Group Information: The INCAPS Investigators Group includes executive committee members A. J. Einstein (chair), T. N. B. Pascual (IAEA project lead), D. Paez (IAEA section head), M. Dondi (IAEA section head); N. Better, S.E. Bouyoucef, G. Karthikeyan, R. Kashyap, V. Lele, F. Mut, V. P. C. Magboo, J. J. Mahmarian, M. Mercuri, M. M. Rehani, and J. V. Vitola, and regional coordinators E. Alexanderson (Latin America), A. Allam (Africa and Middle East), M. H. Al-Mallah (Middle East), N. Better (Oceania), S. E. Bouyoucef (Africa), H. Bom (East Asia), A. Flotats (Europe), S. Jerome (United States), P. A. Kaufmann (Europe), V. Lele (South Asia), O. Luxenburg (Israel), J. Mahmarian (North America), L. J. Shaw (North America), S. R. Underwood (United Kingdom), and J. Vitola (Latin America). Members by region include W. Amouri, H. Essabbah, S. S. Gassama, K. B. Makhdomi, G. I. E. El Mustapha, N. El Ouchdi, N. Qaïs, N. Soni, and W. Vangu (Africa); R. M. Abazid, B. Adams, V. Agarwal, M. A. Alfeeli, N. Alnafisi, L. Bernabe, G. G. Bural, T. Chaiwatanarat, J. M. Chandraguptha, G. J. Cheon, I. Cho, A. S. Dogan, M. Eftekhari, A. Frenkel, I. Garty, S. George, P. Geramifar, H. Golan, S. Habib, R. Hussain, H. Im, H-J. Jeon, T. Kalawat, W. J. Kang, F. Keng, A. Klaipetch, P. G. Kumar, J. Lee, W. W. Lee, I. Lim, C. M. M. Macaisa, G. Malhotra, B. R. Mittal, M. H. Mohammad, P. Mohan, I. D. Mulyanto, D. Nariman, U. N. Nayak, K. Niaz, G. Nikolov, J. M. Obaldo, E. Ozturk, J. M. Park, S. Park, C. D. Patel, H. K. Phuong, A. P. Quinon, T. R. Rajini, Y. Saengsuda, J. Santiago, H. B. Sayman, A. S. Shinto, V. Sivasubramaniyan, M. H. Son, P. Sudhakar, G. M. S. Syed, N. Tamaki, K. Thamnirat, T. Thientunyakit, S. Thongmak, D. N. Velasco, A. Verma, U. Vutrapongwatana, Y. Wang, K. S. Won, Z. Yao, T. Yingsa-nga, R. Yudistiro, K. T. Yue, and N. Zafrir (Asia); S. C. Adrian, D. Agostini, S. Aguadé, G. Armitage, M. Backlund, M. Backman, M. Baker, M. T. Balducci, C. Bavelaar, M. Berovic, F. 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Romeo, M. Rossi, D. Ruiz, N. Sabharwal, B. G. Salobir, A. I. Santos, S. Saranovic, A. Sarkozi, R. P. Schneider, R. Sciagra, S. Scotti, Z. Servini, L. R. Setti, S.-Å. Starck, D. Vajauskas, J. Veselý, A. Vieni, A. Vignati, I. M. Vito, K. Weiss, D. Wild, and M. Zdraveska-Kochovska (Europe); R. N. Agüro, N. Alvarado, C. M. Barral, M. Beretta, I. Berrocal, J. F. Batista Cuellar, T.-M. Cabral Chang, L. O. Cabrera Rodríguez, J. Canessa, G. Castro Mora, A. C. Claudia, G. F. Clavelo, A. F. Cruz Jr, F. F. Faccio, K. M. Fernández, J. R. Gomez Garibo, U. Gonzalez, P. González, M. A. Guzzo, J. Jofre, M. Kapitán, G. Kempfer, J. L. Lopez, T. Massardo, I. Medeiros Colaco, C. T. Mesquita, M. Montecinos, S. Neubauer, L. M. Pabon, A. Puente, L. M. Rochela Vazquez, J. A. Serna Macias, A. G. Silva Pino, F. Z. Tártari Huber, A. P. Tovar, L. Vargas, and C. Wiefels (Latin America); A. Aljizeeri, R. J. Alvarez, D. Barger, W. Beardwood, J. Behrens, L. Brann, D. Brown, H. Carr, K. Churchwell, G. A. Comingore, J. Corbett, M. Costello, F. Cruz, T. Depinet, S. Dorbala, M. Earles, F. P. Esteves, E. Etherton, R. J. Fanning Jr, J. Fornace, L. Franks, H. Gewirtz, K. Gulanchyn, C.-L. Hannah, J. Hays, J. Hendrickson, J. Hester, K. Holmes, S. Jerome, A. Johnson, C. Jopek, H. Lewin, J. Lyons, C. Manley, J. Meden, S. Moore, W. H. Moore, V. Murthy, R. Nace, D. Neely, L. Nelson, O. Niedermaier, D. Rice, R. Rigs, K. Schiffer, E. Schockling, T. Schultz, T. Schumacker, B. Sheesley, A. Sheikh, B. Siegel, A. M. Slim, J. Smith, M. Szulc, N. Tanskersley, P. Tilkemeier, G. D. Valdez, R. Vrooman, D. Wawrowicz, and D. E. Winchester (North America); and A. Alcheikh, B. Allen, E. Atkins, J. Bevan, C. Bonomini, J. Christiansen, L. Clack, E. Craig, H. Dixson, I. Duncan, S. Fredericks, S. Gales, R. Hampson, T. Hanley, K. Hartcher, J. Hassall, B. Kelley, S. Kelly, T. Kidd, T. de Kort, G. Larcos, W. Macdonald, C. McGrath, E. Murdoch, S. O'Malley, M. O'Rourke, M. Pack, R. Pearce, R. Praehofer, S. Ramsay, L. Scarlett, K. Smidt, F. Souvannavong, K. Taubman, G. Taylor, K. Tse, S. Unger, and J. Weale (Oceania).

