Published in final edited form as:

J Trauma Acute Care Surg. 2012 December ; 73(6): 1406–1411. doi:10.1097/TA.0b013e318270d2fb.

Impact of adaptive statistical iterative reconstruction on radiation dose in evaluation of trauma patients

Mark W. Maxfield, MD, Kevin M. Schuster, MD, Edward A. McGillicuddy, MD, Calvin J. Young, MD, Monica Ghita, PhD, S.A. Jamal Bokhari, MD, Isabel B. Oliva, MD, James A. Brink, MD, and Kimberly A. Davis, MD

Departments of Surgery, Yale University School of Medicine, New Haven, Connecticut (M.W.M., K.M.S., E.A.M., C.J.Y., K.A.D.) and Radiology (M.G., S.A.J.B., I.B.A.O., J.A.B.), Yale University School of Medicine, New Haven, Connecticut.

Abstract

BACKGROUND—A recent study showed that computed tomographic (CT) scans contributed 93% of radiation exposure of 177 patients admitted to our Level I trauma center. Adaptive statistical iterative reconstruction (ASIR) is an algorithm that reduces the noise level in reconstructed images and therefore allows the use of less ionizing radiation during CT scans without significantly affecting image quality. ASIR was instituted on all CT scans performed on trauma patients in June 2009. Our objective was to determine if implementation of ASIR reduced radiation dose without compromising patient outcomes.

METHODS—We identified 300 patients activating the trauma system before and after the implementation of ASIR imaging. After applying inclusion criteria, 245 charts were reviewed. Baseline demographics, presenting characteristics, number of delayed diagnoses, and missed injuries were recorded. The postexamination volume CT dose index (CTDI_{vol}) and dose-length product (DLP) reported by the scanner for CT scans of the chest, abdomen, and pelvis and CT scans of the brain and cervical spine were recorded. Subjective image quality was compared between the two groups.

RESULTS—For CT scans of the chest, abdomen, and pelvis, the mean CTDI_{vol} (17.1 mGy vs. 14.2 mGy; $p < 0.001$) and DLP (1,165 mGy·cm vs. 1,004 mGy·cm; $p < 0.001$) was lower for studies performed with ASIR. For CT scans of the brain and cervical spine, the mean CTDI_{vol} (61.7 mGy vs. 49.6 mGy; $p < 0.001$) and DLP (1,327 mGy·cm vs. 1,067 mGy·cm; $p < 0.001$) was lower for studies performed with ASIR. There was no subjective difference in image quality between ASIR and non-ASIR scans. All CT scans were deemed of good or excellent image quality. There were no delayed diagnoses or missed injuries related to CT scanning identified in either group.

Copyright © 2012 by Lippincott Williams & Wilkins

Address for reprints: Kevin M. Schuster, MD, Department of Surgery, Yale School of Medicine, 330 Cedar St, BB310, New Haven, CT 06520-8062; kevin.schuster@yale.edu..

AUTHORSHIP

K.M.S., M.G., S.A.J.B., J.A.B., and K.A.D. designed this study. M.W.M., E.A.M., C.J.Y., S.A.J.B., and I.B.A.O. performed data collection. M.W.M., K.M.S., and E.A.M. analyzed the data, which K.M.S. and M.G. interpreted. M.W.M., K.M.S., E.A.M., J.A.B., and K.A.D. prepared the article. K.M.S., S.A.J.B., I.B.A.O., and K.A.D. contributed critical revisions.

DISCLOSURE

The authors declare no conflicts of interest.

LEVEL OF EVIDENCE: Therapeutic study, level IV.

CONCLUSION—Implementation of ASIR imaging for CT scans performed on trauma patients led to a nearly 20% reduction in ionizing radiation without compromising outcomes or image quality.

