Int J Cardiovasc Imaging (2007) 23:143–147
DOI 10.1007/s10554-006-9148-x

EDITORIAL COMMENT

# Sustainability in the cardiac cath lab

**Eugenio Picano · Gennaro Santoro · Eliseo Vano**

Accepted: 2 August 2006 / Published online: 11 October 2006


**Abstract** Use of radiation for medical examinations and test is the largest manmade source of radiation exposure. Interventional procedures are only 2% of all radiological procedures, but contribute to about 20% of the total collective dose per head per year. On average, a left ventriculography and coronary angiography corresponds to a radiation exposure for the patient of about 300, a coronary stent to 1,000, a peripheral artery intervention to 1,500 to 2,500, and a cardiac radiofrequency ablation to 900-1,500 chest x-rays. Invasive cardiology procedures increased tenfold in the last ten years and growth in the field has been accompanied by concern for the safety of the staff. Interventional cardiologists have an exposure per-head per year two- to three times higher than that of radiologists, with an annual exposure equivalent to around 250 chest x-rays per head. A reduction of occupational doses by a factor of ten can be achieved simply by and intensive training program. The awareness of radiation effects may be suboptimal in the medical community. It is recommended by professional guidelines and reinforced by the European law that the responsibility of all physicians is to minimize the radiation injury hazard to their patients, to their professional staff and to themselves.

**Keywords** Catheterization· Radiation· Sustainability

In response to the article by Rigatelli et al. Impact of intracardiac echocardiography on radiation exposure during adult congenital heart disease catherer-based interventions (DOI: 10.1007/s10554-006-9125-4).

E. Picano (✉)
CNR, Institute of Clinical Physiology, Via Moruzzi, 1, Pisa 56124, Italy
e-mail: picano@ifc.cnr.it

G. Santoro
Interventional Cardiology, Careggi Hospital, Florence, Italy

E. Vano
Radiology Department., Medicine School Complutense University, Madrid, Spain

## 1 Introduction

In this issue of the Journal, Rigatelli et al. present their experience with intracardiac echocardiography to guide transcatheter closure of interatrial communication [1]. The Authors have a long-standing experience in the field and show the benefits of ICE-guided interventions versus conventional fluoroscopy-guided interventions. ICE provides a far more adequate imaging of atrial architecture and more accurate information regarding the devices and catheter positions, resulting in improved safety and accuracy of the procedure itself, as originally proposed by Hijazi [2]. In addition, in the present study the Authors address a very important, original, and usually neglected issue: the capability of ICE-guided interventions to reduce significantly the radiation exposure. To fully appreciate the potential impact of this apparently minor aspect one should put these data in the larger framework provided by the epidemiological impact of medical radiation and more specifically of the impact of medical radiation in the cath lab.

## 2 Exposure to medical radiation

Use of radiation for medical examinations and tests is the largest manmade source of radiation exposure [3]. The medical sources of radiation exposure total a dose equivalent of about 100 chest x-rays per head per year [4], more or less matching the value from natural sources of radiation [5]. Berrington de Gonzalez and Darby, applying the assumption that there is no safe level and that the risk of getting cancer increases linearly with dose, recently calculated that the lifetime risk of developing cancer attributable to diagnostic X-rays in industrialized countries is around 2% (from 0.6% in UK to 3.2% in Japan), on the basis of UNSCEAR's dose estimates of 1991–1996 [6]. In the last decade, the population dose increased several fold. The most recent trends concerning the utilization of cardiac catheterization, CT and nuclear medicine scans are impressive, and the currently available cancer risk estimates from medical radiation are likely to be underestimates [7].