Additional Contributions: João Vitola, MD, PhD, Quanta Diagnóstico & Terapia, Curitiba, Brazil, Ganesan Karthikeyan, MBBS, MD, DM, Department of Cardiology, All India Institute of Medical Sciences, New Delhi, and Ravi Kashyap, MD, and Maurizio Dondi, MD, Section of Nuclear Medicine and Diagnostic Imaging, Division of Human Health, IAEA, Vienna, Austria, reviewed the manuscript. They received no compensation for this role. We thank the INCAPS executive committee, regional coordinators, and investigators group. Investigators group members were compensated for their time and effort involved in data collection.

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Estimating the Reduction in the Radiation Burden From Nuclear Cardiology Through Use of Stress-Only Imaging in the United States and Worldwide

Myocardial perfusion imaging (MPI) is invaluable in diagnosing and managing coronary artery disease; however, it accounts for approximately 10% of the radiation burden to the US population.[1] Use of a "stress-only" imaging protocol, whereby stress imaging is performed first and subsequent rest imaging is omitted when stress images are determined to be normal, has been shown to reduce radiation burden without compromising patient safety.[2] Although single-center data support that a 60% reduction in radiation dose may be realized with the use of stress-only imaging,[2] data from a US survey suggest that stress-only protocols are infrequently performed.[3] We sought to estimate current rates of stress-only imaging in the United States and worldwide, as well as the potential effect of changes in this rate on the radiation burden to the US population.