Keywords

Computed tomography; adaptive statistical iterative reconstruction; trauma; ionizing radiation

During the last two decades, the rate of computed tomographic (CT) scan use has been steadily increasing in the evaluation of trauma patients and in medical evaluations overall. More than 68 million CT scans were performed in the United States in 2008, as compared with approximately 3 million that were obtained in 1980.¹ CT scans are now commonly used for the diagnostic workup of a variety of traumatic injuries, which include but are not limited to traumatic brain injury, cervical spine injury, blunt abdominal trauma, and penetrating thoracoabdominal trauma. Although CT accounts for less than 15% of radiology examinations, it is responsible for more than two thirds of the total radiation dose associated with medical imaging.² Recent literature estimates that between 0.7% and 2% of new cancer cases in the United States each year may be solely attributable to CT scanning.³

The most frequently used measures of radiation in radiologic examinations are absorbed dose and effective dose. The absorbed dose reflects the energy absorbed by the tissue and is measured in grays (Gy); 1 Gy equals 1 J of ionizing radiation energy absorbed per kilogram. The absorbed dose is the most specific and accurate dose of radiation because it measures the ionizing radiation that a specific organ is exposed to. The effective dose measures the amount of ionizing radiation exposure to a nonhomogeneous substance and may be used to estimate the overall harm to the patient caused by the radiation exposure. Effective dose is measured in sieverts (Sv) and is commonly used to compare the amount of ionizing radiation between different diagnostic modalities (e.g., posteroanterior chest radiography is 0.01 mSv and an adult abdominal CT scan is 10 mSv). In CT scan, the standard dosimetric quantities are CT dose index ($CTDI_{vol}$) and dose-length product (DLP). $CTDI_{vol}$ represents the average absorbed dose at the central region of a scan volume and is measured in a standard acrylic cylindrical phantom from a single rotation of the x-ray tube in axial mode and is expressed in milligray. DLP is the product of $CTDI_{vol}$ and the length of the scan and is measured in milligray centimeter. These quantities are therefore relatively accurate estimates of the dose delivered to the patient and represent the quantities we chose to compare for this study. To estimate the effective dose associated with a CT examination, the DLP is multiplied by appropriate dose conversion factors for the anatomic area included in the scan.⁴ The effective dose will be altered by patient factors because calculated effective doses are based on standard size and shaped phantom humans. Both $CTDI_{vol}$ and DLP are sensitive to changes in scan parameters such as tube voltage (in kilo-volt), tube current (in milliamperes), rotation time (in second) and pitch. Typically, the scan parameters are set before the examination and remain constant during the scan. However, modern CT scanners provide scan modes with variable tube current (tube current modulation). An additional setting used for CT examinations performed with variable tube current is the noise index (NI). The NI determines the quality of a given image and is inversely related to the amount of radiation used; it is set before the examination according to the diagnostic task or radiologist preference.

Given the increasing number of CT scans being performed and the ionizing radiation dose associated with CT scan, investigators have been trying to find ways of decreasing radiation exposure in CT scans without compromising image quality. Many of the techniques that have been developed (prepatient collimation of x-ray beams, better filters, electrocardiogram gating, and automatic tube current modulation) are part of image acquisition and

are aimed at decreasing scan time and improving scan efficiency. A different strategy for decreasing ionizing radiation in CT scans involves postacquisition image processing. Algorithms have been developed that use mathematical models to “smooth” images, thereby improving noisy images (that are acquired with low amounts of radiation) to allow them to be of diagnostic quality.