## 3 Cath lab contributions to radiation exposure: high and rising

Interventional procedures are only 2% of all radiological procedures, but contribute to about 20% of the total collective dose per head per year in Germany [4]. This high value is steadily increasing. In Europe, arteriography and interventions were 350,000 in 1993 and over 1 million in 2001 [8]. Each procedure involves a very large radiation exposure. On average, a left ventriculography and coronary angiography corresponds to a radiation exposure of about 300, a coronary stent to 1,000, a peripheral artery intervention to 1,500–2,500, and a cardiac radiofrequency ablation to 900–1,500 chest x-rays [9–13]. The true exposure in the individual patient may vary depending on a number of reasons including complexity of percutaneous interventions, differing approaches to interventional, e.g. direct stent or pre-dilation, different X-ray equipment, different awareness and education of staff in radiation dose estimation, etc. [14]. Various advisory bodies use the conservative assumption that no level of radiation is without excess risk, that is, the zero threshold hypothesis [15, 16]. Currently, a linear relationship between dose and long-term risk of cancer is used in the risk model for low-level exposures. Also for clinical decision making, medical imaging European guidelines suggest that higher doses translate into higher risks and the risk is cumulative, meaning that when several tests or procedures are performed, dose is added to dose and risk to risk [17]. The cumulative exposure per patient, per problem, during a single admission may well reach values around a cumulative exposure of thousands of chest x-rays, as it has already been shown for repetitive CT in renal disease [18]. This raises a concern not only for the population, but also possibly for the individual patient. A cumulative effective dose of 100 mSv, corresponding to 5,000 chest x-rays, can be reached by the execution—one after the after, in the same patient—of a Multislice Computed Tomography (MSCT) (15 mSv), a Thallium scan (20–25 mSv), a coronary angiography (6 mSv), a coronary stenting (15 mSv), a follow-up repeat MSCT (again 15 mSv) and Thallium scan (again 20–25 mSv). This radiological spiral may even be triggered by a screening in an asymptomatic subject ''at risk'', and can end-up in an anatomy-driven coronary revascularization of questionable prognostic benefit on cardiovascular events. The cumulative dose of 100 mSv gives an extra risk of cancer of 1 in 100 exposed patients. Of these 100 patients, 42 will have cancer independently of radiation exposure [16].

## 4 Cardiac cath lab and professional friendly fire

Interventional cardiology is developing at a rate that is ahead of both the supporting research and regulatory framework. Invasive cardiology procedures increased tenfold in the last ten years in Europe and growth in the field has been accompanied by concern for the safety of the staff directly involved with such high radiation procedures (DIMOND Concerted Action II 1999 and III 2001) [9, 19]. Interventional cardiologists have an exposure per-head per year two- to three times higher than that of radiologists and this exposure has increased steadily in the past 20 years. The most active and experienced interventional cardiologists in high volume cath labs have an annual exposure equivalent to around 250 chest x-rays per head . Contemporary interventional cardiologists also show an increased rate of somatic DNA damage, reflected in higher frequency of micronuclei versus controls [20]. Micronuclei are an intermediate endpoint of carcinogenesis and a long-term predictor of cancer [21]. Some of this potential damage in professionaly exposed staff is obviously unavoidable, due to high radiation burden of the procedures, with close presence of the operator near the radiation source, and not infrequently with the patient in clinically critical conditions. Another part of the exposure is however avoidable, and is due to the exposure deriving from inappropriate indications and lack of implementation of safety principle within the cath lab [22]. In the words of an eminent interventional cardiologist, ''increasingly, we have become casual regarding our own exposure in the cath lab. We forget to wear the dosimeters. We pay little heed to monthly or cumulative reports of radiation exposure. While some institutions require a course in radiation safety prior to issuing the radiation dosimetry badges to new fellows, they represent the exception. Not infrequently, there is a machismo disregard for radiation protection'' [23]. The unavoidable, socially valuable friendly fire with fully acceptable individual risks of exposed health professionals, become a largely useless, socially detrimental, and avoidable extra-risk which will not improve, and possibly will decrease, the quality of health care exposing the patient, and the doctor, to increased risks without commensurate increased reward.

