners, 5% others (mainly cardiology fellows). Reasons for drop-outs were inability to attend for the full duration of the course ($n = 10$), unwillingness to enter the study ($n = 5$) or non- interpretable or incomplete questionnaire ($n = 7$).

Each attendee was asked to answer a multiple-choice test at entry (9 A.M.) and again at the end of the class (5 P.M.). The questionnaire was anonymous, and each participant could identify him- or herself with a pre-assigned nickname. Each course offered 8 continuing education credits of Italian Health Ministry. For each attendee, a radiological awareness score was obtained before and after the course, with the same survey of 10 multiple-choice questions (5 answers) on radioprotection basics (doses of common examinations in multiples of chest x-rays; associated cancer risk; etc.). Each answer was scored from 0 ("I don't know"), 1 ("strongly disagree") to 4 ("strongly agree") and a total score was obtained for each attendee before and at the end of the course. In particular, different aspects were addressed:

Rate of inappropriate imaging examinations, reported to be around 50% for echocardiography in Tuscany (question 1) and 30% for radiological imaging in Europe (question 2) [13, 14];

Medical imaging contribution to overall radiation exposure, reported to be around 50% in the USA according to the estimation of National Council on Radiation Protection [3] (question 3);

Cost of a cardiac PET scan, reported to be 14× that of a resting echocardiogram used as a cost comparator [15];

Cancer risk due to radiation, assumed to be statistic (question 4), doubled in children compared to adults (question 7), and cumulative over lifetime (question 10) [16–18];

Effective dose exposure of common imaging examinations, being highest among those listed, for abdominal CT (around 500 chest x-rays) in radiology (question 5) and thallium myocardial perfusion scan

(around 1,500 chest x-rays) in nuclear medicine (question 6) [8];

Legal framework regulating medical imaging with ionizing tests, which forbids unjustified exposure and states responsibility of both the prescriber and the practitioner according to the Euratom law that is at the basis of legislation in European countries (question 9) [19].

Statistical analysis

Data are expressed as mean ± standard deviation. Continuous variables were compared by paired-samples *t* test. The probability value of <0.05 was considered statistically significant. All statistical calculations were performed rising SPSS for Windows, release 12.0 (Chicago, Illinois).

Results

The overall radiological awareness score could range from 20 (= random answers, with average score of 2) to 40 (= full awareness). In the 403 attendees who completed the study, radiological awareness score improved from 31.5 ± 3.7 (before) to 37.3 ± 2.5 (after training, $P < 0.001$ vs. pre-training). The summary presentation of questions and answers is reported in Fig. 1 (questions 1 to 5) and Fig. 2 (questions 6 to 10). As an example, before training, 25% of attendees believed that radiation-induced cancer risk disappears after 6 months (10% of respondents), 12 months (8%) or 5 years (7%), whereas 75% (becoming 98% after training) correctly estimated that radiological damage is cumulative over the lifetime (Fig. 1). Before training, 60% of attendees believed that ionizing medical testing can be prescribed without any legal accountability (25%), or with accountability only for the prescribing physician (20%) or only for the practitioner (15%), whereas 45% (and 96% after the training) correctly answered that the Euratom Law 1997 prescribes that every effort should be made to avoid unjustified use of radiation and there is legal accountability (with a fine of up to € 5,000 Euros and jail up to 3 months) for both the prescriber and the practitioner (Fig. 2).

Discussion

Awareness of radiological doses and risks, as well as of legal and economic implications of imaging testing, albeit essential for risk- and cost-benefit assessment, is uniformly limited among prescribing and practising physicians. However, it can dramatically improve with a limited teaching effort through targeted training focused on radioprotection basics. It is not necessary to have in-depth knowledge of health physics and radiobiology to become familiar with essential information necessary for the responsible practice of medicine.

Comparison with previous studies

In our environment of a highly specialized, high-tech tertiary care cardiology referral center, we have already shown that 40% of stress imaging testing is inappropriate (i.e., it could be avoided) [20, 21] and specialists seriously underestimate and frequently ignore radiological doses and oncogenic risk associated with most common radiological testing with high radiation exposure [12]. This situation is the rule rather than the exception, and similar levels of testing inappropriateness have been found for specialized testing such as stress perfusion imaging [22] or cardiac CT [23]. High levels of radiological unawareness have also been observed in professional communities such as general practitioners [24], radiologists [25], or pediatricians [26]. A recent systematic review of 14 relevant articles shows moderate to low knowledge among physicians concerning radiation doses and the corresponding health risks [27]. This ethically and legally uncomfortable situation also offers a unique opportunity for a knowledge-based increase in appropriateness. If we know the risks, we can include them in the risk–benefit balance necessary to assess the appropriateness of any given procedure.

