A balancing act: potential benefits versus possible risks of radiation exposure

FI Peer (D.Tech: Rad) Nuclear Medicine, Inkosi Albert Luthuli Central Hospital, Durban

Abstract: Non-invasive imaging, that leads to early more precise and much less morbid diagnosis, has revolutionized patient management. There is a significant increase in radiation dose from medical procedures using non-invasive imaging, such as computed tomography and nuclear medicine. Minimizing radiation dose without compromising diagnostic quality is obviously key. Self-referral, the fear of litigation, image quality, training, equipment, and to some extent advanced technology, are identified as factors that contribute to increased radiation dose. There is a need to control and minimize health risks, while maximizing the benefits of radiation in medicine as the inappropriate handling of radiation can result in potential health hazards both for patients and staff [1- 21].
Keywords: computed tomography, nuclear medicine, milli-Sievert

Introduction

Medical imaging has revolutionized medicine and is undoubtedly saving and extending lives [1]. Ionizing radiation is used worldwide in over 4000 million diagnostic procedures and up to eight million radiotherapy treatments per annum [2]. Medical care is hence the largest source of human exposure to ionizing radiation outside of nature. Exposure to radiation is on the increase due to advances in medical imaging systems [2]. The associated increase in radiation dose from increased imaging and therapy to achieve improved health care leads to concerns about possible over-utilisation of these examinations [1]. As the number of imaging and therapeutic radiation studies increases it is important to maintain a balance between the potential benefits and possible risks from radiation exposure.

A March 2009 report from the National Council for Radiation Protection (NCRP) indicates that the increase in radiation exposure is due mainly to a higher utilization of computed tomography (CT) and nuclear medicine. In the population of the United States of America (USA), CT and nuclear medicine contribute 36% of the total radiation exposure and 75% of medical radiation exposure [3]. This is attributed to a more than a sevenfold increase in exposure to medical ionising radiation from the early 1980s to 2006. In Table 1 it is evident that the effective dose per individual in the early 1980s increased from 0.53mSv to 3mSv per individual in 2006.

Table 1: Data from the National Council on Radiation Protection and Measurements, "Ionizing Radiation Exposure of the Population of the United States," March 3, 2009 [3].

Procedure	Effective dose per individual -- 1980s (mSv)	Effective dose per individual -- 2006 (mSv)
CT	0.016	1.47
Radiography and fluoroscopy	0.36	0.33
Interventional fluoroscopy	0.018	0.43
Nuclear medicine	0.14	0.77
Total	0.53	3.00

Data does not include radiation dose from radiation therapy, PET/CT, SPECT/CT, CT/fluoroscopy, and interventional applications.

Although the use of CT grew very rapidly in the late 1990s and early 2000s, it is expected to continue to increase for at least the next decade. The radiation from in-vivo diagnostic nuclear medicine studies increased by some 460% and the collective effective dose increased by 620% from 1982 to 2006 [3]. Cardiac interventional studies across modalities comprise 28% of the total imaging procedures yet the collective effective dose is 53% of the total for all interventional procedures [3].

Dr M Rehani, a radiation safety specialist from the International Atomic Energy Agency (IAEA), during a presentation at the European Congress of Radiology held in 2009, stressed the importance of knowing the radiation dose given to an individual so as to optimise radiation protection [4]. He elaborated that there is a need to assess and optimise patient doses without compromising image quality. He requested that stakeholders become familiar with programs and actions that can help in patient dose management and to consolidate knowledge of radiation protection [4].

There is no doubt that patient management has been revolutionised by non-invasive imaging that leads to early, more precise and much less morbid diagnosis [5]. This increased non-invasive imaging, especially by CT and nuclear medicine, has resulted in a significant increase in the medical radiation dose. Minimising radiation dose without compromising diagnostic quality is obviously key hence certain important issues that impact on increased dose need consideration. Self-referral, the fear of litigation, image quality, training, equipment and, to some extent, advanced technology, need to be addressed.

Self referral

Every user of ionising radiation should be bound by ethical and legal rules and regulations on the use of ionising radiation. However there appears to be some practitioners that could be motivated to overuse certain imaging modalities as it results in increased income for them [6]. According to the Government Accountability Office report in the USA imaging utilization is significantly increased when physicians refer patients to facilities at which that they have financial interests [1, 3]. In the medicare system in the USA, the number of self-referred CT, magnetic resonance imaging (MRI) and nuclear medicine studies grew at triple the rate as compared to the same examinations performed in all settings during the period 1998 to 2005 [1]. According to private insurance studies more than half of the self-referred imaging was unnecessary [1]. Some practitioners opt for advanced imaging procedures in lieu of less expensive diagnostic procedures as this could mean higher revenues for the practitioner without any commensurate improvement in the outcomes [5].

