Trends in Cardiovascular Medicine 26 (2016) 55–65

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/tcm

New approaches to reduce radiation exposure

Kevin D. Hill, MD, MSCI[a,*], *and Andrew J. Einstein, MD, PhD*[b,c]

[a]*Division of Pediatric Cardiology, Duke Clinical Research Institute, Duke University Medical Center, Durham, NC*
[b]*Division of Cardiology, Department of Medicine, Columbia University Medical Center, New York-Presbyterian Hospital, New York, NY*
[c]*Department of Radiology, Columbia University Medical Center, New York-Presbyterian Hospital, New York, NY*

ABSTRACT

Exposure to ionizing radiation is associated with a long-term risk of health effects, including cancer. Radiation exposure to the U.S. population from cardiac imaging has increased markedly over the past three decades. Initiatives to reduce radiation exposure have focused on the tenets of appropriate study *"justification"* and *"optimization"* of imaging protocols. This article reviews ways to optimally reduce radiation dose across the spectrum of cardiac imaging.

Key words: Radiation safety, Cardiac imaging, Cardiac catheterization, Myocardial perfusion imaging, Cardiac computed tomography effective dose.

Introduction

Over the preceding three decades, the U.S. population has seen an estimated sevenfold increase in annual medical imaging ionizing radiation exposure [1]. Cardiac imaging procedures are a major contributor to population radiation exposure in the U.S., collectively accounting for nearly one-fifth of the cumulative radiation dose and approximately 40% of the cumulative dose from medical imaging procedures (Fig. 1) [1–3]. In its 2007 report, the International Commission on Radiologic Protection (ICRP) noted that cardiologists frequently receive inadequate training in radiation protection [4]. Fortunately, this is beginning to change and an increased focus on radiation safety by the cardiology community has led to advances in technology, imaging protocols, and the development of appropriate use criteria to limit radiation exposure. The purpose of this article is to provide an overview of ionizing radiation during medical imaging, including dosing metrics, risk estimation, and strategies to reduce dose and/or mitigate radiation risk during cardiovascular procedures.

How is radiation dose measured?

Radiation dose is a complex topic and there are a slew of different measures that quantify various aspects of radiation (Table 1). Fig. 2 demonstrates how some of these different dose measures used during fluoroscopy will vary depending on the various aspects of radiation dose that are being evaluated. Similarly for other imaging modalities, including CT and nuclear medicine scans, different metrics might be useful depending on the dosing scenario. This review focuses largely on the long-term consequences associated with radiation exposure to various organ and tissue structures. In this respect, the fundamental dose quantity is the absorbed dose,

Dr. Hill is supported in part by Grant KL2TR001115-02 from The National Center for Advancing Translational Sciences of the National Institutes of Health, USA and a grant from the Mend A Heart Foundation. Dr. Einstein is supported in part by Grant R01 HL10971 from the National Heart Lung and Blood Institute and by a Herbert Irving Associate Professorship.
The authors have indicated there are no conflicts of interest.
*Corresponding author. Tel.: +1 919 668 8305; fax: +1 919 287 2612.
E-mail address: kevin.hill@duke.edu (K.D. Hill).

