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Environmental causes of breast cancer and radiation from medical imaging: findings from the Institute of Medicine report

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Susan G. Komen for the Cure, the largest grassroots network of breast cancer survivors and activists in the United States, asked the Institute of Medicine (IOM) to perform a comprehensive and evidenced based review of environmental causes and risk factors for breast cancer, with a focus on identifying evidenced-based actions that women can take to reduce their risk. [1] Environmental exposures were defined broadly to include all factors not genetically inherited, and the IOM committee appointed to write this report included academicians and chairs from departments of environmental health, toxicology, cancer epidemiology, preventive medicine, and biostatistics in addition to breast cancer patient advocates. Committee members conducted their own reviews of the peer–reviewed epidemiological and basic science literature, commissioned several papers specifically for their report, and drew on evidenced-based reviews already completed by organizations such as the Agency for Research on Cancer, and the World Cancer Research Fund International. The publication *Breast Cancer and The Environment: A life course approach* was released on-line in December 2011.

Interestingly, none of the consumer products (i.e. bisphenol A, phthalates), industrial chemicals (i.e. benzene, ethylene oxide), or pesticides (i.e. DDT/DDE) considered could be conclusively linked to an increased risk of breast cancer, although the IOM acknowledged that the available evidence was insufficient to draw firm conclusions for many of these exposures, calling for more research in these areas. The IOM did find sufficient evidence to conclude that the two environmental factors most strongly associated with breast cancer were exposure to ionizing radiation and to combined postmenopausal hormone therapy. [1] Since the Women's Health Initiative reported that combined estrogen and progestin hormone therapy increases a woman's risk of breast cancer, [2] there has been a steep decline in hormone therapy use followed by small decline in breast cancer incidence.[3] Thus the most significant conclusion of the IOM report is that in order to reduce her risk of breast cancer, a woman should avoid inappropriate radiation exposure. In particular, because the radiation doses delivered by computed tomography (CT) imaging are high, women should reduce any unnecessary exposure to CT. The IOM also concluded that several lifestyle factors may modestly reduce a woman's risk of breast cancer, such as limiting alcohol consumption, maintaining a healthy bodyweight, and reducing active smoking, all of which have health benefits beyond lowering a risk woman's risk of breast cancer.

The IOM's conclusion of a causal relation between radiation exposure and cancer is consistent with a large and varied literature showing that exposure to radiation in the same range as used for CT will increase the risk of cancer. [4–6] Many national and international

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organizations such as the National Council on Radiation Protection (NCRP), the International Council on Radiation Protection (ICRP), and the International Atomic Energy Agency (IAEA) were established in part to promote radiation protection, given its carcinogenic. What is surprising is the IOM's focus on the *avoidance* of medical imaging as one of the most important and concrete steps that women can take to reduce their risk of breast cancer, reflecting the growing awareness that computed tomography is overused - and that a reduction in unnecessary use would lead to health improvement. Further, the IOM highlighted that excess radiation exposure is aggravated by the large variation in CT doses for the same imaging test conducted among different institutions, as well as dosing errors by inadequately trained or supervised technologists, and poorly designed equipment. A reduction in variation in doses across patients and institutions and elimination of over-dosing errors would greatly improve the safety of CT and reduce its potential for causing cancer. The IOM estimated that 2,800 future breast cancers would result from one year of medical radiation exposure among the entire U.S. female population, with 2/3 of those cases resulting from CT radiation exposures. While these represent a small proportion of all breast cancers.[1,7,8], they are important because they can potentially be reduced.

The use of CT has increased nearly five-fold over the last two decades. [9–14] Currently 75 million CTs are done annually in the U.S., [15] around half in women, reflecting the large number of individuals who are exposed to this source of radiation. Thought leaders in radiology are often quoted as estimating that 30% or more of advanced imaging tests may be unnecessary, [8,16] and while there are few scientific data to precisely estimate the amount of overuse, many radiologists feel the proportion may be even higher.

The reasons for overuse of CT are many [16], but include the ease of conducting this examination and the potential to get rapid answers to troubling diagnostic questions. Intense marketing and rapid purchase of machines prior to completely understanding how this technology should be used to improve health outcomes has created excess capacity yet few evidenced based guidelines for its use. [17] Strong financial incentives [18] reflected in the growing ownership of CT scanners by non-radiologists for use in their private medical offices [19,20] strong patient demand (in part resulting from direct-to-consumer advertisements that do not mention untoward effects [21]), and medical malpractice concerns leading to defensive test ordering.[22] have all further contributed to high excess use. Thus, while CT is clearly indicated and valuable in many cases – for example for patients with acute appendicitis and pulmonary embolism - CT is frequently used in the absence of evidence. The threshold for using CT for imaging has dropped dramatically [23], and thus it is not surprising that the IOM suggested unnecessary radiation exposure from medical imaging should be curtailed to reduce cancer risks.