One method of decreasing the amount of ionizing radiation used in CT scan is a postacquisition algorithm titled Adaptive Statistical Iterative Reconstruction (ASIR; GE Healthcare, Waukesha, WI). ASIR is a newly developed iterative reconstruction algorithm that is faster than its predecessors and has been shown to allow for equivalent image noise at a reduced radiation dose. Using a CT scan that acquires images using the traditional filtered back projection algorithm, ASIR uses matrix algebra to repeatedly transform the pixel Hounsfield values until they converge on a final value.⁵ ASIR produces significant noise reduction that potentially improves image quality and allows reduction in radiation dose. For a given examination, a radiologist can choose to decide to what degree ASIR is used in the reconstruction of images. A 100% ASIR setting would produce a CT scan with no noise but correspondingly with no diagnostic value. A 0% ASIR setting would produce a CT scan using the traditional filtered back projection method. Most protocols that use ASIR use between 10% and 40% ASIR settings. A thorough review of the literature reveals more than 20 peer-reviewed publications that have investigated ASIR use in clinical applications. To our knowledge, this is the first study that investigates the use of ASIR in trauma patients. Minimizing exposure to ionizing radiation in trauma patients is particularly important because trauma patients are generally younger and therefore more likely to be harmed by radiation. It is also likely that trauma patients, being younger, will have repeated medical radiation exposure during their lifetimes. The potential adverse outcome of missed injury in trauma patients has not been investigated in previous studies of ASIR.

On June 22, 2009, our Level I trauma center instituted ASIR on CT scans performed on all trauma patients. The purposes of our study were threefold, to compare the amount of radiation in CT scans performed with and without ASIR, to assess the clinical impact of ASIR on missed injuries, and to identify differences in image quality between non-ASIR and ASIR diagnostic studies.

PATIENTS AND METHODS

Study Design

This was a retrospective study approved by the Yale University Human Investigations Committee. We retrospectively reviewed 300 patients who presented to our Level I trauma center before and after implementation of ASIR imaging, which occurred on June 22, 2009. Two thirds of the patients activated the trauma system at the highest level in our two-tier system. The remaining 100 patients were lower level activations. All adult (>16 years) patients presenting to our trauma center between April 6, 2009, and September 25, 2009, were evaluated for inclusion. Inclusion in this study required a CT scan of the chest, abdomen, and pelvis with simultaneous acquisition of radiation dose data. Our study consisted of two cohorts: 137 patients who presented before implementation of ASIR and 163 patients who presented after. Patients who underwent CT imaging at an outside institution were excluded (Fig. 1).

Demographics

Baseline demographics, including age, sex, date of arrival, and level of activation were recorded. Injury Severity Score (ISS), Revised Trauma Score (RTS), hospital length of stay, number of delayed diagnoses, and missed injuries were recorded. The presence of the

following in each patient was recorded: hypertension, diabetes, aspirin use, warfarin use, clopidogrel use, renal insufficiency, peripheral vascular disease, coronary artery disease, and chronic obstructive pulmonary disease. As a surrogate to measure effect on image quality, we examined rates of missed injury and diagnostic delay before and after ASIR use.

CT Protocol

All studies were performed on a 64-slice Lightspeed VCT (GE Healthcare, Waukesha, WI) scanner. CT images of the chest, abdomen, and pelvis (CT C/A/P) were obtained from all patients included in this study. For the non-ASIR group, an NI of 11.5 was used for CT C/A/P and an NI of 10.0 was used for CT brain/cervical spine. For the ASIR group, CT C/A/P were performed with NI ranging from 11.5 to 14.6 and a 20% to 40% ASIR setting. For the ASIR group, CT brain/cervical spine was performed with NI ranging from 11.7 to 16.5 and a 30% ASIR setting.

Radiation Dose Assessment

Scanner-reported CTDI_{vol}, DLP, and image noise for CT scans of the head, cervical spine, chest, abdomen, and pelvis were recorded and compared between the two groups.

Qualitative Analysis

Two board-certified radiologists independently performed blinded analysis of 60 CT scans: 30 non-ASIR and 30 ASIR. The radiologists were unaware of the date of the study and did not have any access to patient information. Image quality was graded on a scale of 1 to 4. Images of excellent quality were graded 4; images of good quality were graded 3; images of poor quality but adequate for evaluation were graded 2; and nondiagnostic images were graded 1.²

Statistical Analysis

Statistical analysis was performed using IBM SPSS (version 18, Chicago, IL). Descriptive statistical analysis was performed to compare characteristics of patients in the two treatment groups. Student's t test was used for continuous variables with normal distribution, χ^2 test for dichotomous variables, and Mann-Whitney U-test was used for ordinal variables. Cohen's κ test measured of interrater agreement.