Litigation

Fear of litigation, advanced technology and patient demand are also cited as possible reasons for increased radiation dose [1, 3]. The commentary on the NCRP Report no 160 indicates that most of the physicians surveyed, reported that they practiced 'defensive medicine' [5]. Approximately a third of the CT scans requested by obstetricians/ gynaecologists, emergency physicians and family practitioners were not motivated by medical need [5]. Mc Donald in his editorial [6] states that practitioners experience 'pressure' not to under use radiological imaging as when faced with legal action, radiographic images may help defend their actions in a court of law [1].

Image quality

In a multinational survey performed by the IAEA, it was found that 53% of the x-ray images evaluated in developing countries were of poor quality and hence impacted on diagnostic information. Patients often have to have repeat examinations so that the images are of useful diagnostic quality [7, 8]. This contributes not only to unnecessary radiation dose but also to loss of diagnostic information and increased social costs. After implementing quality control measures, the number of repeat examinations were reduced and there was a significant improvement in image quality and reduction in radiation dose [8].

Training

Variations in the levels of training health professionals, choice of radiographic technique, and radiation protection measures, impact on the final patient dose [8]. It is important to educate all stakeholders in the appropriate utilization of imaging and in the principles of radiation safety. Persons performing examinations should be certified; referring physicians need to be educated on the most appropriate imaging study for given indications [1]. Most non-radiologist providers receive little, if any, imaging or radiation physics training. Government should regulate all providers that perform studies using radiation [1]. The requests for repeat studies due to previous records not being available should be minimised.

An important aspect of training is that of the development of protocols for the various examinations. The additional rotation of the x-ray tube at each end of the scan length to allow for the first and last slices to be reconstructed, that is, over-scanning in CT examinations contributes significantly to patient dose [9]. It is essential that CT protocols are checked and appropriate beam collimation, pitch and reconstruction slice width are selected especially in paediatric patients where non-optimised scan protocols contribute considerably to radiation dose.

Radiographers need to go back to basics and be encouraged, where possible, to increase tube voltage and reduce mAs. Parameters should be selected according to patient size, age, gender and the clinical question. In CT, reducing scan length and minimising the number of scans would help optimise radiation dose [9].

Equipment

Radiation dose can vary by up to a factor of ten between institutions [9]. This may be partly attributed to different imaging systems. Some countries are ill-equipped to manage radiation exposures because of poor equipment [2]. Often developing countries are given secondhand or refurbished equipment that lacks software to control patient radiation dose [2]. During the IAEA survey, the poor quality of images was also attributed to equipment performance and malfunction [8]. Imaging equipment requires regular surveillance by medical physicists to ensure optimal function [1]. Repair and optimization of x-ray equipment, new intensifying screens and improving film processors all contributed to the improved quality of images and hence reduced patient dose [8].

Technique

In a presentation at the American College of Cardiology meeting in 2009, it was reported that sequential scanning during coronary CT angiography reduces the radiation dose significantly without compromising image quality when compared to standard spiral data acquisition [10]. In interventional CT, 3D navigational tools may help reduce the need for repeated scanning [11].

Paediatric imaging

Although imaging is an invaluable diagnostic and management planning tool for health-care providers treating children, patients are often ignorant of the possible risks and radiation dose associated with radiation imaging and therapy. In their attempts to get a rapid diagnosis and treatment, parents may contribute to the increasing demand for imaging techniques, like CT, without actually understanding the potential risks. It is important to discuss the potential radiation risks with caregivers so that they may make informed decisions. Parents have a right to participate in decisions about the benefits and risks of their child's medical management [12]. The Alliance for Radiation Safety in Pediatric Imaging launched the *'Image Gently'* campaign that encompasses 34 medical organisations worldwide [3]. They have developed some educational tools on potential radiation risks for patients and parents [12]. The goal of *Image Gently* is 'to change practice by increasing awareness of the opportunities to lower radiation dose in the imaging of children' [13]. Radiation dose needs to be tailored for children; protocols need to be especially developed for children. Imaging studies on children should not just be 'adapted' from adult protocols, hence the slogan on Figure 1 that one size does not fit all. The campaign recommends that 'when CT is the right thing to do: Child size the kVp and mA; one scan (single phase) is often enough, and scan only the indicated area' [13].

Figure 1. One size does not fit all... (Courtesy of: http://www.pedrad.org/ associations/5364/ig)

Much is known about the quantitative effects of exposure to ionizing radiation however considerable uncertainties remain about the health effects of low doses. Hence it is important to perform CT examinations that are medically justified using the protocols incorporating the lowest dose scanning parameters that provide quality diagnostic images or where possible to substitute with non-radiation modalities.