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Methods | Data on MPI protocols used in clinical practice were collected as part of the International Atomic Energy Agency Nuclear Cardiology Protocols Study (INCAPS),[4] a cross-sectional registry of 7911 patients undergoing MPI in 308 laboratories in 65 countries. Laboratories provided data, including protocols, radiopharmaceuticals, and administered activities, for all studies performed during a 1-week period between March 18 and April 22, 2013. Data analysis was performed from August 18, 2014, to July 16, 2015. We excluded from analysis 1196 patients (339 from the United States) who underwent single-photon emission computed tomographic imaging reflecting myocardial perfusion at rest only, with no stress testing performed; a protocol involving thallium 201, for which information regarding perfusion at rest or myocardial viability may be of interest in addition to findings from stress testing; or positron emis-

Table 1. Protocol Use and Radiation ED By Geographic Region for Studies Eligible for Stress-Only Protocol

Characteristic	Africa	Asia	Europe	Latin America[a]	North America	Oceania	Total	*P* Value
Patients, No.	336	1077	2130	1033	1734	405	6715	
Rest-first imaging, No. (%)[b]	34 (10.1)	343 (31.8)	333 (15.6)	613 (59.3)	1601 (92.3)	320 (79.0)	3244 (48.3)	<.001
Stress-first imaging, No. (%)[c]	302 (89.9)	734 (68.2)	1797 (84.4)	420 (40.7)	133 (7.7)	85 (21.0)	3471 (51.7)	<.001
Stress-only imaging, No. (%)	109 (32.4)	122 (11.3)	422 (19.8)	53 (5.1)	54 (3.1)	40 (9.9)	800 (11.9)	<.001
ED, mSv								
Non-stress-only imaging, mean (SD) ED	12.8 (4.2)	11.2 (2.6)	9.0 (2.5)	12.4 (3.5)	12.0 (3.0)	9.9 (3.0)	11.0 (3.2)	
Stress-only imaging, mean (SD) ED	3.9 (2.4)	3.7 (1.7)	3.9 (1.4)	5.4 (1.9)	5.2 (3.0)	2.3 (0.7)	4.0 (1.9)	
Mean ED difference	8.9	7.5	5.1	7.0	6.8	7.6	7.0	<.001
Decrease in mean ED, %	69.5	67.0	56.7	56.5	56.7	76.8	63.6	

Abbreviation: ED, effective dose.

SI conversion factor: To convert millisieverts to roentgen equivalent man [rem], multiply by 0.1.

[a] Latin America includes Mexico.

[b] Rest-first imaging denotes a protocol where technetium Tc 99m rest imaging was performed before technetium Tc 99m stress imaging.

[c] Stress-first imaging denotes a protocol where technetium Tc 99m stress imaging was performed first, creating the possibility of a stress-only protocol; thus, stress-only imaging constitutes the subset of stress-first imaging in which rest imaging was omitted.

sion tomographic imaging, in which radiation doses are lower and stress-only imaging is generally not warranted. We compared regional rates of stress-only imaging and associated radiation effective doses among the remaining 6715 patients. We modeled the effect on radiation exposure to the US population if stress-only imaging were performed at the same rate as at European INCAPS sites (19.8%), a large US tertiary care center reported by Chang et al[2] (29.0%), the 90th percentile of all INCAPS laboratories (42.1%), and the 90th percentile of European INCAPS laboratories (60.0%). We also modeled radiation exposure if stress-only imaging were performed in all studies with normal myocardial perfusion,[5] a theoretical maximum. Modeling assumed that US nuclear cardiology practice is similar to that in the INCAPS population in the United States, that 9.25 million MPI studies are performed annually, and that annual all-source effective dose to the US population averages 6.2 mSv per person (to convert to roentgen equivalent man [rem], multiply by 0.1).[1] We also modeled the effect on the world nuclear cardiology population. Categorical variables were compared using the Fisher exact test and continuous variables were compared using analysis of variance, with STATA/SE, version 13.1 (StataCorp LP). The Columbia University Institutional Review Board approved the study and deemed it exempt from the requirements of US federal regulations for the protection of human subjects, as no individually identifiable health information was collected.

