Standardization and Optimization of CT Protocols to Achieve Low Dose

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The increase in radiation exposure due to CT scans has been of growing concern in recent years. CT scanners differ in their capabilities, and various indications require unique protocols, but there remains room for standardization and optimization. In this paper, the authors summarize approaches to reduce dose, as discussed in lectures constituting the first session of the 2013 UCSF Virtual Symposium on Radiation Safety and Computed Tomography. The experience of scanning at low dose in different body regions, for both diagnostic and interventional CT procedures, is addressed. An essential primary step is justifying the medical need for each scan. General guiding principles for reducing dose include tailoring a scan to a patient, minimizing scan length, use of tube current modulation and minimizing tube current, minimizing tube potential, iterative reconstruction, and periodic review of CT studies. Organized efforts for standardization have been spearheaded by professional societies such as the American Association of Physicists in Medicine. Finally, all team members should demonstrate an awareness of the importance of minimizing dose.

Key Words: CT, radiation dose, optimization, justification

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INTRODUCTION

The first of 12 sessions held as part of the 2013 UCSF Virtual Symposium on Radiation Safety in Computed Tomography (CT) focused on the standardization and optimization of protocols to achieve low dose. Talks in this session addressed a wide range of applications of CT, including diagnostic and interventional procedures, special populations such as pregnant patients, and the role of team members such as technologists and physicists. This paper serves as a summary of the session.

RADIATION EXPOSURE FROM MEDICAL IMAGING: EVIDENCE FOR HARMFUL EFFECTS

The opening plenary session, by Andrew Einstein of Columbia University, focused on basic concepts of radiation and the evidence relating radiation exposure to cancer risk. Tissue reactions (formerly referred to as deterministic effects) such as skin erythema and hair loss, which are due to radiation-induced cell death or damage, stand in contrast to stochastic effects such as cancer, which are due to mutations. The concepts of risk and dose were contrasted: the former is a probability of a

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Table 1. Effective doses of some medical sources of radiation

Source	Typical Dose (mSv)	Number of Chest X-Rays
X-ray		
Chest X-ray (PA)	0.02	1
Mammography	0.7	35
Abdomen: kidney, ureter, and bladder	0.7	35
Nuclear medicine		
Thyroid (^{123}I)	2	100
Thyroid (^{99m}Tc pertechnetate)	5	250
Lung ventilation-perfusion	2	100
GI bleeding	8	400
Bone scan	6	300
CT		
Head	2	100
Chest	10	500
Chest (PE)	15	750
Abdomen/pelvis	10	500
Virtual colonoscopy	10	500

Note: From various sources (eg, Mettler et al [1]). GI = gastrointestinal; PA = posteroanterior; PE = pulmonary embolism.

deleterious event occurring, whereas the latter is a measure of energy deposition in matter. A variety of types of dose quantities are used, including organ doses, modality-specific measures such as the dose-length product (DLP) in CT, and effective dose. Typical radiation doses from radiologic procedures have been described (Table 1) [1], but there is tremendous variability in the range of radiation dose indices for a given procedure [2].

Several studies have addressed the cumulative radiation burden from medical imaging [3-5]; together, these demonstrate that the high burden from medical radiation to the US population is growing and is not evenly distributed. Rather, dose distributions are skewed, and a small subset of the population receives a much higher dose of radiation, with gender, racial, and regional differences.

The evidence base relating low-dose (<100 mSv) radiation exposure to cancer risk is limited because of the large sample size required for a study to have adequate power to detect an increased risk, given that radiation is a weak carcinogen. No study published contains all the elements of the ideal epidemiologic study for drawing conclusions about radiation risk. The best low-dose evidence available derives from atomic bomb survivors, nuclear industry workers, children exposed in utero to x-rays [6], and now from two large epidemiologic studies of children undergoing CT [7,8]. Notwithstanding the limitations of current evidence [9], it all points toward a slightly increased cancer risk at the levels many patients receive when undergoing medical imaging. This underscores the importance of tailoring studies to limit exposure to only what is needed for diagnosis and of practicing patient-centered imaging.

PROFESSIONALS' ROLES IN CT PROTOCOL REVIEW

The Physician

Physicians influence patient radiation dose through monitoring protocols and targeting body part–specific and disease-specific protocols that can minimize dose. The goal in selecting protocols is not necessarily to create the highest technical quality image but to generate a diagnostic image using the lowest dose possible. Strategies to reduce medical radiation exposure have in large part revolved around two aims: first, to achieve higher awareness regarding the significance of medical radiation exposure and, second, to leverage new technology to obtain high-quality images from inherently noisier data. These two objectives are exemplified by widely publicized efforts on the part of professional medical imaging organizations such as Image Wisely® (http://www.imagewisely.org) in the first case and by the development of new iterative reconstruction algorithms for low-dose CT in the second. The thrust of efforts such as these is to reduce overall medical radiation exposure to the public. By reviewing and designing CT protocols, imaging physicians stand in a unique position to further reduce exposure to patients within the scope of their own practice.

According to many practice models, the primary role of the physician in these efforts is that of a gatekeeper to imaging. Most radiologists are comfortable answering questions about when CT is indicated or whether other imaging modalities may be more appropriate. Imaging physicians are also now increasingly familiar with the concept of tailoring scan parameters to better match patient size in an effort to reduce dose. However, there has been relatively little focus on how examinations such as CT can be more deliberately adjusted to match clinical indication. In neuroradiology, for example, most practices still adopt a "one size fits all" approach to CT protocols. A head CT is a head CT, and the selection of parameters such as reconstruction algorithm, tube current, and tube voltage is based on a consideration of what results in the highest technical quality of the final image. Often, significant dose reductions can be achieved in individual patients by adopting a different mentality, one not based on the absolute quality of the image but rather on the diagnostic quality of the image for a specific clinical indication and on a consideration of how the ability to detect certain abnormalities ultimately influences clinical management.

A number of CT protocols lend themselves easily to dose reduction when clinical indication and diagnostic impact are considered together. For example, children with suspected craniosynostosis are frequently referred for evaluation by CT, as it is the best modality to verify