Radiology

Body CT Scanning in Young Adults: Examination Indications, Patient Outcomes, and Risk of Radiation-induced Cancer[1]

Robert L. Zondervan, BA
Peter F. Hahn, MD, PhD
Cheryl A. Sadow, MD
Bob Liu, PhD
Susanna I. Lee, MD, PhD

Purpose: To quantify patient outcome and predicted cancer risk from body computed tomography (CT) in young adults and identify common indications for the imaging examination.

Materials and Methods: This retrospective multicenter study was HIPAA compliant and approved by the institutional review boards of three institutions, with waiver of informed consent. The Research Patient Data Registry containing patient medical and billing records of three university-affiliated hospitals in a single metropolitan area was queried for patients 18–35 years old with a social security record who underwent chest or abdominopelvic CT from 2003 to 2007. Patients were analyzed according to body part imaged and scanning frequency. Mortality status and follow-up interval were recorded. The Biologic Effects of Ionizing Radiation VII method was used to calculate expected cancer incidence and death. Examination indication was determined with associated ICD-9 diagnostic code; 95% confidence intervals for percentages were calculated, and the binomial test was used to compare the difference between percentages.

Results: In 21 945 patients, 16 851 chest and 24 112 abdominopelvic CT scans were obtained. During the average 5.5-year (± 0.1 [standard deviation]) follow-up, 7.1% (575 of 8057) of chest CT patients and 3.9% (546 of 13 888) of abdominal CT patients had died. In comparison, the predicted risk of dying from CT-induced cancer was 0.1% (five of 8057, $P < .01$) and 0.1% (eight of 12 472, $P < .01$), respectively. The most common examination indications were cancer and trauma for chest CT and abdominal pain, trauma, and cancer for abdominopelvic CT. Among patients without a cancer diagnosis in whom only one or two scans were obtained, mortality and predicted risk of radiation-induced cancer death were 3.6% (215 of 5914) and 0.05% (three of 5914, $P < .01$) for chest CT and 1.9% (219 of 11 291) and 0.1% (six of 11 291, $P < .01$) for abdominopelvic CT.

Conclusion: Among young adults undergoing body CT, risk of death from underlying morbidity is more than an order of magnitude greater than death from long-term radiation-induced cancer.

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[1] From the Department of Radiology (R.L.Z., P.F.H., B.L., S.I.L.) and Webster Center for Radiation Research and Education (B.L., S.I.L.), Massachusetts General Hospital, 55 Fruit St, Boston, MA 02114; and Department of Radiology, Brigham and Women's Hospital, Boston, Mass (C.A.S.). Received June 27, 2012; revision requested July 31; final revision received September 3; accepted October 2; final version accepted October 15. **Address correspondence to** R.L.Z. (e-mail: *robert.zondervan@gmail.com*).

As computed tomography (CT) utilization continues to increase in the United States, so have questions in regard to its health risk to those scanned. In the past 15 years, the rate of CT use has increased approximately 10% per year and now accounts for over 50% of the population's radiation exposure (1). In 2010, there were nearly 80 million CT scans obtained in the United States alone (2). On the basis of extrapolation models, it has been estimated that 1.5%–2.0% of cancers in the United States could be attributable to CT scanning (3).

The average effective radiation dose for chest and abdominopelvic CT is 7 mSv and 10 mSv, respectively (4). This is approximately equivalent to 2–3 years of background radiation (5). While seemingly trivial, these small doses may increase the risk of radiation-induced cancer, a risk that is thought to be additive with each subsequent scan (6). Moreover, it is in children and young adults that this risk is the most clinically relevant, as they are both more susceptible to ionizing radiation and more likely to live for the approximately 10–20 years considered necessary to develop the radiation-induced malignancy (7–9).

In our previous work (10), we evaluated the risk of radiation-induced cancer in the relatively small cohort of patients scanned more than 15 times in 5 years. However, only 3% of the cancers in the entire cohort were predicted to occur in these frequently scanned patients. Moreover, because scanning in this group was performed in the care of life-threatening illness, nearly one-half of them died before any radiation-induced cancer would be a factor in their health (10).