When ionizing radiation is used outside the medical world – be it in the nuclear power industry, the military, or for homeland security - justification for its use must be provided. There is particular concern for limiting radiation exposures in occupational and industrial settings where the person exposed does not receive direct benefit from that exposure, although the broad principle of justifying radiation exposure should be the same whether it occurs in medicine or other contexts. It is important to gain insights from other applications of nuclear technology in the management of risks in medicine, and this is something that needs far more consideration in the U.S. In Europe, in contrast, very clear justification for CT is required, as reported in the referral guidelines for imaging published by the European Commission *"in view of the potential high doses, CT should only be carried out after proper clinical justification by an experienced radiologist. Examinations on children require a higher level of justification, since such patients are at greater risk from radiation.*[24] Justification in the U.S. for medical imaging that delivers radiation was present in the earlier years of its use, but ironically, as the doses of radiation used in medical imaging have

increased, the requirement for justification for its use has declined. Recently, and surprisingly, its known harms have even been trivialized by some [25] in contrast to the large and varied literature which has clearly documented the potential for radiation doses in the same range as used in CT for causing cancer

In order to reduce inappropriate medical imaging, individual patients, health care providers and patient advocacy organizations all have a role to play, and the IOM highlights steps that can be taken to limit unnecessary exposures. Individual patients and their families should expect that their health care providers will discuss both the expected health benefits and potential harms of any imaging test that has been ordered-—particularly if the test involves exposure to radiation—and patients should directly question any health care provider who does not provide a complete picture. This picture should be appropriate for the clinical context - the likely benefit, the potential risk if imaging is not performed, as well as the radiation the test is likely to deliver. A useful rule of thumb is that patients should ask if a test is likely to alter their clinical management or add confidence to their clinician's diagnosis.

It is the responsibility of individual health care providers who order medical imaging to understand and weigh the risk of any medical procedures against the expected benefit. New imaging technologies are delivering vastly larger radiation doses than conventional x-rays. For example, a chest CT may deliver a dose 100 to 500-fold higher than a chest radiograph. [26] With radiographs, the radiation dose is relatively small, so decisions about whether or not to order radiographs can be made based upon less careful weighing of these risks. New imaging, and complex scanning protocols developed for CT, generate much larger doses, in the range where increased rates of cancer can be measured, and where the doses have gotten so high that accidents have occurred resulting in hair loss or radiation burns. [27] Many ordering physicians are insufficiently informed about radiation doses and the cancer risks attributable to the medical images they order, [28] and yet this information is crucial if appropriate justification for the use of CT, as well as other high dose studies, is to be provided to patients and families. Robert Brook recently hypothesized that showing clinicians the cost of a medical test every time they ordered one for their patient might lead to the more judicious and cost effective use of medical care. [29] Similarly, if clinicians were provided with detailed information about the expected radiation exposure of a procedure, as well as about a patient's cumulative exposure to medical radiation at the time a test is ordered, they might chose the tests they ordered more judiciously. Current electronic medical records, and test ordering platforms, can be adopted to include this information, as well as information on the likely benefit of any imaging examination, and this would help to fulfill the Centers for Medicare and Medicaid Services (CMS) requirements for meaningful use of these information systems. There is a pressing need for educational information for the broad medical community (i.e. not just medical physicists) to enhance understanding of the doses of radiation involved in diagnostic imaging tests and the health risks associated with those doses.

Health care advocates, such as the National Partnership for Patients, should lobby for research that quantifies the risks and the benefits of medical imaging, given how important advanced imaging is to medical care. Currently the National Institute of Biomedical Imaging (the NIH institute tasked with medical imaging related research) has spent the majority of its resources on the development of new imaging modalities, rather than on quantifying the risks and benefits of existing imaging technology. Lastly, Congress and CMS, as well as other payers, have already enacted payment reforms targeted to reducing the expenditures on imaging and to removing some of the financial incentives that have led to the rapid rise in imaging. These measures have slowed the growth rate of imaging over the last few years. [9,30] The recently released White House health care budget specifically calls for an

additional $820 million dollar reduction in payments for imaging, and introduces prior authorization to further reduce utilization, although these specific recommendations may not be incorporated into the final approved budget. Since prior authorization adds costs, complexities, and time delays into the medical care process, it is in the self-interest of both payers and providers to develop alternative approaches to improving the appropriateness of imaging orders. There are some promising initiatives in that regard [31], including the implementation of clinical decision support in the electronic medical record of several large health systems.[32,33]