## 5 Sustainability in the cath lab

In this larger framework, the data of Rigatelli et al. can be better appreciated in their specific impact on radiation exposure and on the culture of safety in the cardiac cath lab. ICE reduced significantly the radiation exposure to the patient. For instance, if 10,000 procedures of transcatheter closure of interatrial communications are performed each year worldwide with a median exposure of 5 mSv (250 chest x-rays), the long-term risk associated with a fluoroscopic procedure corresponds to about five new cancers, of which one half will be fatal [16]. The ICE procedure will cool down this long-term risk, and four new cancers (instead of five) will develop from the same hypothetical 10,000 procedures. This is an appealing fringe benefit for the ICE procedure, that is even more accurate with ICE than the traditional fluoroscopy-guided intervention [1, 2]. More generally, the inclusion of the risk-side in the risk-benefit approach will have far-reaching implications in our daily practice. In the short-term, the awareness of long-term risk will unavoidably lead to implementing a culture of safety in the cath lab, with benefits to the patient and the staff. A reduction of occupational doses by a factor of ten can be achieved simply by an intensive training program in radiation protection [24]. In the medium term, an industrial and scientific strategy should include upgrading of technological apparatus, since obsolete and/or malfunctioning instruments are a major cause of useless radiation exposure, and possibly implementation of radiation-sparing techniques for more intensive procedures especially in children and adolescents, who are two to three-fold more sensitive than adults to the damaging effects of radiation exposure [15, 16]. These radioprotection assumptions have been recently corroborated by direct assessment of increased chromosomal aberrations in peripheral lymphocytes of young adolescents who were exposed to low-level radiation at age $<1$ year for congenital heart disease

[25]. In this context, ICE–assisted ablation of atrial fibrillation [26] or MRI-guided cardiac catheterization and intervention in children [27] are especially attractive options for abating societal and individual costs of long-term damage. Eventually, the sustainability will become a dominant issue in medical imaging—and especially in the cath lab, which is at present the epicentre of the contemporary medical radiological tsunami. Sustainability is an advantage for the standards of our health care, but also economically advantageous. After all, in 2000, the Swiss ''Union of Private Bankers''- not exactly a philanthropic society—sponsored a study on the importance of ecologic performances on competitiveness. The conclusion of this report was that eco-efficiency reinforces competitiveness: ''*the transition towards sustainability is necessary and, on the long run, unavoidable. In a world in which resources are diminishing, those who first recognize the need of sustainability and adopt adequate strategies will obtain the best results in the future global competition*'' [28]. Most recent guidelines of interventional cardiologist clearly state ''the responsibility of all physicians is to minimize the radiation injury hazard to their patients, to their professional staff, and to themselves'' [29]. We hope that cardiologists, within and outside the cath lab, will be the first to recognize the need of sustainability, in their own interest and in the interest of their patients.