Results | Marked variation existed between regions regarding the use of stress-first and stress-only protocols; the rates of these protocols were lowest in North America (**Table 1**). Among eligible studies, the mean effective dose decreased 63.6% (11.0 vs 4.0 mSv; $P < .001$) when a stress-only protocol was used.

The model estimates a 20.9% reduction in the mean effective dose from MPI if US laboratories were to adopt stress-only imaging at the same rate as the top 10% of INCAPS laboratories. This percentage reduction corresponds to a 21.2 million person-mSv reduction in cumulative radiation burden to the US population. While risk projection modeling is fraught with uncertainties, as a very rough estimate, the US Food and Drug Administration estimates an increase in the possibility of developing a fatal cancer of 1 in 2000 for a 10-mSv exposure,[6] suggesting that increased adoption of stress-only MPI might prevent hundreds of cases of cancer annually. Estimates for each model scenario are presented in **Table 2**.[1,2,4,5]

Discussion | Adopting a practice of stress-only imaging among the majority of patients undergoing MPI and who have normal myocardial perfusion and function would dramatically decrease the average radiation dose to patients, significantly improving nuclear cardiology's radiation safety profile for the US population.

Increasing the rate of stress-only imaging is currently hindered by a low rate of performing stress imaging before rest imaging, especially in North America, where stress imaging was performed first in 133 of 1734 eligible studies (7.7%) vs 1797 of 2130 studies (84.4%) in Europe. The ability to perform stress-only imaging requires workflow changes, with real-time physician review of stress images to assess the need for same-day rest imaging, or rest imaging performed, when needed, on a later day than stress imaging, as is common outside the United States.

In addition, current remuneration schemes create disincentives to performing stress-only MPI. In the United States, there exist 2 *Current Procedural Terminology* billing codes for single-photon emission computed tomographic scan MPI: 78451 (single study, eg, stress-only imaging performed) and 78452 (multiple studies, eg, both rest and stress imaging performed); Medicare global reimbursements for these procedures are $355.74 and $492.65, respectively. Given this $137 difference, it is not surprising that the 3.0% rate of stress-only imaging among eligible studies in the United States was far lower than the rates observed worldwide (11.9%) and in Europe (19.8%).

Table 2. Effect of Increase in the Rate of Stress-Only Protocol Use on Radiation Burden to US and World Nuclear Cardiology Populations, and to the Entire US Population[a]

Strategy	Rate of Stress-Only Imaging, %	Mean Effective Dose per Study, mSv[5]		Strategy-Associated Population Reduction in Radiation Dose, Person-mSv, No. (%)[d]	Radiation Burden				All-Source Radiation Dose Reduction, %
		All Studies[b]	Studies Eligible for Stress-Only Imaging[c]		Nuclear Cardiology Radiation Burden		All-Source Radiation Burden		
					Person-mSv	mSv per Person	Person-mSv	mSv per Person	
Nuclear Cardiology Patients, United States					**Entire US Population**				
Current practice[4]	3.0[e]	11.0	12.2	0	101 472 500	0.32	1 953 000 000	6.2[1]	0
Rate attained[f]									
European[4]	19.8	10.0	11.0	9 102 000 (9.0)	92 370 500	0.29	1 943 898 000	6.17	0.5
Chang et al[g]	29.0	9.4	10.3	14 411 000 (14.2)	87 061 000	0.28	1 938 588 500	6.15	0.7
90th Percentile worldwide[4]	42.1	8.7	9.4	21 238 000 (20.9)	80 234 500	0.25	1 931 762 000	6.13	1.1
90th Percentile in Europe[4]	60.0	7.6	8.1	31 250 000 (30.8)	70 222 300	0.22	1 921 749 800	6.1	1.6
Stress-only imaging in all normal cases[h]	67.6	7.2	7.6	35 270 000 (34.9)	66 202 500	0.21	1 917 730 000	6.09	1.8
Nuclear Cardiology Patients, Worldwide									
Current practice[4]	11.9	10.0	10.2	0					
Rate attained[f]									
European[4]	19.8	9.4	9.6	10 080 000 (5.1)					
Chang et al[g]	29.0	8.9	9.0	20 160 000 (10.1)					
90th Percentile worldwide[4]	42.1	8.2	8.1	35 280 000 (17.7)					
90th Percentile in Europe[4]	60.0	7.1	6.8	57 120 000 (28.7)					
Stress-only imaging in all normal cases[h]	67.6	6.7	6.3	65 520 000 (32.9)					

Abbreviation: INCAPS, International Atomic Energy Agency Nuclear Cardiology Protocols Study.