Clinical implications

Radiological unawareness is one of the recognized sources of a high rate of inappropriate examination in ionizing medical imaging, even for procedures with high radiation doses. Doctors (on average) do not always know what they do with ionizing radiation. This leads to waste of resources and accumulation of

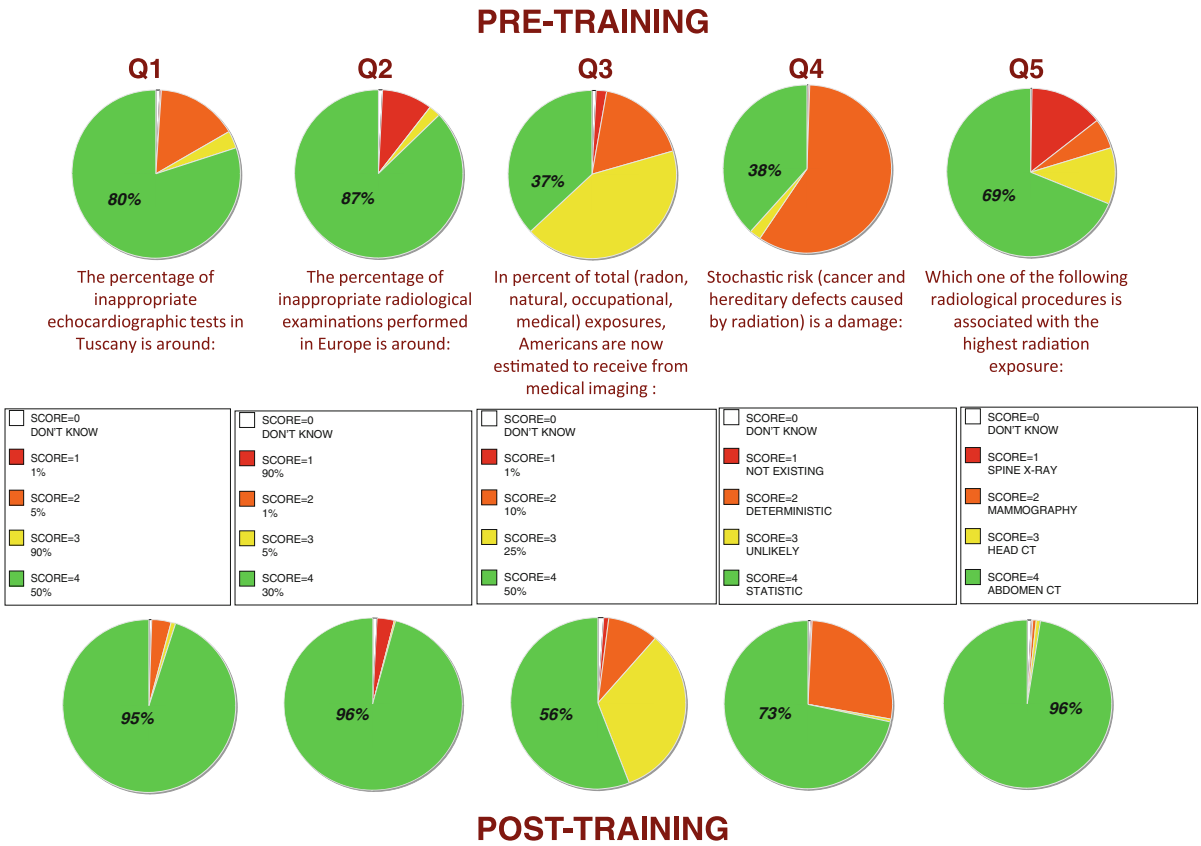

Fig. 1 Pie graphs showing distribution of answers to questions 1–5 (from *left* to *right*) before (*upper panels*) and after (*lower panels*) the course. The percentage of correct answers before and after training is shown in the green part of the pie

avoidable cancer risk, but it also offers a unique opportunity to spare a considerable amount of resources by merely targeting radioprotection culture and knowledge. Reducing inappropriate testing will eventually improve the quality of health care, shorten waiting lists inflated by useless examinations, and reduce long-term cancer risk due to ionizing radiation [28–30].

What to do for better education

Radiation safety issues are not adequately taught either at medical schools or during postgraduate years, in most of the countries, except in radiology residencies. As suggested by the American College of Radiology [28], Food and Drug Administration [29], International Atomic Energy Agency [7] and US President's Cancer Panel [30], radiation protection must be an integral component of training programs of new physicians, at least in cardiology and general practitioners. Courses regarding both the risks associated with radiation and the appropriate clinical indications for imaging use should be mandatory in the curriculum of medical students. Art. 45 of the draft of a new Directive of the European Commission that is expected to be published in 2012 states: "Member States shall ensure the introduction of a course on radiation protection in the basic curriculum of medical and dental schools" [31]. This aspect is especially important for invasive cardiologists, whose high and unprecedented levels of radiation exposure can be reduced by a factor of 10 by targeted radioprotection training [32].