At a population level, most of the body CT in young adults is performed in those scanned rarely, typically once or twice. Consequently, most of the CT-induced cancers are predicted to result from sporadic rather than frequent scanning (10). Thus, while cumulative patient dose from multiple scans is of importance, the risk-versus-benefit assessment of CT scanning should also focus on the infrequently scanned patients in whom most of the CT-induced cancers are predicted to occur.

The aim of this retrospective study was to quantify patient outcome and predicted cancer risk from body CT in young adults and identify common indications for the imaging examination.

Advances in Knowledge

- Among young adults undergoing chest CT and abdominopelvic CT, short-term risk of death from underlying morbidity (7.1% and 3.9%, respectively) is much greater than long-term risk from radiation-induced cancer (0.1% and 0.1% respectively) ($P < .01$).
- Most common noncancer indications for body CT are trauma and abdominal pain.
- Most of the radiation-induced cancers are predicted to occur in those scanned very rarely (ie, once or twice,) rather than in those scanned repeatedly because, while the risk for any individual is lower in the former group, at a population level, those who are very rarely scanned undergo the overwhelming proportion of examinations.

Implications for Patient Care

- When advising on radiation concerns, the radiologist should inform patients that potential adverse outcomes are much more likely to occur from the underlying medical morbidity, rather than from CT-induced cancer for most common examination indications.
- Radiation reduction efforts should also focus on patients who are very rarely scanned, and not only on those who are scanned repeatedly.
- Models for estimating radiation-induced cancer risk that assume perfect health and great longevity should be reassessed to account for underlying patient morbidities.

Materials and Methods

This retrospective multicenter study was Health Insurance Portability and Accountability Act compliant and was approved by the institutional review board of three institutions, with waiver of informed consent. The Research Patient Data Registry containing patient medical and billing records was queried, and data were collected from three major university-affiliated hospitals in a single greater metropolitan area (Massachusetts General Hospital, Brigham and Women's Hospital, and Dana-Farber Cancer Institute, all in Boston, Mass) (11). These hospitals receive referrals from 4385 hospital-based staff physicians and approximately 1100 community-based physicians in six counties with a total population of more than 4.5 million. Together with their two emergency rooms and level I trauma centers and their affiliated community health centers, the hospitals receive 2.8 million outpatient visits per year and account for 94 681 admissions and 66 902 surgical procedures annually. Eighteen CT scanners are located at the hospitals themselves and at outlying imaging centers in urban and suburban settings.

Study Population

The study population consisted of patients who were 18–35 years old in whom one or more chest and/or

Published online before print
10.1148/radiol.12121324 **Content codes:** CT HP

Radiology 2013; 267:460–469

Author contributions:
Guarantor of integrity of entire study, R.L.Z.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, R.L.Z., B.L., S.I.L.; experimental studies, S.I.L.; statistical analysis, R.L.Z., P.F.H., S.I.L.; and manuscript editing, all authors

Conflicts of interest are listed at the end of this article.

abdominopelvic CT scans were obtained during a 5-year period from January 1, 2003, to December 31, 2007. The patients were identified by a query of a searchable database that includes all medical records from the three hospitals. The age of 18 years was chosen as the lower limit to exclude pediatric patients. The age of 35 years was chosen as the upper limit, as estimated lifetime attributable risk of cancer from low-dose radiation in adults plateaus beyond this age (3). A social security record requirement was imposed to allow for query of mortality status; that is, we excluded patients for whom the database failed to retrieve a social security number. Any individual CT scan that covered the relevant body part was included. Thus, chest CT scans included examinations performed to image the heart, lungs, mediastinal and pulmonary vessels, or thoracic spine, and abdominopelvic CT scans included examinations performed to image the abdomen or pelvic viscera, pelvic vessels, or lumbosacral spine. Within each body part (chest or abdominopelvic), patients were grouped according to the number of examinations that they underwent during the 5-year study period as very rarely scanned (one to two scans), rarely scanned (three to five scans), moderately scanned (6–15 scans), or frequently scanned (>15 scans). Patients without a cancer diagnosis in their electronic medical record were classified as being in the noncancer subgroup.

Approximately 0.3% (70 of 21 945) of the patients included in our study population have been part of a previously reported cohort. Specifically, 70 patients who underwent more than 15 CT scans of either the chest or abdomen were described by Zondervan et al (10). Of those 70 patients, all 70 with a social security number are included here. The present article includes death rates for these 70 patients as part of the analysis of all young patients who underwent CT.