RESULTS

Of the 300 patients that were reviewed, 245 met study criteria (109 patients before ASIR; 136 after ASIR) (Fig. 1).

Between the two groups (non-ASIR vs. ASIR), there was no significant difference between presenting characteristics with the exception of age (Table 1). There were no missed injuries or delayed diagnoses in either group.

Between the two study groups, there was no significant difference in any of the following categories: no medical history, hypertension, diabetes mellitus, aspirin, warfarin use, clopidogrel use, chronic renal insufficiency, peripheral vascular disease, coronary artery disease, and chronic obstructive pulmonary disease (Table 1).

There was a significant difference between non-ASIR and ASIR groups for CT scans of the chest, abdomen, and pelvis in CTDI_{vol}, DLP, and NI. All p values were <0.001. Similarly, there was a significant difference in CT scans of the brain/cervical spine in radiation dosage and NI before and after implementation of ASIR. All p values were <0.001 (Table 2).

Two board-certified radiologists evaluated 61 of the same CT scans: 30 non-ASIR and 31 ASIR. Neither radiologist scored any CT scan a 1 or 2, meaning that all CT scans performed were of good or excellent quality (Table 3). There was no statistically significant difference in image quality between non-ASIR and ASIR CT scans. To measure the level of agreement between the two radiologists, a Cohen's J coefficient was calculated (0.694) (Table 3). One radiologist recorded whether she thought ASIR was used on each CT scan evaluated. She was correct 70% of the time (43 of 61 scans).

The average DLP in CT C/A/P was calculated and converted to effective dose (non-ASIR, 19.8 mSv; ASIR, 17.1 mSv). Using established statistical modeling, rates of excess cancers seen for patients exposed to these radiation dosing were calculated (Table 4).⁶

DISCUSSION

Iterative reconstruction as a means of reducing radiation used for diagnostic imaging has been used in single-photon emission computed tomographic and positron emission tomographic imaging for many years and is increasingly being used in CT scanning. ASIR is a postacquisition image processing algorithm and smooths noisy images, thereby producing a radiologic study of diagnostic quality. For ASIR to be used correctly, a higher NI is set by radiologists for a given study, which leads to a noisy image (that is then improved with ASIR) and subsequently less radiation exposure to the patient. In our study, the NI increased after implementation by 19% in CT scans of the chest, abdomen, pelvis, brain, and cervical spine. That the image noise was increased after ASIR use in our study in each type of CT scan confirms that ASIR is being used appropriately by the radiologists involved in image acquisition at our institution.

At our Level I trauma center, implementation of ASIR on all CT scans of trauma patients led to a statistically significant reduction in radiation exposure compared with CT scans performed before ASIR. Ionizing radiation exposure decreased by 14% for scans of the chest, abdomen, and pelvis and by 19% for scans of the brain and cervical spine. This is the first published study that evaluates the use of ASIR in CT scans performed on trauma patients. Despite a significant reduction in ionizing radiation seen in our study, there were no missed injuries or delayed diagnoses, and there was not a statistically significant difference in the length of stay between the two groups. More than 20 clinical studies have been published examining radiation reduction in CT scans using ASIR. These studies evaluated between 10 and 574 patients and reported radiation reductions ranging from 20% to 75% (Table 5). Our study showed reductions between 14% and 19%. Most of the studies listed, however, used fewer patients than were used in our study. In fact, only two clinical studies to date have used more patients than are presented here.

The advantage of ASIR processing in CT scanning is that high-quality images are provided with less ionizing radiation. The advantage of less radiation, however, is negated if images are insufficient or suboptimal for diagnosing injuries in the trauma patient population. In this study, 100% of CT scans evaluated (non-ASIR and ASIR) were of diagnostic quality, according to two board-certified radiologists. Our data also show that there was no significant difference in image quality before and after ASIR use. The two radiologists agreed on grading in 46 (77%) of 60 CT scans and demonstrated appropriate concordance as evidenced by a Cohen's J coefficient of 0.694 (0, complete disagreement; 1, complete agreement; >0.7, excellent agreement; >0.5, good agreement). For this study, we used a validated image quality scoring system. Despite the technique being inherently subjective, it is a commonly used technique in previously published studies on ASIR and is sufficient until more quantitative techniques of image assessment are developed.