It is also true that radiation information is typically absent or difficult to find and understand [33]. Up to now most of the imaging equipment in use is unable to produce dose information. Moreover, dose parameters are presented with non-standardized terminology that make it difficult for clinicians to really understand the dose.

The second questionnaire showed statistically significant better results and showed that a specific

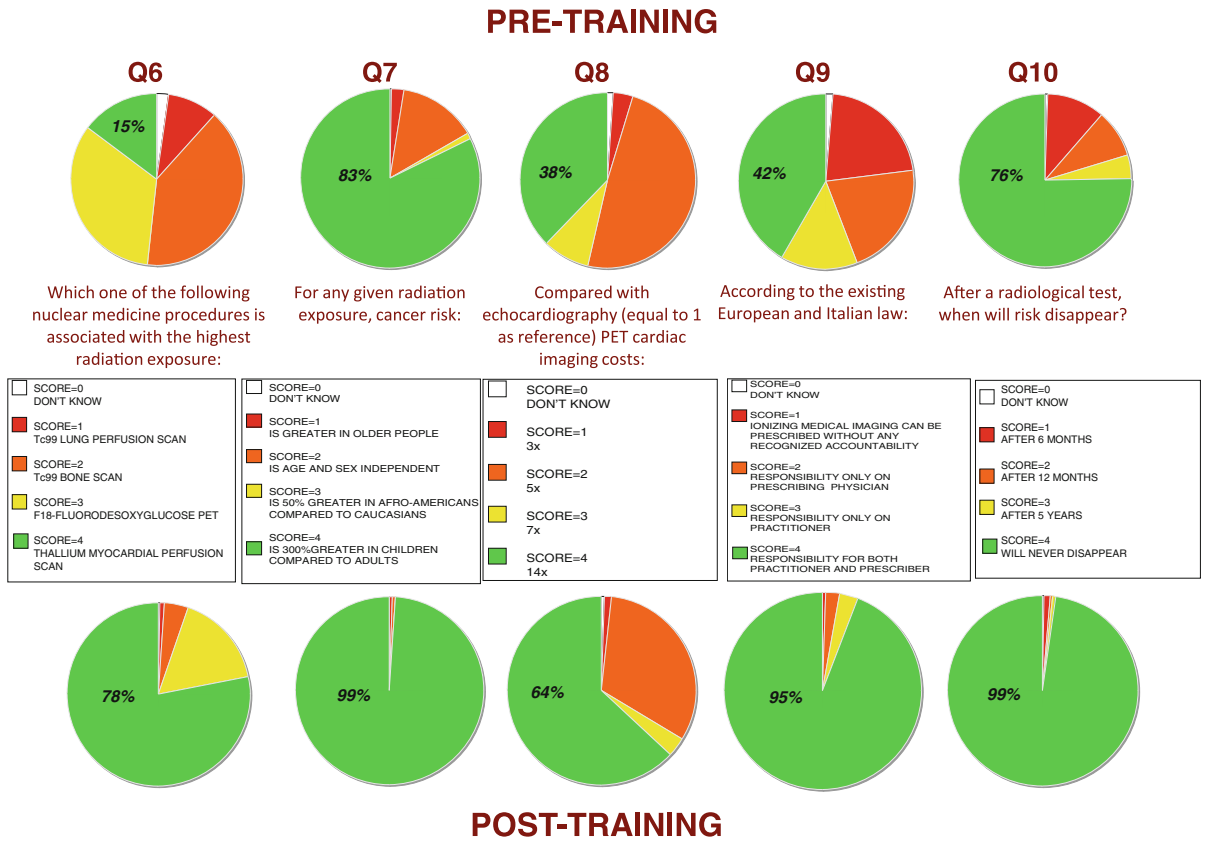

Fig. 2 Pie graphs showing distribution of answers to questions 6–10 (from *left* to *right*) before (*upper panels*) and after (*lower panels*) the course. The percentage of correct answers before and after training is shown in the green part of the pie

radioprotection course with a clear and concise approach, presenting the basic concepts of legal aspects, public health risks and economic impact of imaging procedures has a cultural benefit.

Conclusions

Awareness of radiological doses and risks, albeit essential for risk–benefit assessment of radiological testing, is limited among physicians. However, it can dramatically improve by means of a limited teaching effort through targeted training.

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Conflict of interest We declare that does not exist conflict of interest.

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