A second, and equally important, strategy for reducing inappropriate exposures to radiation from medical radiation is to lower the doses delivered for each imaging examination. This can be done through the development of greater oversight of CT as well as direct patient demands for improvement. Patients should ask their physicians about the radiation doses involved in their exams, and request a record of the doses to which they are exposed. The National Quality Forum recently adopted a quality measure focused on CT radiation dose that calls for facilities who conduct CT to record their doses. [34] Consumers and physicians should ask the facilities they use, and the health plans to which they belong, to adopt this measure, and to publically report dose information. This would rapidly improve a facility's knowledge of the doses they use, as well as motivate them to do what ever they can to lower and standardize radiation dose. Further this would allow patients and providers to use this information in their decision-making, regarding where to go for imaging.

The Food and Drug Administration (FDA) created a road map for reducing and standardizing the doses patients are exposed to when they undergo CT; they called for the creation of benchmarks (standard dosing levels), recording doses in the medical record, and creating evidenced-based guidelines for imaging. [35] However, they have not moved these efforts forward, instead asking medical societies and professional groups to take the lead. Unfortunately, there has been little progress in these areas since the FDA initially made these recommendations in early 2010. Radiology professional organizations could take the lead in creating concrete dose benchmarks, working closely with the FDA. The argument that it is too complicated to create dose standards is not supported by the evidence – and the current variation in doses could be markedly reduced. There is also the potential for legislators to get involved in this area; successful efforts in standardizing doses in mammography through the *Mammography Quality Standards Act* (MQSA) can be used as model for how legislation can optimize use of radiation in medial imaging. [36] At a minimum, the US Congress should pass the CARE Bill (H.R. 2104, The Consistency, Accuracy, Responsibility and Excellence in Medical Imaging and Radiation Therapy) [37] that is currently under consideration in the US congress as a way to improve the training of those who order and conduct imaging examinations. California has recently enacted legislation that goes into effect in July 2012 (Senate Bill 1237) requiring the dose used for CT exams be recorded in every patient's medical record, and further requires inadvertent CT radiation over-doses to be immediately reported to the state. [38] This will inform patients and referring providers about dose, and will further encourage facilities to begin assessing and reducing the doses they are delivering to their patients. The California legislation provides a template for consideration of national legislation.

Lastly, while manufacturers are developing and marketing devices that can create diagnostic images using considerably lower doses of radiation, it may take decades for these devices to replace those currently in operation. Thus the manufacturers should work closely will all facilities who use their equipment to provide existing software upgrades to immediately reduce the doses to which patients are exposed. Currently, the costs of these software upgrades are marketed at prices outside the reach of many facilities that conduct CT. Further, as the IOM suggested, manufacturers could adopt uniform design standards – as has

been successfully done in other areas of medicine (such as anesthesia) and outside of medicine (such as the airline industry) - that would make it easier for technologists to move between different manufacturers and machines to improve safety. For example, the different manufacturers have developed different techniques to modulate the tube current for patients of different sizes, in order to reduce the doses patients receive. GE has defined a measure known as the noise index, and the *higher* values in the noise index result in *lower* dose. Siemens has defined reference mAs –*higher* values in the effective mAs resulting in *higher* dose. Thus if a technologist has a small patient and would like to reduce the dose, they need to turn the noise index *up* on a GE machine, whereas they need to turn the effective mAs *down* on a Sieman's machine - seemingly opposite directions to lower the dose.

Computed tomography is a highly valuable tool, but unnecessary use may lead to a small, but real increase in a patients' risk of cancer, and patients should be appropriately involved in the decision to undergo imaging.[39] Many imaging enthusiasts believe patients cannot be told about the radiation exposure associated with medical imaging, believing they will make poor choices and refuse *indicated* imaging. [40,41] This fear has not been substantiated. When given balanced information about both risks and benefits, patients usually have made informed and appropriate decisions regarding medical imaging for themselves or their families. For example, in one study of caregivers, informed of the radiation risk associated with a diagnostic CT for their child, they preferred the lower risk option of observation if the physician felt it would be equally effective, and chose in favor of CT if it was preferred and recommended by their physician [42] Now we need to develop the evidence needed by both physicians and patients, so they can take advantage of this tool in the situations where it will be most important to do so.