In addition to the subjective grading of images in this study, there are two other limitations. The first is the retrospective nature of the study. The second is the applicability to trauma centers where board-certified radiologists do not read all CT scans on trauma patients. It is possible that the rate of missed injuries or delayed diagnoses may be higher when CT scans with ASIR are evaluated by nonradiologists or practitioners with little experience in the diagnosis of traumatic injuries by CT scan.

This study is promising in that there was a significant reduction in radiation dose to trauma patients undergoing CT scans with ASIR without a deleterious effect on image quality or patient outcomes. There are established models that predict cancer incidence that can be attributable to a given radiation exposure.⁶ The most established model currently used is based on the 2006 BEIR VII report (Biological Effects of Ionizing Radiation). One of the goals of this publication was to estimate the health risks from exposure to low levels of ionizing radiation, like those found in CT scanners. Most of the data from which these mathematical models were derived are incident cancer rates in survivors of atomic bombings in Hiroshima and Nagasaki. This mathematical model provides an estimate of cancer incidence given a level of ionizing radiation exposure. The radiation exposure experienced by atomic blast survivors may not have similar biologic effects when compared with medical x-rays. These models however represent the best estimates available for calculating cancer risk. Using these models and data from this study, we calculated that for every 100,000 CT scans performed, the use of ASIR with the associated reduction in ionizing radiation may prevent 24 cancers among men and 39 among women (Table 4).

To validate these findings, further studies must be conducted evaluating short-, medium-, and long-term outcomes for trauma patients who underwent CT imaging with ASIR. ASIR clearly reduces radiation dose but more definitive proof that injuries will not be missed will be important. In addition, development of quantitative tools to assess image quality could allow for optimization of ASIR level and provide further evidence that ASIR images are of good or excellent quality. If there is no significant difference in image quality and clinical outcomes with ASIR imaging, then its widespread implementation across the country in trauma centers will lead to a reduction in aggregate radiation exposure and will theoretically lead to a decrease in long-term cancer incidence and cancer-related morbidity and mortality.

Acknowledgments

This study was presented at the 42nd annual meeting of the Western Trauma Association, February 26–March 2, 2012, in Vail, Colorado.

REFERENCES

1. Rapalino O, Souza LCS, Mukta J, Sahani DV. Cranial CT with adaptive statistical iterative reconstruction: improved image quality with con-comitant radiation dose reduction. *AJNR Am J Neuroradiol*. Jan 19.2012 Epub.
2. Cornfeld D, Israel G, Detroy E, Bokhari J, Mojibian H. Impact of Adaptive Statistical Iterative Reconstruction (ASIR) on radiation dose and image quality in aortic dissection studies: a qualitative and quantitative analysis. *AJR Am J Roentgenol*. 2011; 196:336–340.
3. Sodickson A, Baeyens P, Andriole K, et al. Recurrent CT, cumulative radiation exposure, and associated radiation-induced cancer risks from CT of adults. *Radiology*. 2009; 251:175–184. [PubMed: 19332852]
4. American Association of Physicists in Medicine T group 23. AAPM Report No. 96: The Measurement, Reporting, and Management of Radiation Dose in CT. American Association of Physicists in Medicine; College Park, MD: 2008.
5. Amis ES. CT radiation dose: trending in the right direction. *Radiology*. 2011; 261:5–8. [PubMed: 21931137]