SI conversion factor: To convert millisieverts to roentgen equivalent man [rem], multiply by 0.1.

[a] The rates of stress-only imaging and mean effective doses are estimated as per the INCAPS study,[4] unless otherwise noted.

[b] Mean Effective Dose per Study, All Studies includes those not eligible for the stress-only protocol.

[c] As detailed in the Methods section, studies eligible for stress-only imaging excludes positron emission tomographic scan studies and studies with rest imaging alone, which have lower radiation effective doses, thus accounting for the generally higher mean radiation dose for studies eligible for stress-only imaging compared with all studies.

[d] Our calculations assume 9.25 million nuclear cardiology procedures in the United States (82% eligible for stress-only protocol, as per INCAPS[4]), and 20 million worldwide (85% eligible, as per INCAPS[4]). All calculations based on US and world population estimates at the time of data collection (March 18 through April 22, 2013).

[e] This rate is consistent with the Centers for Medicare & Medicaid Services' observation that 96% of myocardial perfusion imaging is billed with *Current Procedural Terminology* code 78452.

[f] Stress-only imaging was performed at the same rate as in the following 5 scenarios.

[g] Chang et al[2] rate is that achieved in a single US center between 1999 and 2007, and is virtually identical to the 75th percentile rate in Europe in INCAPS (30%).

[h] We used a conservative estimate of the "normal" rate—67.6%—based on the 2009-2012 period in Duvall et al,[5] who, in a multicenter study, reported a lower rate of normal studies than in previous work.

However, equalization of reimbursement for stress-only MPI with multiple-study imaging is also undesirable because it could disincentivize performing rest imaging (which entails additional costs) where needed (eg, when attenuation artifacts impede image interpretation). In patients with established cardiomyopathy, or myocardial infarction and a known scar, stress-only imaging may be inapplicable.

Nevertheless, the present reimbursement system provides strong financial disincentive for many US laboratories to consider stress-only imaging. Increasing reimbursement for single-study MPI without increasing total payment for MPI (approximately $800 million annually in the Center for Medicare & Medicaid Service's Outpatient Prospective Payment System) could eliminate this disincentive, thereby decreasing radiation exposure to the US population. In addition, a policy mandating reimbursement for single-study imaging (eg, stress-only imaging), if multiple-study imaging had been preauthorized, would provide physicians performing MPI the flexibility needed to perform stress-only imaging when clinically warranted.

In conclusion, our findings suggest a clear need for change in the United States to achieve parity with worldwide practice in the use of stress-only imaging, and thereby reduce the radiation burden from MPI.

Mathew Mercuri, PhD
Thomas N. B. Pascual, MD
John J. Mahmarian, MD
Leslee J. Shaw, PhD
Maurizio Dondi, MD
Diana Paez, MD
Andrew J. Einstein, MD, PhD;
for the INCAPS Investigators Group

Author Affiliations: Division of Cardiology, Department of Medicine, Columbia University Medical Center, New York–Presbyterian Hospital, New York (Mercuri, Einstein); Section of Nuclear Medicine and Diagnostic Imaging, Division of Human Health, International Atomic Energy Agency, Vienna, Austria (Pascual, Dondi, Paez); Department of Cardiology, Houston Methodist DeBakey Heart and Vascular Center, Houston, Texas (Mahmarian); Division of Cardiology, Department of Medicine, Emory University School of Medicine, Atlanta, Georgia (Shaw); Emory Clinical Cardiovascular Research Institute, Emory University School of Medicine, Atlanta, Georgia (Shaw); Department of Radiology, Columbia University Medical Center, New York–Presbyterian Hospital, New York (Einstein).