In nuclear medicine radiopharmaceutical dosimetry varies from institution to institution as universal standards for paediatric radiopharmaceutical doses do not exist [14]. Doses are usually based on adult doses. Although it is generally agreed that paediatric doses should be the lowest possible to result in a satisfactory examination, there needs to be standards for paediatric radiopharmaceutical doses administered to paediatric patients [14]. There is also a need to explore instrumentation, new technology and reconstruction software as a means of reducing radiation dose in the paediatric population. For example, use of the OSEM-3D data reconstruction software as compared to filtered back-projection software in the reconstruction of single photon emission computed tomography (SPECT) renal images allows the total administered radiopharmaceutical activity to be reduced by a factor of two without compromising image quality [14, 15].

Researchers at Brown University at Rhode Island Hospital found that the number of CT scans in pregnant women had increased some 25% over the period 1997-2006. In certain conditions, CT scans may be necessary for life threatening conditions [16] however as CT exposes the fetus to radiation, albeit low levels of radiation, caution needs to be exercised when scanning pregnant women.

Optimise radiation dose

In the quest to maintain a balance between maximising the benefit and reasonably minimising the risks associated with ionising radiation, health professionals would need to ensure that they practice according to the 'as low as reasonably achievable' (ALARA) principles. This would not only benefit the general public and patients but also enhance the well-being of persons occupationally exposed to ionising radiation [17].

It is the responsibility of every radiographer, technologist, radiologist, oncologist and nuclear medicine physician, as the key role players in the imaging industry, to ensure that every study is appropriately indicated. Radiation healthcare practitioners need to increase awareness for the need to decrease radiation dose especially in children. Protocols should be reviewed and amended accordingly [18,19]. Before exposing a patient to radiation, one needs to weigh the benefit to the patient against the possible risk [3]. The *Image Gently* campaign also advocates that parents keep a record of their children's medical imaging procedures. This will help healthcare providers make informed decisions regarding the optimal timing of future radiologic studies [1]. All stakeholders should be educated in the principles of radiation safety and appropriate utilisation of imaging [1].

Although positron emission tomography-CT (PET-CT) scans have led to increased accuracy in diagnosis, there is higher radiation exposure as the patient receives radiation from both the PET tracer and the CT scan. It is important that appropriate parameters and clinical indications are defined. The use of separate CT scans for diagnosis, PET-attenuation and radiotherapy planning results in unnecessary radiation exposure [9]. Personnel working with PET-CT are also exposed to higher radiation levels. Although minimising radiation dose without compromising diagnostic quality is key, it is important that the benefits of CT and PET-CT, as well as the risks, are considered [9].

Government intervention is paramount in regulating the radiation industry. Radiographers administering the tests must be certified and registered; imaging and therapy equipment must be licensed and should be regularly surveyed using quality control measures; and providers interpreting images should meet basic training requirements [1,9]. The World Health Organisation has launched a 'Global Initiative in Health Care Settings' that focuses on risks and benefits of the use of radiation in medicine. This includes diagnostic and interventional radiology, radiotherapy, and nuclear medicine. Also considered are appropriateness criteria and referral guidelines to prevent unintended medical exposure [5]. In July 2009, a bill was introduced in the USA to close the loophole in legislation that allows physicians to self-refer patients for certain imaging studies but this bill still has to be passed and adopted as legislation [20].

Concluding comments

Although exposure to natural radiation sources is relatively unavoidable and the medical use of radiation has become an integral part of healthcare, all stakeholders need to be aware of the potential risks associated with increased radiation exposure. It is vitally important that patients do not put off needed imaging care based on fear. The tremendous and undeniable benefits of medical imaging need to be considered; patients must make informed risk/benefit decisions regarding their imaging care based on all the facts available and in consultation with their health professionals [3] (Figure 2). In an emergency or critical care situation, a considerable radiation dose might be delivered to a patient and there should be no argument with the decision to proceed. However, a diagnostic study in a non-critical scenario should employ the appropriate levels of radiation [6].

Figure 2. Balance: Potential benefits vs possible risks

International standards, with regard to uniformity in medical radiation exposure, should be developed to provide guidance on the measurement and recording of radiation dose. Dose values may be expressed in terms of 'years of background radiation' [11]. The United Nations' reference value for natural background radiation is 2.4mSv per annum. The International Commission on Radiological Protection for standard man puts organ doses as 1mSv to 30mSv and effective doses from below 1mSv to 20mSv [11].