Effective CT Radiation Dose

Effective dose estimates of 7 mSv and 10 mSv were assigned for chest and abdominopelvic CT scans, respectively (4). These values reflect prevailing typical adult dose estimates averaged over the patient population at the studied institutions and are within the range of published estimates (4,12–18). Effective dose represents a whole-body equivalent dose that would be expected to produce the same overall cancer risk as partial-body radiation. This dose is calculated as a sum of each organ's equivalent dose multiplied by a weighting factor that incorporates the relative risk of radiation-induced carcinogenesis in that organ. Thus, effective dose is commonly used to compare different exposures of different anatomic regions (19).

CT effective doses are known to be dependent on patient size and on scanner parameters and technology. As such, the effective dose estimates were determined from representative institutional dose-length–product surveys for common examinations. These were then converted to estimates of effective dose through use of body region–specific conversion coefficients (20,21). As the effective dose estimate represents a per-examination value averaged over the institutional patient population, all examinations including the approximately 23% of examinations with more than one pass through the same body part were assigned the same effective dose. Cumulative effective doses from multiple examinations were obtained by summing doses.

Predicted CT-induced Cancer Death

Once the estimated dose was obtained, the Biologic Effects of Ionizing Radiation VII method was used to calculate expected cancer incidence and death in each patient group (6). The Biologic Effects of Ionizing Radiation VII method assumes a "linear-no-threshold" model that stipulates even small dosages of radiation can lead to cancer. Cancer risk is extrapolated from rates observed in humans exposed to severalfold higher radiation doses. The model takes into account age, sex, and magnitude of radiation dose at time of exposure. With these assumptions, the lifetime attributable risk (ie, the risk above and beyond baseline rates) is estimated for the radiation doses administered by diagnostic imaging. The model assumes no underlying comorbidities affecting the average life expectancy.

Examination Indication

A primary indication was assigned to each CT examination on the basis of a patient encounter entry in the electronic medical record database. Each radiologic procedure performed had an associated ICD-9 diagnostic code (22). Individual ICD-9 codes were categorized on the basis of the presenting sign or symptom or underlying disease.

Mortality Status

Patient mortality status was accessed by using the Social Security Death Index, a database of death records from the U.S. Social Security Administration Death Master File Extract. Patient social security numbers were used to query the Social Security Death Index until the follow-up cutoff date of October 1, 2011.

For purposes of computing the length of the follow-up interval, follow-up interval was considered to start with the first CT examination and conclude with the last entry in the electronic medical record. For patients who had died, the follow-up was considered to extend through October 1, 2011.

Patient Outcome for Common Examination Indications

To more directly compare mortality status and cancer risk according to examination indication, a subset analysis was performed to assess outcome of the patients undergoing one chest CT or abdominal CT for each of the common indications. The analysis was limited to patients in whom only one scan was obtained during the study period to exclude those in whom multiple scans were obtained for different indications.

Statistical Analysis

The 95% confidence intervals for percentages were calculated. The end points are $x - 1.96 \cdot \sqrt{[x \cdot (1 - x)/n]}$, $x + 1.96 \cdot \sqrt{[x \cdot (1 - x)/n]}$, where n is

Table 1

Outcome and Predicted CT-induced Cancer Risk in Patients Undergoing Chest CT

Frequency of Scanning	No. of Patients	No. of Dead Patients	Percentage of Dead Patients	No. of CT Cancer Cases	No. of CT Cancer Deaths	Percentage of CT Cancer Deaths
Very rarely, 1–2 scans	6620	313	4.7	5	3	0
Rarely, 3–5 scans	884	125	14.1	2	1	0.1
Moderately, 6–14 scans	505	113	22.4	3	1	0.3
Frequently, >15 scans	48	24	50.0	1	0	0.6
Overall	8057	575	7.1	11	5	0.1

Note.—For all comparisons, $P < .001$.

