NCRP Report Number 160: Its Significance to Medical Imaging

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The National Council on Radiation Protection and Measurements (NCRP) is an advisory body to the US government that routinely publishes reports on various topics related to radiation measurements and radiation protection. As described by its mission statement, the NCRP "seeks to formulate and widely disseminate information, guidance, and recommendations on radiation protection and measurements which represent the consensus of leading scientific thinking" [1]. Even though NCRP reports and documents do not directly specify or formulate regulations, they often form the basis for many of the radiation protection standards, regulations, and policies in the United States at both the federal and state levels. One recent such report is of particular interest to the field of medical imaging [2].

NCRP Report No 160, *Ionizing Radiation Exposure of the Population of the United States* [2], was published in March 2009. NCRP Scientific Committee 6-2 on radiation exposure of the US population, through the efforts of 5 subcommittees, each addressing a specific category of radiation sources, including medical exposure of patients, prepared the report. The report evaluates the radiation doses to the US population from all sources of radiation for 2006, such as exposure from background radiation, including radon in homes; exposure from consumer products involving radiation sources; exposure to workers from their occupations; exposure from industry, security, medical, education, and research radiation sources; and exposure to patients from medical procedures.

Report No 160 updates NCRP Report No 93, published in 1987 [3]. The report describes the relative dose contributions to individuals and the population from a variety of sources, and it clearly specifies that it does not quantify or discuss any associated health risks or benefits associated with any of the radiation sources, including medical procedures.

According to NCRP Report No 160, the largest increase in radiation exposure to the US population compared with the previous report is found to be from patient exposure to medical procedures. Since the early 1980s, the magnitude and distribution among the various sources of radiation exposure to the US population have changed, primarily because of the increased utilization of ionizing radiation in diagnostic, nuclear, and interventional medical procedures. The reported radiation exposure from medical procedures was 0.54 mSv in the NCRP Report No 93; it is 3.0 mSv in the current report. This overall increase in radiation exposure (nearly 600%) from medical procedures is drawing considerable attention to those procedures contributing the largest growth, such as CT imaging, nuclear medicine, and international procedures [4].

RADIATION EXPOSURE TO PATIENTS FROM MEDICAL PROCEDURES

The report examines the medical exposure of patients in 4 main categories of medical procedures that involve ionizing radiation: CT imaging, nuclear medicine, conventional radiography and fluoroscopy, and interventional fluoroscopy. The number of procedures in each category was based on a variety of data sources, including IMV benchmark reports and Medicare data that included claims data for Medicare fee-for-service enrollees. The report describes in detail how the effective doses for medical imaging procedures used in the estimation of collective dose were derived using a variety of methods and also discusses the limitations and uncertainties in the effective dose estimations for each category.

Among the different categories of medical procedures, the largest contributor is CT procedures. Technological advances in CT imaging (such as helical and multiple-row detector CT imaging) and the ease of use of this technology have led to many clinical applications that have increased the use of CT imaging at a rate of 8% to 15% per year over the past 7 to 10 years. The number of CT examinations performed in the United States has been growing at a rapid rate, with nearly 62 million procedures (nearly 67 million scans after adjusting for those procedures with two scans) performed in 2006 alone. Among the CT procedures, pediatric CT scans account for nearly 8% to 10% of all procedures. The various categories of CT procedures, along with the number of CT scans and the collective effective doses, are listed in Table 1. Head, chest, abdominal, and pelvic procedures constituted nearly 80% of all CT procedures performed in the United States in 2006 and contributed nearly 84% of the collective effective dose. Overall, the collective effective dose from CT imaging amounts to nearly 440,000 person-Sieverts and translates to an effective dose per capita of nearly 1.5 mSv. The contribution from CT imaging alone is nearly 3 times that of the collective dose

0091-2182/09/$36.00 • DOI 10.1016/j.jacr.2009.09.014

Table 1. Estimated numbers and collective effective doses for CT

Study	Number (Millions)	%	Collective Dose (Person-Sieverts)	%
Head*	19.0	28	38,000	8.7
Chest	10.6	16	74,000	17.0
Abdomen/pelvis	25.4	39	254,000	58.0
Extremity	3.5	5	500	0.1
CT angiography†	4.3	6	56,000	12.8
Miscellaneous	4.2	6	15,000	3.4
Total‡	67.0		438,000	

Note: Head, chest, and abdominal/pelvic scans accounted for 84% of the collective dose.
*Includes brain, head, and neck.
†Includes head (2.0 million) and heart (2.3 million).
‡The 62 million procedures for 2006 adjusted by category for procedures with two scans.

listed for the entire medical exposure category in the earlier NCRP report [3] and is one reason why NCRP Report No 160 is drawing so much attention to CT procedures and to the radiation dose associated with such procedures.

The category of medical procedures that saw the next largest increase in the contribution of effective dose per capita is nuclear medicine. Among the various nuclear medicine procedures, nuclear cardiac procedures accounted for nearly 57%, contributing nearly 85% of the collective effective dose. Overall, the collective effective dose from nuclear medicine amounts to nearly 231,000 person-Sieverts, which translates to an effective dose per capita of nearly 0.8 mSv. Similar contributions in terms of collective effective dose and effective dose per capita from all categories of medical exposure of patients are listed in Table 2. Overall, the radiation exposure to the US population from medical procedures accounts for nearly 3.0 mSv, an increase of nearly 600% from the previous NCRP report [3]. Examining this closely, and if one removes the effect of population growth between the two reports (a nearly 30% increase in the US population between 1982 and 2006), the increase in the effective dose per person due to medical procedures is due mostly to the higher utilization of various medical imaging modalities, particularly CT, nuclear medicine, and interventional fluoroscopy.