http://dx.doi.org/10.1016/j.tcm.2015.04.005
1050-1738/

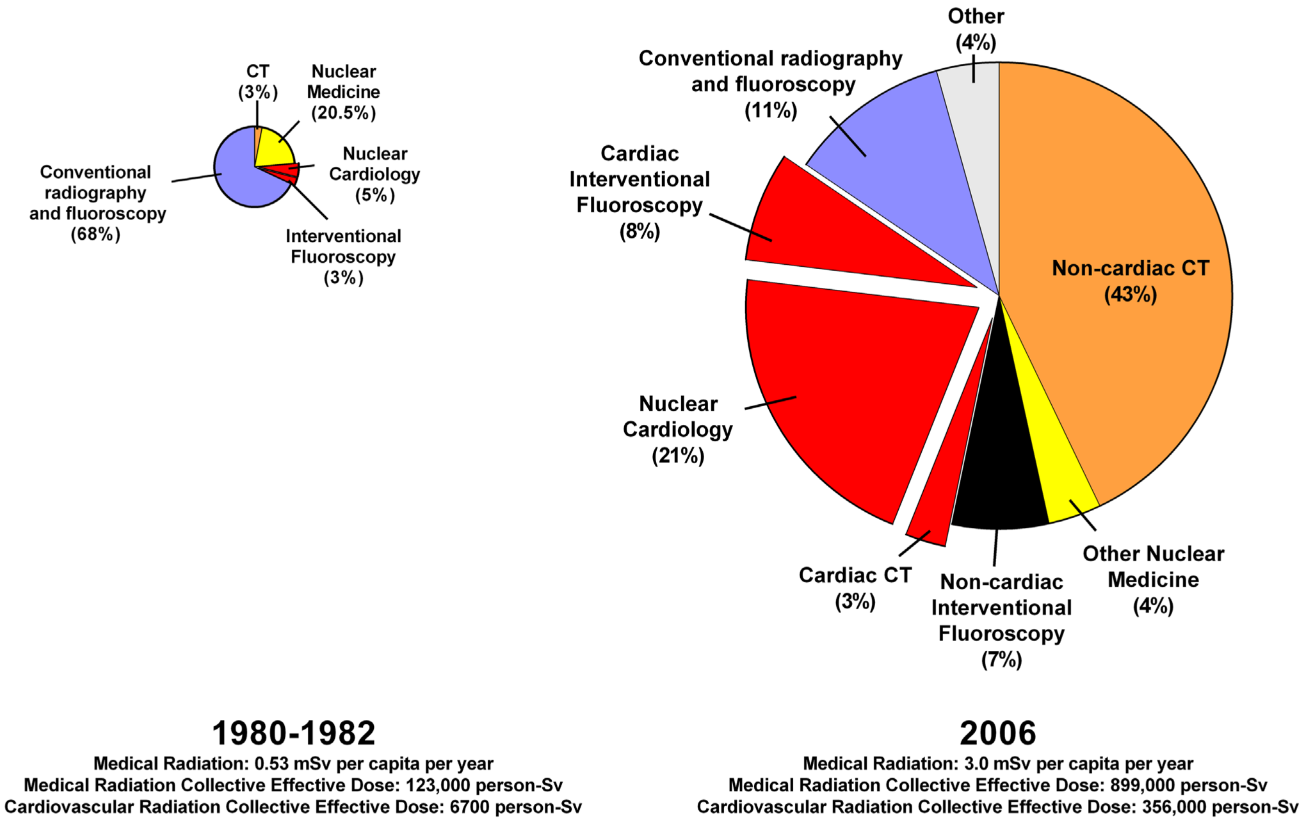

Fig. 1 – Medical imaging radiation exposure to the U.S. population.

reflecting the concentration of energy deposited in a tissue or organ. However, more commonly reported is the effective dose, a whole-body quantity that weights organ-absorbed doses to reflect their relative effects from radiation and to reflect the type of radiation used.

Effective dose is often used for comparison of long-term risks between modalities or across imaging protocols because effective dose values can be readily compared when different tissue structures are exposed or when comparing whole versus partial body exposure scenarios. These comparisons are possible because effective dose is calculated using tissue weighting factors that are published by the ICRP and reflect estimates of tissue sensitivity to radiation. For example, breast, lung, stomach, colon, or bone marrow is more heavily

Table 1 – Common radiation dose metrics.

Metric	Description	Unit
Radioactivity	Atom decay/time	Curie (Ci) Becquerel (Bq)
Exposure	Total charge of ions traveling through air	Roentgen (R)
Metrics reflecting kinetic energy	Kerma: Sum of kinetic energy of charged particles liberated per unit mass	
	Incident air Kerma: Kerma to air from an incident X-ray beam at the patient/phantom surface without backscatter included	Gray (Gy)
	Entrance surface air Kerma: Kerma to air at the patient/phantom surface including backscatter	Gray (Gy)
	Air Kerma—area product: integral of Air Kerma over the area of the x-ray beam (independent of distance)	Gy m^2
	Air Kerma—length product: Integral of Air Kerma over a line of length	Gy m
Absorbed dose	Radiation deposited in tissue per unit weight	Gray (Gy)
Metrics reflecting biologic effects	*Equivalent dose*: Multiplies dose with a radiation weighting factor to account for relative biological effect	Sievert (Sv)
	Effective dose: Weighted sum of equivalent doses. Accounts for biological effectiveness and tissue sensitivity by multiplying equivalent dose with a tissue sensitivity weighting factor	