Table 2

Outcome and Predicted CT-induced Cancer Risk in Patients Undergoing Abdominopelvic CT

Frequency of Scanning	No. of Patients	No. of Dead Patients	Percentage of Dead Patients	No. of CT Cancer Cases	No. of CT Cancer Deaths	Percentage of CT Cancer Deaths
Very rarely, 1–2 scans	11 905	306	2.6	12	7	0.1
Rarely, 3–5 scans	1334	138	10.3	4	2	0.2
Moderately, 6–14 scans	606	88	14.5	4	2	0.4
Frequently, >15 scans	43	14	32.6	1	0	0.8
Overall	13 888	546	3.9	21	11	0.1

Note.—For all comparisons, $P < .001$.

the sample size and x is the fraction of total scans. The binomial test (*http://www.vassarstats.net/binomialX.html*) was used to compare observed with predicted percentages, using approximations to the binomial distribution in groups with large numbers of patients. The limit for significance was set at P less than .001.

Results

A total of 18 979 patients who were 18–35 years old and underwent body CT during the study period were identified by using a database query, and 16 804 patients with a social security record were included. In these patients, 16 851 chest CT and 24 112 abdominopelvic CT scans were obtained. The sum of CT examinations exceeds the number of patients in the cohort, as some patients underwent both chest and abdominopelvic examinations. Among the 8057 chest CT patients, 6620, 884, 505, and 48 were very rarely scanned (one to two scans), rarely scanned (three to five scans), moderately scanned (6–15 scans), and frequently scanned (>15 scans), respectively. Among the 13 888 abdominopelvic CT patients, 11 905, 1334, 606, and 43 were very rarely, rarely, moderately, and frequently scanned. Median follow-up time was 5.5 years (± 0.1 [standard deviation]); 14 436 patients were identified in the noncancer subgroup.

Tables 1 and 2 summarize the mortality outcome and predicted radiation-induced cancer case and death rates according to scanning frequency. Among patients who underwent chest CT, 7.1% (575 of 8057) died during follow-up, with the lowest rate among those very rarely scanned at 4.7% (313 of 6620). In this group, 0.1% (five of 8075) were predicted to die of their radiation-induced cancer, a risk that decreased to 0.05% (three of 6620) in the very rarely scanned patients. Among patients who underwent abdominopelvic CT, 3.9% (546 of 13 888) died during follow-up, with the lowest rate among those very rarely scanned at 2.6% (306 of 11 905). In this group, 0.1% (11 of 13 888) of the abdominopelvic CT patients were predicted to die of their radiation-induced cancer, with 0.1% (seven of 11 905) risk in the very rarely scanned. Over the entire study cohort, when analyzed at a patient level, 3.93% (660 of 16 804) died during follow-up.

Most common chest CT indications, in order of frequency, were cancer, trauma, cardiac complaint, and respiratory complaint (Table 3). Most common abdominopelvic CT indications, in order of frequency, were abdominal pain, cancer, trauma, urinary tract disease, bowel-related complaint, and cardiopulmonary complaint (Table 4). When analyzed according to scanning frequency of the patient undergoing the examination (Figure), cancer was the most common diagnosis in all but those very rarely scanned for both chest and abdominopelvic CT. In those very rarely scanned, trauma (26.7%, 2239 of 8387) and abdominal pain (26.8%, 3722 of 13 882) were the most common indications for chest and abdominopelvic CT, respectively.