## References


1. Rigatelli G, Cardaioli P, Roncon L et al (2006) Impact of intracardiac echocardiography on radiation exposure during adult congenital heart disease catheter-based interventions. Int J Cardiovasc Imaging Jul 5 (in press)
2. Hijazi Z, Wang Z, Cao Q et al (2001) Transcatheter closure of atrial septal defects and patent foramen ovale under intracardiac echocardiographic guidance: feasibility and comparison with transesophageal echocardiography. Catheter Cardiovasc Interv 52:194–199
3. United Nations. Sources and effects of ionising radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, 1996. Report to the General Assembly with Scientific annexes. United Nations sales publication E.96.IX.3 United Nations, New York, 1996
4. Regulla DF, Eder H (2005) Patient exposure in medical X-ray imaging in Europe. Radiat Prot Dosim 114:11–25
5. Picano E (2004) Sustainability of medical imaging. Brit Med J 328:578–580 (Review)
6. Berrington de Gonzalez A, Darby S (2004) Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries. Lancet 363:345–351
7. Picano E (2004) Risk of cancer from diagnostic X-rays. Lancet 363:1909–1910
8. Togni M, Balmer F, Pfiffner D et al (2004) Working Group, Interventional Cardiology and Coronary Pathophysiology, European Society of Cardiology (2004). Percutaneous coronary interventions in Europe 1992–2001. Eur Heart J 25:1208–1213
9. Neofistou V, Vano E, Padovani R et al (2003) Preliminary reference levels in interventional cardiology. Eur Radiol 13:2259–2263
10. Picano E (2004) Informed consent and communication of risk from radiological and nuclear medicine examinations: how to escape from a communication inferno. Brit Med J 329:849–851 (Review)
11. Bonomo L, Del Favero C, Pesce B, Tamburrini O, Scotti G, Salvatore M, et al. Agenzia per i Servizi Sanitari Regionali. La diagnostica per immagini. Linee guida. http://www.sirm.org/professione/pdf_lineeguida/linee_diag_x_img.pdf
12. Kocinaj D, Cioppa A, Ambrosini G et al (2005) Radiation dose exposure during cardiac and peripheral arteries catheterisation. Int J Cardiol Dec 1 (in press)
13. Coles DR, Smail MA, Negus IS et al (2006) Comparison of radiation doses from multislice computed tomography coronary angiography and conventional diagnostic angiography. J Am Coll Cardiol 47:1840–1845
14. Bernardi G, Padovani R, Morocutti G et al (2000) Clinical and technical determinants of the complexity of percutaneous transluminal coronary angioplasty procedures: analysis in relation to radiation exposure parameters. Catheter Cardiovasc Interv 51:1–9
15. International Commission on Radiological Protection (ICRP) (2005) Publication 99. Low-dose extrapolation of radiation-related cancer risk. Ann ICRP 35: 1–140
16. Health Risks from Exposure to low Levels of Ionising Radiation: BEIR VII 2005. Phase 2. books.nap.edu/catalog/11340.html.
17. European Commission. Radiation protection 118: referral guidelines for imaging. http://www.europa.eu.int/comm/environment/radprot/118/rp-118-en.pdf.
18. Martin DR, Semelka RC (2006) Health effects of ionising radiation from diagnostic CT. Lancet 367:1712–1714
19. Tsapaki V, Kottou S, Vano E et al (2005) Correlation of patient and staff doses in interventional cardiology. Radiat Prot Dosim 117(1–3):26–29
20. Andreassi MG, Cioppa A, Botto N et al (2005) Somatic DNA damage in interventional cardiologists: a case-control study. FASEB J 19:998–999
21. Fenech M (2006) Cytokinesis-block micronucleus assay evolves into a ''cytome'' assay of chromosomal instability, mitotic dysfunction and cell death. Mutat Res Jul 3 (in press)
22. Rehani MM (2006) Training of interventional cardiologists in radiation protection-the IAEA's initiatives. Int J Cardiol Mar 6 (in press)

23. Watson RM (1997) Radiation exposure: clueless in the cath lab, or sayonara ALARA. Cathet Cardiovasc Diag 42:126–127
24. Vano E, Gonzalez L, Fernandez JM et al (2006) Occupational radiation doses in interventional cardiology: a 15-year follow-up. Br J Radiol 79:383–388
25. Andreassi MG, Ati-Ali L, Botto N, et al (2006) Cardiac catheterization and long-term chromosomal damage in children with congenital heart disease. Eur Heart J May 17
26. Szili-Torok T, McFadden EP, Jordaens LJ et al (2004)Visualization of elusive structures using intracardiac echocardiography: insights from electrophysiology. Cardiovasc Ultrasound 2:6
27. Moore P (2005) MRI-guided congenital cardiac catheterization and intervention: the future? Catheter Cardiovasc Interv 66:1–8 (Review)
28. Sturm A, Wackernagel M, Muller K (2000) The winners and losers in global competition: why eco-efficiency reinforces competitiveness: a study of 44 Nations. Verlag Ruegger, Zurich
29. Hirshfeld JW Jr, Balter S, Brinker JA et al American College of Cardiology Foundation; American Heart Association/; HRS; SCAI; American College of Physicians Task Force on Clinical Competence and Training (2005). ACCF/AHA/HRS/SCAI clinical competence statement on physician knowledge to optimize patient safety and image quality in fluoroscopically guided invasive cardiovascular procedures: a report of the American College of Cardiology Foundation/American Heart Association/ American College of Physicians Task Force on Clinical Competence and Training. Circulation 111:511–532