Corresponding Author: Andrew J. Einstein, MD, PhD, Division of Cardiology, Department of Medicine, Columbia University Medical Center, New York–Presbyterian Hospital, 622 W 168th St, Office PH 10-203, New York, NY 10032 (andrew.einstein@columbia.edu).

Published Online: December 28, 2015. doi:10.1001/jamainternmed.2015.7106.

Author Contributions: Drs Mercuri and Einstein had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Mercuri, Pascual, Mahmarian, Dondi, Paez, Einstein.
Acquisition, analysis, or interpretation of data: Mercuri, Pascual, Mahmarian, Shaw, Einstein.
Drafting of the manuscript: Mercuri, Einstein.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Mercuri, Einstein.
Obtained funding: Einstein.
Administrative, technical, or material support: Pascual, Mahmarian, Shaw, Paez, Einstein.
Study supervision: Dondi, Einstein.

Conflict of Interest Disclosures: Dr Einstein reported receiving institutional research grants to Columbia University for other research from GE Healthcare, Philips Healthcare, Spectrum Dynamics, and Toshiba America Medical Systems. No other disclosures were reported.

Funding/Support: This study was supported by the International Atomic Energy Agency, the Margaret Q. Landenberger Research Foundation in memory of A. Donny Strosberg, PhD, and the Irving Scholars Program.

Role of the Funder/Sponsor: Drs Pascual, Dondi, and Paez are employed by the International Atomic Energy Agency and contributed as noted above. The other sponsors had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