Table 3

Indications for Chest CT

Chest Examination Indications	No. of Examinations	Percentage of Total Chest CT Examinations	95% Confidence Interval	
			Upper Bound (%)	Lower Bound (%)
Cancer	5325	31.6	32.3	30.9
Trauma	2488	14.8	15.3	14.2
Cardiac complaint, including chest pain, dysrrhythmia, and cardiac disease	1169	6.9	7.3	6.6
Respiratory complaint, including dyspnea, cough, hemoptysis, hypoxia, and others	1119	6.6	7.0	6.3
Lymphadenopathy	731	4.3	4.6	4.0
Abnormality at prior imaging	605	3.6	3.9	3.3
Musculoskeletal complaint, including back or joint pain and radiculopathy	577	3.4	3.7	3.1
Unspecified pulmonary disease	559	3.3	3.6	3.0
Abdominal symptom or disease	555	3.3	3.6	3.0
Pleural effusion	460	2.7	3.0	2.5
Fever or systemic Infection	403	2.4	2.6	2.2
Other	380	2.3	2.5	2.0
Complications of surgery or interventional procedure, such as catheter and radiation therapy	346	2.1	2.3	1.8
Vascular disease, including aneurysm, embolus, dissection, thrombosis, vasculitis, and others	344	2.0	2.3	1.8
Congenital anomalies, disease, or phacomatosis	306	1.8	2.0	1.6
Pulmonary infection, including pneumonia, empyema, and bronchitis	300	1.8	2.0	1.6
Asthma, emphysema, or chronic obstructive pulmonary disease	182	1.1	1.2	0.9
Respiratory failure	173	1.0	1.2	0.9
Pregnancy-related complications	163	1.0	1.1	0.8
Central nervous system disease or complaint, including myelopathy, limb weakness or paralysis, and brain abnormlities	150	0.9	1.0	0.7
Altered mental status, including delirium, psychosis, and convulsion	115	0.7	0.8	0.6
Spontaneous pneumothorax	106	0.6	0.7	0.5
Endocrine, metabolic, and autoimmune disease	90	0.5	0.6	0.4
Blood dyscrasia, including thrombocytopenia, anemia, and sickle cell disease	78	0.5	0.6	0.4
Naso- or oropharynx and sinus complaint, including sinusitis, pharyngitis, and enlarged tonsils or adenoids	58	0.3	0.4	0.3
Cutaneous or musculoskeletal tumor or infection, including bone tumor, osteomyelitis, cellulitis, ulcer, abscess, and cyst	42	0.2	0.3	0.2
Lung transplant	27	0.2	0.2	0.1
Total	16 851	100	...	...

Tables 5 and 6 show the subset analysis of patients scanned once, with mortality outcome compared with CT-induced cancer death according to the most common examination indications. Among chest CT patients, death rate in short-term follow-up outweighed the risk of long-term cancer death for all of the four most common examination indications (ie, trauma, cardiac complaint, respiratory complaint, and cancer). This is also true among abdominopelvic CT patients for three of the four most common examination indications (ie, abdominal pain, trauma, and cancer). However, for urinary tract disease, short-term mortality was not shown to be different from the risk of radiation-induced cancer death.

Tables 7 and 8 summarize the mortality outcome and predicted radiation-induced cancer case and death rates obtained when the patients with cancer diagnoses were excluded from the cohort. Among patients who underwent chest CT, 4.7% (300 of 6439) died during follow-up, with the lowest rate among the very rarely scanned at 3.6% (215 of 5914). Among patients who underwent abdominopelvic CT, 2.5% (309 of 12 472) died during follow-up, with the lowest rate among the very rarely scanned at 1.9% (219 of 11 291). The predicted CT radiation-induced cancer death rates are the same in the noncancer patients as those for the entire cohort at 0.1% (four of 6439) for the chest and 0.1% (eight of 12 472) for the abdominopelvic CT cohorts. When the noncancer cohort was analyzed at a patient level, 3.7% (578 of 15 780) died during follow-up.