According to NCRP Report No 160, the estimated overall radiation exposures to the US population from all radiation sources for 2006 is 1.87-million person-Sieverts, which translates to an effective dose per capita of 6.2 mSv on the basis of a US population of 300 million. Figure 1 compares the distribution of effective doses from all radiation sources to the US population as reported in NCRP Report No 160 (data are for 2006) with that of Report No 93 (data from the early 1980s).

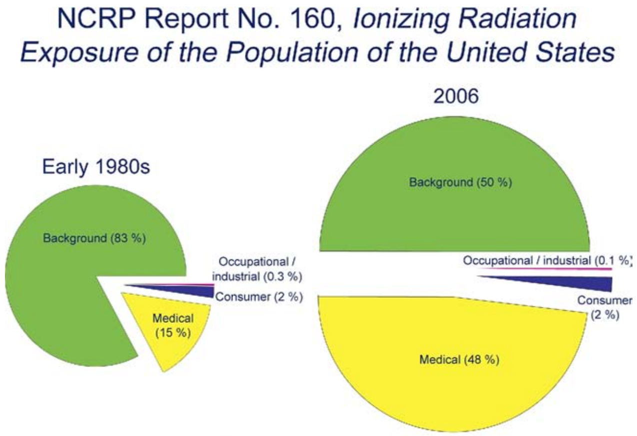
SIGNIFICANCE OF REPORT NO 160

The report provides well-documented information about the numbers and types of procedures that involve radiation exposure to patients and the approximate radiation dose that each procedure delivers. It also provides information about the range of doses that have been reported for various

Table 2. Estimated number and collective effective doses from various medical imaging categories using ionizing radiation

Modality	Number of Procedures (Millions)	%	Collective Effective Dose (Person-Sieverts)	%	Per Capita (mSv)
CT	67*	17	440,000	49	1.50
Nuclear medicine	18	5	231,000	26	0.80
Radiography and fluoroscopy†	293	74	100,000	11	0.30
Interventional	17	4	128,000	14	0.40
Total	~395		899,000		~3.0

*Number of scans.
†Excludes dental bitewing and full-mouth procedures but includes 2,500 person-Sieverts for collective dose.



	Early 1980s	2006
Collective effective dose (person-Sv)	835,000	1,870,000
Effective dose per individual in the U.S. population (mSv)	3.6	6.2

Fig 1. Radiation exposure to the US population from all sources. (Reprinted with permission of the National Council on Radiation Protection and Measurements, http://NCRPonline.org)

procedures. Thus, an individual can get a nominal value of radiation dose for a specific medical radiation procedure or estimate the total dose from multiple procedures by simply summing the value of the radiation dose from each procedure.

Radiation risks and benefits are not analyzed or discussed in the report, so various groups and researchers are estimating the radiation risks on the basis of the data presented in the report and drawing considerable attention to the use of CT imaging, nuclear medicine, and interventional procedures.

Few publications are focusing on the long-term risks of radiation, namely, radiation-induced cancer, especially from CT procedures [5,6]. With the increasing number of CT procedures performed in the United States and worldwide annually, this is drawing attention both in the medical and in the regulatory arena.

A positive aspect of the report is that it is raising awareness in the medical community about the need to optimize the doses received by patients in the best possible way. It is also drawing attention to the monitoring of radiation doses that patients receive from various medical procedures. In fact, a recently announced policy statement from the National Institutes of Health requiring new diagnostic imaging devices to automatically record radiation exposure [7] bases the need for such recording on the results in NCRP Report No 160.

The downside to the report is the misuse of information by some regarding the number of medical imaging procedures and the associated radiation risks, without discussing the associated medical benefits of such procedures to patients.

In general, the report is drawing more attention to the need for improved radiation dose optimization and radiation dose-reducing strategies in medical imaging procedures and the need to examine the appropriateness of each medical imaging procedure that uses radiation.

CONCLUSION

NCRP Report No 160 not only provides current data on the magnitude of medical imaging procedures performed in the United States and the radiation doses from all different sources but also draws considerable attention to improvement in radiation dose optimization and evaluation of the appropriateness of performing medical imaging procedures that use radiation.

REFERENCES

1. National Council on Radiation Protection and Measurements. Our mission. Available at: http://www.ncrponline.org/AboutNCRP/Our_Mission.html. Accessed October 2, 2009.
2. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States (NCRP Report No 160). Bethesda, Md: National Council on Radiation Protection and Measurements; 2009.
3. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States (NCRP Report No 93). Bethesda, Md: National Council on Radiation Protection and Measurements; 1987.
4. Mettler FA, Thomadsen BR, Bhargavan M, et al. Medical radiation exposure in the US in 2006: preliminary results. Health Phys 2008; 95:502-7.
5. Brenner DJ, Hall EJ, Computed tomography—an increasing source of radiation exposure. N Engl J Med 2007;237:2277-84.
6. Fazel R, Krumholz HM, Wang Y, et al. Exposure to low-dose ionizing radiation from medical imaging procedures. N Engl J Med 2009;361:849-57.
7. National Institutes of Health. New diagnostic imaging devices at the NIH Clinical Center to automatically record radiation exposure. Available at: http://www.nih.gov/news/health/aug2009/cc-17.htm. Accessed October 2, 2009.

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