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Alfeeli, N. Alnafisi, L. Bernabe, G. G. Bural, T. Chaiwatanarat, J. M. Chandraguptha, G. J. Cheon, I. Cho, A. S. Dogan, M. Eftekhari, A. Frenkel, I. Garty, S. George, P. Geramifar, H. Golan, S. Habib, R. Hussain, H. Im, H-J. Jeon, T. Kalawat, W. J. Kang, F. Keng, A. Klaipetch, P. G. Kumar, J. Lee, W. W. Lee, I. Lim, C. M. M. Macaisa, G. Malhotra, B. R. Mittal, M. H. Mohammad, P. Mohan, I. D. Mulyanto, D. Nariman, U. N. Nayak, K. Niaz, G. Nikolov, J. M. Obaldo, E. Ozturk, J. M. Park, S. Park, C. D. Patel, H. K. Phuong, A. P. Quinon, T. R. Rajini, Y. Saengsuda, J. Santiago, H. B. Sayman, A. S. Shinto, V. Sivasubramaniyan, M. H. Son, P. Sudhakar, G. M. S. Syed, N. Tamaki, K. Thamnirat, T. Thientunyakit, S. Thongmak, D. N. Velasco, A. Verma, U. Vutrapongwatana, Y. Wang, K. S. Won, Z. Yao, T. Yingsa-nga, R. Yudistiro, K. T. Yue, and N. Zafrir (Asia); S. C. Adrian, D. Agostini, S. Aguadé, G. Armitage, M. Backlund, M. Backman, M. Baker, M. T. Balducci, C. Bavelaar, M. Berovic, F. Bertagna, R. Beuchel, A. Biggi, G. Bisi, R. Bonini, A. Bradley, L. Brudin, I. Bruno, E. Busnardo, R. Casoni, A. Choudhri, C. Cittanti, R. Clauss, D. C. Costa, M. Costa, K. Dixon, M. Dziuk, N. Egelic, I. Eriksson, G. Fagioli, D. B. de Faria, L. Florimonte, A. Francini, M. French, E. Gallagher, I. Garai, O. Geatti, D. Genovesi, L. Gianolli, A. Gimelli, E. del Giudice, S. Halliwell, M. J. Hansson, C. Harrison, F. Homans, F. Horton, D. Jędrzejuk, J. Jogi, A. Johansen, H. Johansson, M. Kalnina, M. Kaminek, A. Kiss, M. Kobylecka, M. Kostkiewicz, J. Kropp, R. Kullenberg, T. Lahoutte, O. Lang, Y. H. Larsson, M. Lázár, L. Leccisotti, N. Leners, O. Lindner, R. W. Lipp, A. Maenhout, L. Maffioli, C. Marcassa, B. Martins, P. Marzullo, G. Medolago, J. B. Meeks, C. G. Mendiguchía, S. Mirzaei, M. Mori, B. Nardi, S. Nazarenko, K. Nikoletic, R. Oleksa, T. Parviainen, J. Patrina, R. Peace, C. Pirich, H. Piwowarska-Bilska, S. Popa, V. Prakash, V. Pubul, L. Puklavec, S. Rac, M. Ratniece, S. A. Rogan, A. 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Comingore, J. Corbett, M. Costello, F. Cruz, T. Depinet, S. Dorbala, M. Earles, F. P. Esteves, E. Etherton, R. J. Fanning Jr, J. Fornace, L. Franks, H. Gewirtz, K. Gulanchyn, C.-L. Hannah, J. Hays, J. Hendrickson, J. Hester, K. Holmes, S. Jerome, A. Johnson, C. Jopek, H. Lewin, J. Lyons, C. Manley, J. Meden, S. Moore, W. H. Moore, V. Murthy, R. Nace, D. Neely, L. Nelson, O. Niedermaier, D. Rice, R. Rigs, K. Schiffer, E. Schockling, T. Schultz, T. Schumacker, B. Sheesley, A. Sheikh, B. Siegel, A. M. Slim, J. Smith, M. Szulc, N. Tanskersley, P. Tilkemeier, G. D. Valdez, R. Vrooman, D. Wawrowicz, and D. E. Winchester (North America); and A. Alcheikh, B. Allen, E. Atkins, J. Bevan, C. Bonomini, J. Christiansen, L. Clack, E. Craig, H. Dixson, I. Duncan, S. Fredericks, S. Gales, R. Hampson, T. Hanley, K. Hartcher, J. Hassall, B. Kelley, S. Kelly, T. Kidd, T. de Kort, G. Larcos, W. Macdonald, C. McGrath, E. Murdoch, S. O'Malley, M. O'Rourke, M. Pack, R. Pearce, R. Praehofer, S. Ramsay, L. Scarlett, K. Smidt, F. Souvannavong, K. Taubman, G. Taylor, K. Tse, S. Unger, and J. Weale (Oceania).

Additional Contributions: We thank the International Atomic Energy Agency Nuclear Cardiology Protocols Study executive committee, regional coordinators, and investigators group. Investigators were compensated for time and effort involved in data collection.

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LESS IS MORE

Use of Computed Tomography in Emergency Departments in the United States: A Decade of Coughs and Colds

Computed tomography (CT) can be an essential tool in guiding the management of acute or life-threatening pulmonary disease. Increasing use of CT, however, has raised concerns about the effects of ionizing radiation on organs within the radiation field, including the thyroid, lungs, and breast.[1] Beyond the risk posed by ionizing radiation, high resolution CT may have unintended downstream consequences related to incidental findings and overdiagnosis, leading to a costly and potentially harmful diagnostic, therapeutic, or interventional cascade.[2] Increasing use of CT is most concerning among patients with the least to gain (eg, patients with illnesses of low acuity or at low risk of serious pathological conditions) or the most to lose (eg, young patients in whom CT carries the greatest risk of causing future radiation-related cancers). We sought to examine trends in the use of CT, and in clinical decision-making, for patients presenting to the emergency department (ED) with respiratory symptoms.