If a procedure does not fit the clinical indication it should not be performed. This will not only reduce patient dose but also costs. Appropriateness criteria for medical imaging covering 160 clinical conditions and over 700 variants have been published by the American College of Radiology [5]. The benefits of justified and properly performed imaging examinations will outweigh the risks for an individual child but unnecessary exposure to radiation will be associated with unnecessary risk. The most vulnerable groups to environmental threats are children and fetuses in pregnant females as they have longer life-spans to develop long term effects. Inappropriate handling of radiation can result in potential health hazards both for patients and staff. There is a need to control and minimize health risks, while maximizing the benefits of radiation in medicine [21].

References

1. Self-Referral of Medical Imaging Exams a Primary Factor in Six-fold Increase to Americans' Radiation Exposure from Scans Since 1980. 2009. [Accessed 24 June 2009 http://www.acr.org/MainMenuCategories/media_room/FeaturedCategories/PressReleases/ACRResponsetoNCRPReport.aspx]
2. Better Radiation Protection for Patients. Radiation Exposure Growing from CT Scans, X-rays for Varied Reasons. 2008. [Accessed 22 June 2009 http://www.iaea.org/NewsCenter/News/2008/betterprotect.html]

3. Barnes E. NCRP report: CT drives massive increase in medical radiation dose. 2009. [Accessed 24 June 2009. http://www.auntminnie.com/index.asp]
4. Rehani MM. International action plan on the radiological protection of patients. 2009. Presentation at ECR March 2009. [Accessed 10 March 2009. http://www.iaea.org]
5. Schauer DA & Linton OW. Commentary on NCRP Report No. 160, Ionizing Radiation Exposure Of The Population Of The United States, Medical Exposure – Are We Doing Less With More, And Is There A Role For Health Physicists? 2009. *Health Physics 97 (1) July 2009*.
6. Mc Donald JC. Too much of a good thing? 2009. *Radiation Protection Dosimetry* 134, (1) 2009:1-2.
7. X-rays Often Repeated for Patients in Developing Countries. IAEA Moves to Help Improve Quality of Medical Radiography. 2009. [Accessed 26 June 2009. http://www.iaea.org/NewsCenter/News/2008/xraysrepeat.html]
8. Kleen C. Global Radiation Dose Higher Than Necessary. 2008. [Accessed 11 March 2009. http://www.auntminnie.com/index.asp?Sec=sup&Sub=xra&Pag=dis&ItemId=81322]
9. Dose-Reduction Strategies: A fine Balance. 2009. [Accessed 24 June 2009. http://www.medicalphysicsweb.org/cws/article/research/38165]
10. Susman E. ACC study: Sequential CT delivers less radiation, good image quality. 2009. [Accessed 1 April 2009. http://www.auntminnie.com/index.asp]
11. Gould P. In interventional CT, radiation dose can be limited by using only two scans. 2009. [Accessed 24 June 2009. http://www.Diagnosticimaging.com]
12. Bulas D, Goske M, Applegate K & Wood B. Commentary entitled; Image Gently: Improving Health Literacy for Parents about CT Scans for Children. 2009. *Pediatric Radiology* (2009) 39:112-116.
13. Alliance for Radiation Safety in Pediatric Imaging 2009. [Accessed 3 July 2009 http://www.pedrad.org/associations/5364/ig/index.cfm?page=364]
14. Treves ST, Davis RT & Fahey FH. Administered Radiopharmaceutical Doses in Children: A Survey of 13 Pediatric Hospitals in North America. 2008. *Journal of Nuclear Medicine* June 2008 (49) 6:1024-1027.
15. Forrest W. SPECT with OSEM-3D reconstruction lowers pediatric radiation dose.[Accessed 6 May 2009. www.auntminnie.com]
16. Imaging during pregnancy on the rise. 2009. [Accessed 19 March 2009. www.healthimaging.com]
17. General Guidelines With Regard To Personal Monitoring.[Accessed 10 March 2006 http://www.doh.gov.za/department/radiation/01.html]
18. Morrison G. Child-size the radiation delivered to your pediatric patients. 2009. [Accessed 24 June 2009 www.pedrad.org]
19. Goske M. What can I do? – Radiologists. 2009. [Accessed 24 June 2009 www.pedrad.org]
20. Yee KM. House bill would close Stark in-office loophole. 2009. [Accessed 3 July 2009. www.auntminnie.com]
21. Pérez M, Shannoun F & Van Deventer E. Thematic paper: Radiation and Children's Health: The Case of Pediatric Imaging. Presented at the 3rd International WHO Conference on Children's Health and Environment. 2009. [Accessed 11 March 2009. www.ceh2009.org]