6. NRC. Health Risks From Exposure to Low Levels of Ionizing Radiation BEIR VII Phase 2. National Academy Press; Washington, DC: 2007.
7. Leipsic J, Labounty T, Heilbron B, et al. Adaptive statistical iterative reconstruction: assessment of image noise and image quality in coronary CT angiography. *AJR Am J Roentgenol.* 2010; 195:649–654. [PubMed: 20729442]
8. Sagara Y, Hara AK, Pavlicek W, et al. Abdominal CT: comparison of low-dose CT with adaptive statistical iterative reconstruction and routine-dose CT with filtered back projection in 53 patients. *AJR Am J Roentgenol.* 2010; 195:713–719. [PubMed: 20729451]
9. Leipsic J, Nguyen G, Brown J, Sin D, Mayo JR. A prospective evaluation of dose reduction and image quality in chest CT using adaptive statistical iterative reconstruction. *AJR Am J Roentgenol.* 2010; 195:1095–1099. [PubMed: 20966312]
10. Singh S, Kalra M, Gilman M, et al. Adaptive statistical iterative reconstruction technique for radiation dose reduction in chest CT: a pilot study. *Radiology.* 2012; 259:565–573. [PubMed: 21386048]
11. Vorona GA, Ceschin RC, Clayton BL, et al. Reducing abdominal CT radiation dose with the adaptive statistical iterative reconstruction technique in children: a feasibility study. *Pediatr Radiol.* 2011;1174–1182. [PubMed: 21594551]
12. Kambadakone AR, Chaudhary N, Desai GS, et al. Low-dose MDCT and CT enterography of patients with Crohn disease: feasibility of adaptive statistical iterative reconstruction. *AJR Am J Roentgenol.* 2011; 196:743–752.
13. Mitsumori LM, Shuman WP, Busey JM, Kolokythas O, Koprowicz KM. Adaptive statistical iterative reconstruction versus filtered back projection in the same patient: 64 channel liver CT image quality and patient radiation dose. *Eur Radiol.* 2012; 22:138–143. [PubMed: 21688003]
14. Miéville F, Gudinchet F, Rizzo E, et al. Paediatric cardiac CT examinations: impact of the iterative reconstruction method ASIR on image quality—preliminary findings. *Pediatr Radiol.* 2011; 41:1154–1164. [PubMed: 21717165]
15. Erbas G, Guryildirim M, Arac M, Ilgit E. Lowering the dose in head CT using adaptive statistical iterative reconstruction. *AJNR Am J Neuroradiol.* 2011; 32:28–32.
16. Mueck FG, Körner M, Scherr MK, et al. Upgrade to iterative image reconstruction (IR) in abdominal MDCT imaging: a clinical study for detailed parameter optimization beyond vendor recommendations using the adaptive statistical iterative reconstruction environment (ASIR). *Rofo.* 2011; 184:23.
17. Flicek KT, Hara AK, Silva AC, et al. Reducing the radiation dose for CT colonography using adaptive statistical iterative reconstruction: a pilot study. *AJR Am J Roentgenol.* 2010; 195:126–131. [PubMed: 20566805]
18. Prakash P, Kalra MK, Kambadakone AK, et al. Reducing abdominal CT radiation dose with adaptive statistical iterative reconstruction technique. *Invest Radiol.* 2010; 45:202–210. [PubMed: 20177389]
19. Prakash P, Kalra MK, Digumarthy SR, et al. Radiation dose reduction with chest computed tomography using adaptive statistical iterative reconstruction technique: initial experience. *J Comput Assist Tomogr.* 2010; 34:40–45. [PubMed: 20118720]

Figure 1.
Patient flow diagram.