Table 4

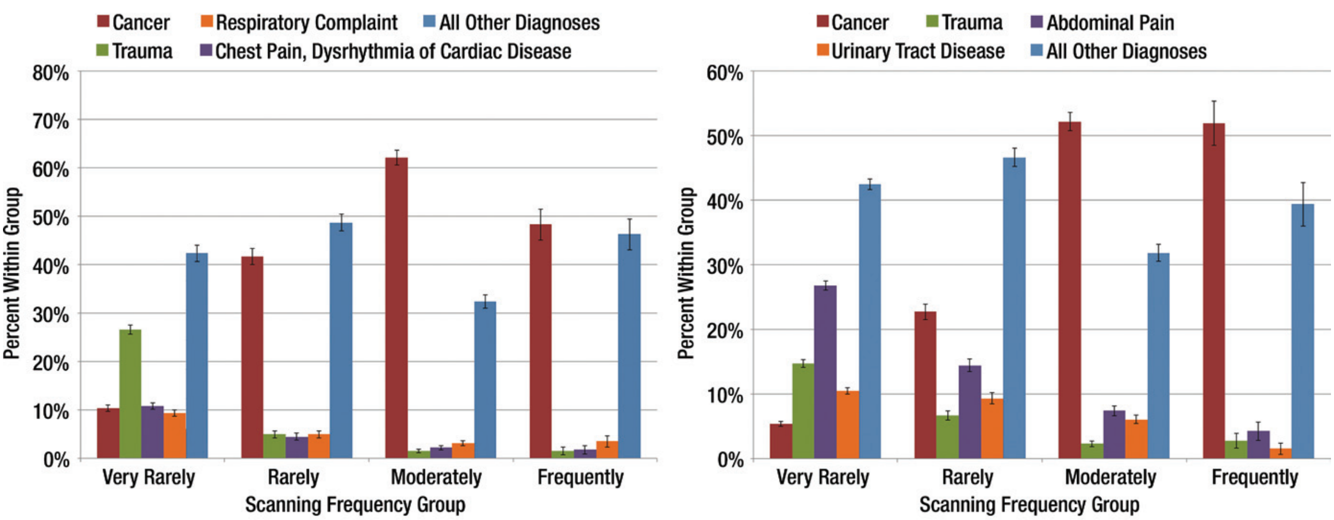
Indications for Abdominopelvic CT

Abdominopelvic Examination Indications	No. of Examinations	Percentage of Total Abdominal CT Examinations	95% Confidence Interval	
			Upper Bound (%)	Lower Bound (%)
Abdominal pain	4786	19.8	20.4	19.3
Cancer	4715	19.6	20.1	19.1
Trauma	2503	10.4	10.8	10.0
Urinary tract disease, including nephrolithiasis, hematuria, hydronephrosis, and others	2199	9.1	9.5	8.8
Bowel-related complaint, including nausea and vomiting, bowel obstruction, diarrhea, and others	1759	7.3	7.6	7.0
Cardiopulmonary complaint, including chest pain, shortness of breath, pneumonia, and others	1582	6.6	6.9	6.2
Musculoskeletal complaint, including back or joint pain and radiculopathy	840	3.5	3.7	3.3
Other	732	3.0	3.3	2.8
Fever or systemic infection	730	3.0	3.2	2.8
Ascites, abdominal mass, or distention	640	2.7	2.9	2.5
Suspected bowel perforation or abscess, including appendicitis, diverticulitis, and peritonitis	548	2.3	2.5	2.1
Inflammatory bowel disease	498	2.1	2.2	1.9
Complications of surgery or interventional procedure, such as catheter and intrauterine device	487	2.0	2.2	1.8
Abnormality at prior imaging	331	1.4	1.5	1.2
Gynecologic disease or complaint	253	1.0	1.2	0.9
Liver disease	225	0.9	1.1	0.8
Pregnancy-related complications	219	0.9	1.0	0.8
Vascular disease, including aneurysm, embolus, dissection, thrombosis, vasculitis, and others	217	0.9	1.0	0.8
Pancreatitis	205	0.9	1.0	0.7
Blood dyscrasia, including thrombocytopenia, anemia, and sickle cell disease	169	0.7	0.8	0.6
Altered mental status, including delirium, psychosis, and convulsion	112	0.5	0.6	0.4
Congenital anomalies, disease, or phacomatosis	95	0.4	0.5	0.3
Cutaneous or musculoskeletal tumor or infection, including bone tumor, subcutaneous collection or cyst, osteomyelitis, cellulitis, and ulcer	91	0.4	0.5	0.3
Endocrine, metabolic, and autoimmune disease	72	0.3	0.4	0.2
Central nervous system disease or complaint, including myelopathy, limb weakness or paralysis, and brain abnormaities	62	0.3	0.3	0.2
Male genital disease or complaint, including prostatitis, infertility, and others	42	0.2	0.2	0.1
Total	24 112	100	...	...

Discussion

In young patients undergoing body CT, the assumed risk of CT radiation cancer and resulting death was far outweighed by risk of intercurrent death presumably from their underlying morbidities. This was true for all categories of scanning frequency and for patients undergoing either chest or abdominopelvic CT. Even patients without underlying cancer were much more likely to die in the near-term rather than die of CT-induced cancer over the long-term. Over the population, most of the radiation-induced cancers are predicted to occur in the very rarely scanned; however, at the individual level, the greatest risk is predicted in the frequently scanned in whom the dose is additive over multiple examinations. These results emphasize that radiologists should also focus radiation reduction efforts on patients who are very rarely scanned, and not just on those who are more frequently scanned.