In conclusion, the IOM conclusion that current evidenced-based options for women to reduce their risk of breast cancer are limited. Most of the known risks factors for breast cancer – such as the age of menarche or family history - cannot be controlled. Avoiding and reducing exposure to medical radiation is one of the primary evidenced-based actions that could reduce breast cancer risk, and the medical community should do everything in our power to reduce unnecessary exposures as quickly as possible

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References

1. Institute of Medicine. Breast Cancer and The Environment: A Life Course Approach. The National Academies; 2011.
2. Rossouw JE, Anderson GL, Prentice RL, et al. Risks and benefits of estrogen plus progestin in healthy postmenopausal women: principal results From the Women's Health Initiative randomized controlled trial. JAMA. 2002; 288:321–333. [PubMed: 12117397]
3. Ravdin PM, Cronin KA, Howlader N, et al. The decrease in breast-cancer incidence in 2003 in the United States. N Engl J Med. 2007; 356:1670–1674. [PubMed: 17442911]
4. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. Washington, D.C.: The National Academies Press; 2006. Board of Radiation Effects Research Division on Earth and Life Sciences National Research Council of the National Academies.
5. Preston DL, Ron E, Tokuoka S, et al. Solid cancer incidence in atomic bomb survivors: 1958-1998. Radiat Res. 2007; 168:1–64. [PubMed: 17722996]
6. Charles M. UNSCEAR report 2000: sources and effects of ionizing radiation. United Nations Scientific Comittee on the Effects of Atomic Radiation. J Radiol Prot. 2001; 21:83–86. [PubMed: 11281539]

7. Berrington de Gonzalez A, Mahesh M, Kim KP, et al. Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch Intern Med. 2009; 169:2071–2077. [PubMed: 20008689]
8. Brenner DJ, Hall EJ. Computed tomography--an increasing source of radiation exposure. N Engl J Med. 2007; 357:2277–2284. [PubMed: 18046031]
9. Government Accountability Office. Medicare: trends in fees, utilization, and expenditures for imaging services before and after implementation of the Deficit Reduction Act of 2005. (GAO-08-1102R.). Washington, DC: GAO; 2008. (Accessed June 10, 2010, at http://www.gao.gov/new.items/d081102r.pdf.)
10. Wall BF, Hart D. Revised radiation doses for typical X-ray examinations. Report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB. National Radiological Protection Board. Br J Radiol. 1997; 70:437–439. [PubMed: 9227222]
11. United States Government Accountability Office. Rapid spending growth and shift to physician offices indicate need for CMS to consider additional management practices. Washington D.C.: U.S. Government Accountability Office; 2008 Jun. Medicare Part B Imaging Services.
12. Smith-Bindman R, Miglioretti D, Johnson E. Use of Diagnostic Imaging Studies and Associated Radiation Exposure For Patients Enrolled in Large Integrated Healthcare Systems, 1996-2010 s and Patient Radiation Exposure Across Eight Integrated Healthcare Systems submitted for publication. 2012 al. LCe.
13. Larson DB, Johnson LW, Schnell BM, Salisbury SR, Forman HP. National trends in CT use in the emergency department: 1995-2007. Radiology. 2011; 258:164–173. [PubMed: 21115875]
14. Iglehart JK. The new era of medical imaging--progress and pitfalls. N Engl J Med. 2006; 354:2822–2828. [PubMed: 16807422]
15. Nationwide Evaluation of X-ray Trends: NEXT 2005-2006. Presentation given by David Spelic, physicist with the Food and Drug Administration. 39th Conference of Radiation Control Program Directors annual meeting; 2007 May 21 - 24, 2007; Spokane Washington. 2007.
16. Hendee WR, Becker GJ, Borgstede JP, et al. Addressing overutilization in medical imaging. Radiology. 2010; 257:240–245. [PubMed: 20736333]
17. Baker LC, Atlas SW, Afendulis CC. Expanded use of imaging technology and the challenge of measuring value. Health Aff (Millwood). 2008; 27:1467–1478. [PubMed: 18997202]
18. [accessed March 12, 2012] Statement by Herb Kuhn, Director Center for Medicare Management, discusinng Payment for Imaging Services under the Medicare Physician Fee Schedule before the House Subcommittee on Health of The Committee on Energy and Commerce. 2006 Jul 18. available on line http://www.cms.hhs.gov/apps/media/press/release.asp?Counter=1903
19. Hillman BJ, Goldsmith J. Imaging: the self-referral boom and the ongoing search for effective policies to contain it. Health Aff (Millwood). 2010; 29:2231–2236. [PubMed: 21134924]
20. Shreibati JB, Baker LC. The relationship between low back magnetic resonance imaging, surgery, and spending: impact of physician self-referral status. Health Serv Res. 2011; 46:1362–1381. [PubMed: 21517834]
21. Report to the Congress — improving incentives in the Medicare program. Washington, DC: Medicare Payment Advisory Commission; 2009 Jun. Impact of physician self-referral on use of imaging services within an episode; p. 81-96.(Accessed March 11, 2012, at http://www.medpac.gov/documents/Jun09_EntireReport.pdf.)
22. Studdert DM, Mello MM, Sage WM, et al. Defensive medicine among high-risk specialist physicians in a volatile malpractice environment. JAMA : the journal of the American Medical Association. 2005; 293:2609–2617. [PubMed: 15928282]
23. Baker LC, Afendulis CC, Atlas SW. Assessing cost-effectiveness and value as imaging grows:the case of carotid artery CT. Health Aff (Millwood). 2010; 29:2260–2267. [PubMed: 21134928]
24. Radiation protection 118 : referral guidelines for imaging. Luxembourg European Commission, Directorate-General for the Environment. 2001
25. The American Association of Physicists in Medicine. AAPM Position Statement on Radiation Risks from Medical Imaging Procedures. 2011 Dec 13. In. ed.
26. Mettler FA Jr, Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. Radiology. 2008; 248:254–263. [PubMed: 18566177]