TABLE 1

Presenting Characteristics and Medical Background of Non-ASIR and ASIR Groups

	Non-ASIR	ASIR	<i>p</i>
Male sex, n (%)	75/109 (69.4)	92/136 (67.6)	0.76
Age, y	49	43	0.05
Highest level of trauma activation, n (%)	70/109 (64.8)	90/136 (66.1)	0.82
ISS	9.2	9.69	0.62
RTS	7.65	7.51	0.282
Length of stay, d	5.1	6.7	0.24
Missed injuries	0/109	0/136	–
Delayed diagnoses	0/109	0/136	–
No medical history, n (%)	57/109 (52.8)	58/136 (42.6)	0.11
Other, n (%)	39/109 (36.1)	59/136 (43.3)	0.25
Hypertension, n (%)	25/109 (23.1)	24/136 (17.6)	0.29
Diabetes mellitus, n (%)	9/109 (8.3)	16/136 (11.7)	0.38
Aspirin, n (%)	7/109 (6.4)	11/136 (8.0)	0.63
Warfarin, n (%)	6/109 (5.5)	5/136 (3.7)	0.48
Clopidogrel, n (%)	4/109 (3.7)	2/136 (1.5)	0.26
Chronic renal insufficiency, n (%)	0/109 (0)	1/136 (1)	0.37
Peripheral vascular disease, n (%)	1/109 (0.9)	1/136 (0.7)	0.87
Coronary artery disease, n (%)	5/109 (4.6)	6/136 (4.4)	0.93
COPD, n (%)	4/109 (3.7)	1/136 (0.7)	0.10

COPD, chronic obstructive pulmonary disease.

TABLE 2

Comparison of Radiation Doses from Different CT Scans With and Without ASIR

Diagnostic Study	Parameter	Non-ASIR	ASIR	Percent Change	<i>p</i>
CT C/A/P	CTDI _{vol} , mGy	17.07	14.19	-16.9	<0.001
	DLP, mGy cm	1,165	1,004	-13.8	<0.001
	NI	11.5	13.7	+19.1	<0.001
CT brain/cervical spine	CTDI _{vol} , mGy	61.7	49.6	-19.6	<0.001
	DLP, mGy cm	1,327	1,067	-19.5	<0.001
	NI	10.0	11.9	+19	<0.001

TABLE 3

Subjective Scoring of Image Quality Between ASIR and Non-ASIR Scans by Two Board-Certified Attending Radiologists

Parameter	Score	<u>No. Scans</u> Non-ASIR	<u>κ</u> ASIR	p	
Reader 1					
	4	21	25		
	3	9	6		
	2	0	0		
	1	0	0		
Reader 2				0.694	0.99
	4	16	22		
	3	14	9		
	2	0	0		
	1	0	0		

TABLE 4

Radiation Dosing and Estimated Radiation-Induced Cancers in Non-ASIR and ASIR Groups

		Non-ASIR	ASIR
CT C/A/P	Effective dose, mSv	19.8	17.1
	Excess cases of solid cancers in male patients per 100,000 exposed*	160 (80–320)	136 (68–544)
	Excess cases of solid cancers in female patients per 100,000 exposed*	260 (138–500)	221 (117–425)

* With 95% subjective confidence intervals in parenthesis.

TABLE 5

Clinical Studies Performed Measuring Radiation Dose Reduction Using ASIR

Authors	Year of Publication	Type of Study	No. Patients	Reduction in Radiation Dose with ASIR, %
Leipsic et al. ⁷	2010	Coronary CTA	574	27
Sagara et al. ⁸	2010	Abdominal CT	53	23–66
Leipsic et al. ⁹	2010	Chest CT	292	36
Cornfeld et al. ²	2011	CT aortography	31	20–29
Singh et al. ¹⁰	2012	Chest CT	23	75
Vorona et al. ¹¹	2011	Abdominal CT (pediatric)	11	33–37
Kambadakone et al. ¹²	2011	CT enterography	48	34
Mitsumori et al. ¹³	2012	Liver CT	19	41
Miéville et al. ¹⁴	2011	Cardiac CT	10	36
Erbas et al. ¹⁵	2011	Head CT	149	31
Mueck et al. ¹⁶	2011	Abdominal CT	42	38
Rapalino et al. ¹	2012	Head CT	150	26
Flicek et al. ¹⁷	2010	CT colonography	18	50
Prakash et al. ¹⁸	2010	Abdominal CT	222	25
Prakash et al. ¹⁹	2010	Chest CT	152	28

CTA, computed tomography angiography.