Our findings demonstrate that young adults undergoing body CT are at a higher risk of dying of radiation-induced cancer than the general population. The average risk of an American man or woman between the ages of 18 and 35 dying within a 5-year window is 1.1% (23). In contrast, the observed mortality rate over the 5.5-year follow-up period in our study was 7.1% and 3.9% in the



a.   b.

Common examination indications according to frequency of scanning. The four most common reasons for **(a)** chest and **(b)** abdominal CT are shown in scanning frequency group. Error bars = 95% confidence intervals.

Table 5

Outcome and Predicted Cancer Risk in Patients Undergoing One Chest CT Examination

Examination Indication	No. of Patients	No. Dead	Percentage Dead	No. of CT Cancer Cases	No. of CT Cancer Deaths*
Trauma	1855	36	1.9	2	1
Cardiac complaint	705	13	1.8	1	0
Respiratory complaint	620	7	1.1	1	0
Cancer	465	60	12.9	0	0
All other indications	2461	104	4.2	2	1
Overall	6106	220	3.6	6	2

Note.—For all comparisons, $P < .001$.

* The estimated risk of death from cancer induced by radiation from a single chest CT examination estimated from Biologic Effects of Ionizing Radiation VII was one of 3280.

Table 6

Outcome and Predicted Cancer Risk in Patients Undergoing One Abdominopelvic CT Examination

Examination Indication	No. of Patients	No. Dead	Percentage Dead	No. of CT Cancer Cases	No. of CT Cancer Deaths*
Abdominal pain	2809	22	0.8	2	1
Trauma	1655	29	1.8	1	1
Urinary tract disease	978	1	0.1	1	0
Cancer	410	61	14.9	0	0
All other indications	4093	110	2.7	3	2
Overall	9945	223	2.2	7	4

Note.—For all comparisons, $P < .001$. For urinary tract disease, there was no significant difference ($P = .62$).

* The estimated risk of death from cancer induced by radiation from a single abdominopelvic CT examination estimated from Biologic Effects of Ionizing Radiation VII was one of 2631.

chest and abdominopelvic CT cohorts, respectively; even among very rarely scanned noncancer patients, in whom the lowest death rates were observed, mortality was still higher than in the general population at 3.6% and 1.9%, respectively. In this context, the added 0.1% death risk attributable to radiation from CT scanning, while not negligible, is tiny in comparison.

Our results allow both radiologists and referring physicians to place the risk-benefit analysis of CT examinations into a clinically relevant context. Although Brenner and colleagues (24) have pointed out that underlying patient comorbidities have an effect on cancer risk estimates, most models that estimate CT radiation-induced cancer risk assume perfect health (ie, no other morbidities) and great longevity (ie, alive for decades through the radiation-induced cancer latency period). Our results indicate that these assumptions and the conclusions arising from them will need to be reconsidered. Moreover, for the radiologist advising a patient or referring physician about radiation concerns, our results define the patient's underlying medical morbidity, rather than CT-induced cancer, as the dominant factor driving a potentially adverse outcome.

Table 7

Outcome and Predicted CT-induced Cancer Risk for Patients Undergoing Chest CT without a Known Cancer Diagnosis

Frequency of Scanning	No. of Patients	No. Dead	Percentage Dead	No. of CT Cancer Cases	No. of CT Cancer Deaths	Percentage of CT Cancer Deaths
Very rarely, 1–2 scans	5914	215	3.6	5	3	0
Rarely, 3–5 scans	418	51	12.2	1	1	0.1
Moderately, 6–14 scans	95	28	29.5	0	0	0.3
Frequently, > 15 scans	12	6	50.0	0	0	0.6
Overall	6439	300	4.7	6	4	0.1

Note.—For all comparisons, $P < .001$.