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Methods | Using data from 2001 to 2010 in the National Hospital Ambulatory Medical Care Survey (NHAMCS), an annual national survey that obtains information about patients, presenting symptoms, and management for a systematic sample of visits, we identified visits by adults 18 years of age and older who presented to the ED of a hospital in the United States with a primary respiratory symptom. Data analysis was conducted from November 2013 through February 2015. The complex sampling strategy and analytic design of the NHAMCS allow the derivation of nationally representative information about the use of ambulatory-care services. We stratified ED visits according to symptom location in the lower respiratory (eg, cough or shortness of breath) vs upper respiratory tract (eg, sore throat or nasal congestion) and acuity of illness based on triage rating and vital signs.

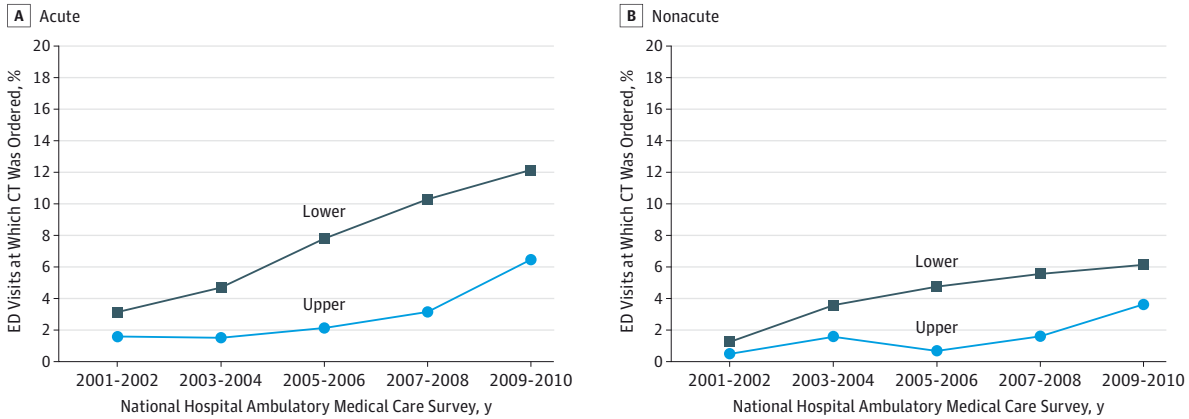
Our primary outcome variable was CT performed during an ED visit. Secondary outcomes included diagnosis and management strategies (antibiotic prescription and hospital admission). We present weighted crude point estimates (in 2-year intervals) and, using multiple logistic regression, time trends, both crude and adjusted for age, race, sex, region, and insurance status.

Dartmouth College's institutional review board waived review of this research.

Results | The 23 416 ED visits among adults with respiratory symptoms recorded in the NHAMCS between 2001 and 2010 represented an estimated 79 million ED sample visits in the United States. Overall use of CT imaging quadrupled during the 10-year period, from 2.2% (2001-2002) to 9.4% (2009-2010) (odds ratio, 4.6; 95% CI, 3.4-6.2) of visits. Use of CT increased at least 4-fold within each symptom group, increasing most steeply among patients with the least acute reason for imaging (ie, the lowest absolute CT rates), those with nonacute upper respiratory symptoms, among whom the use of CT increased from 0.5% to 3.6% (odds ratio, 7.4; 95% CI, 1.3-42.0) (**Figure**). Odds ratios cited represent crude likelihood in 2009-2010 vs 2001-2002. Adjusted odds ratios were comparable (**Table**).

The use of CT increased comparably across all age strata, including a 4-fold increase among the youngest patients (aged 18-39 years) (Table). Management (antibiotic prescription and hospital admission) did not appear to change, while the proportion of patients discharged without a diagnosis (ie, with a symptom-based diagnosis) increased during the study period.

Figure. Ten Years of CT Use for Adults With Respiratory Symptoms Presenting to EDs of US Hospitals, by Acuity and Symptom Location (2001-2010)



Crude estimates are shown. CT indicates computed tomography; ED, emergency department; lower, lower respiratory tract; upper, upper respiratory tract.