27. US Food and Drug Administration. Safety Investigation of CT Brain Perfusion Scans: Update 11/9/2010. 2009
28. Lee CI, Haims AH, Monico EP, Brink JA, Forman HP. Diagnostic CT scans: assessment of patient, physician, and radiologist awareness of radiation dose and possible risks. Radiology. 2004; 231:393–398. [PubMed: 15031431]
29. Brook RH. Do physicians need a "shopping cart" for health care services? JAMA : the journal of the American Medical Association. 2012; 307:791–792. [PubMed: 22357829]
30. Levin DC, Rao VM, Parker L, Frangos AJ, Sunshine JH. Bending the curve: the recent marked slowdown in growth of noninvasive diagnostic imaging. AJR Am J Roentgenol. 2011; 196:W25–W29. [PubMed: 21178027]
31. Armao D, Semelka RC, Elias J Jr. Radiology's ethical responsibility for healthcare reform: Tempering the overutilization of medical imaging and trimming down a heavyweight. J Magn Reson Imaging. 2012; 35:512–517. [PubMed: 22180215]
32. Sistrom CL, Dang PA, Weilburg JB, Dreyer KJ, Rosenthal DI, Thrall JH. Effect of computerized order entry with integrated decision support on the growth of outpatient procedure volumes: seven-year time series analysis. Radiology. 2009; 251:147–155. [PubMed: 19221058]
33. Solberg LI, Wei F, Butler JC, Palattao KJ, Vinz CA, Marshall MA. Effects of electronic decision support on high-tech diagnostic imaging orders and patients. Am J Manag Care. 2010; 16:102–106. [PubMed: 20148614]
34. National Quality Forum, endorsed patient safety measure, Radiation Dose of Computed Tomography. Endorsed August. 2011 In.
35. FDA White Paper: Initiative to Reduce Unnecessary Radiation Exposure from Medical Imaging. 2010. (Accessed at http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/RadiationDoseReduction/ucm199994.htm., March 10, 2012)
36. Public Law 102-539. The Mammography Quality Standards Act of 1992.
37. S.B. 2104, The CARE Bill Legislation: Consistency, Accuracy, Responsibility and Excellence in Medical Imaging and Radiation Therapy. 2011.
38. Gov. Schwarzenegger of California signed into law SB 1237, which will require, starting in 2012, for all CT procedures in California include a radiation exposure measure on both printed materials and digitally for the patient's historical records. This is all in an effort to reduce radiation exposure for patients and is widely viewed as a potential model for other state laws as well.
39. Semelka RC, Armao DM, Elias J Jr, Picano E. The information imperative: is it time for an informed consent process explaining the risks of medical radiation? Radiology. 2012; 262:15–18. [PubMed: 22190653]
40. American Association of Physicists in Medicine Position Statement on Radiation Risks from Medical Imaging Procedures. 2011 (Accessed March 12, 2012, at https://http://www.aapm.org/org/policies/details.asp?id=318&type=PP&current=true.).
41. William Hendee, RSNA. Chicago Il: 2011. Radiologic Society of North America (RSNA), Special Plenary Lecture, "Risk in Medical Imaging: Separating Fact from Fantasy".
42. Larson DB, Rader SB, Forman HP, Fenton LZ. Informing parents about CT radiation exposure in children: it's OK to tell them. AJR Am J Roentgenol. 2007; 189:271–275. [PubMed: 17646450]