Table 8

Outcome and Predicted CT-induced Cancer Risk for Patients Undergoing Abdominopelvic CT without a Known Cancer Diagnosis

Frequency of Scanning	No. of Patients	No. Dead	Percentage Dead	No. of CT Cancer Cases	No. of CT Cancer Deaths	Percentage of CT Cancer Deaths
Very rarely, 1–2 scans	11 291	219	1.9	12	6	0.1
Rarely, 3–5 scans	952	66	6.9	3	1	0.2
Moderately, 6–14 scans	219	21	9.6	1	1	0.4
Frequently, > 15 scans	10	3	30.0	0	0	0.8
Overall	12 472	309	2.5	16	8	0.1

Note.—For all comparisons, $P < .001$.

While our study defines the mortality risks in young adults undergoing body CT, both from the examination itself and their underlying morbidity, we did not measure the benefits incurred by imaging. A controlled randomized trial comparing outcomes of patients who did and did not undergo a CT examination for specific presentations would be the definitive paradigm in which to answer this question. In many medical scenarios, however, where CT scanning is regarded as the optimum standard of care (eg, trauma or suspected pulmonary embolus), such a trial would not be feasible. Hence, to design studies to accurately measure the benefits of CT scanning is methodologically challenging. Moreover, aside from the solidly measurable outcomes such as decreased overall mortality or cost, quantifying benefits such as patient reassurance or physician confidence would be even more elusive. Conversely, much of the debate as to what constitutes unnecessary CT examinations is hampered by lack of reliable data on how often and in which medical scenarios we are deriving the benefits.

Although there is widespread agreement decrying unnecessary use of CT scanning, there is little guidance for the individual physician treating an individual patient. One approach to more uniform practice could refer to guidelines for CT utilization on the basis of presenting symptoms or findings. While evidence-based guidelines have been developed for CT in head injury (25,26) and radiography in patients who are suspected of having cervical spine (27,28) and ankle (29) injuries, widely accepted guidelines for body CT utilization have yet to be developed. The American College of Radiology Appropriateness Criteria (30) represent evidence-based consensus recommendations available for this purpose, but surveys indicate that they have not been generally adopted. Our results identify the examination indications in which establishing clinical criteria for CT scanning would have the maximum effect on CT utilization rates. These include trauma, the most common reason for chest CT and the second most common reason for abdominopelvic CT, and abdominal pain, the most common indication for abdominopelvic CT. Algorithms for evaluating patients presenting with these complaints would ideally be derived from data on when imaging is likely to be of benefit and also incorporate, when appropriate, other imaging modalities, such as ultrasonography and magnetic resonance imaging, which do not involve radiation, or low-radiation-dose CT protocols, such as for renal colic where predicted mortality from the underlying disease is predicted to be low.

Our study had a number of important limitations. In estimating CT scanning risk, we assumed that radiation-induced cancer follows a linear-no-threshold model. This model was chosen because it is the most conservative, but its validity is debated among radiation biologists, especially in the low–radiation-dose ranges conferred by diagnostic CT (31,32). Our calculations also assumed an average standard dose for chest and abdominopelvic CT. Yet radiation dose of the same radiologic procedure can vary with the institution and the scanner (33). Although this produces some uncertainty concerning individual scan dose, over the entire population, it should confer reasonable accuracy. It is important to note that, given the efforts in CT radiation dose reduction, the dose assumptions applied to our cohort may overestimate the current population risk from CT (34,35). Finally, because our cohort is derived from three academically affiliated medical centers in a single metropolitan area, the extent to which our findings are generalizable to other practices and geographic settings is unclear. However, it seems unlikely that short-term mortality rates of young adults undergoing CT scanning would vary greater than an order of magnitude (ie, the difference observed between radiation-induced and morbidity-related patient death) among centers in the United States.

In conclusion, among young adults undergoing body CT, risk of intercurrent death is more than an order of magnitude greater than from long-term radiation-induced cancer death. This is true for all scanning frequencies, for patients undergoing either chest or abdominopelvic CT, and for the subgroup of patients without an underlying cancer. When consulting on radiation concerns, the radiologist should counsel that the underlying medical morbidity, rather than CT-induced cancer, is the much greater driver of a potentially adverse patient outcome.

Disclosures of Conflicts of Interest: **R.L.Z.** No relevant conflicts of interest to disclose. **P.F.H.** No relevant conflicts of interest to disclose. **C.A.S.** No relevant conflicts of interest to disclose. **B.L.** No relevant conflicts of interest to disclose. **S.I.L.** No relevant conflicts of interest to disclose.

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