Academic Emergency Medicine
Official Journal of the Society for Academic Emergency Medicine

ORIGINAL CONTRIBUTION

Overtesting and the Downstream Consequences of Overtreatment: Implications of "Preventing Overdiagnosis" for Emergency Medicine

Christopher R. Carpenter, MD, MSc, Ali S. Raja, MD, MBA, MPH, and Michael D. Brown, MD, MSc

Abstract

Overtesting, the downstream consequences of overdiagnosis, and overtreatment of some patients are topics of growing debate within emergency medicine (EM). The "Preventing Overdiagnosis" conference, hosted by The Dartmouth Institute for Health Policy and Clinical Practice, with sponsorship from consumer organizations, medical journals, and academic institutions, is evidence of an expanding interest in this topic. However, EM represents a compellingly unique environment, with increased decision density tied to high stakes for patients and providers with missed or delayed diagnoses in a professional atmosphere that does not tolerate mistakes. This article reviews the relevance of this reductionist paradigm to EM, provides a first-hand synopsis of the first "Preventing Overdiagnosis" conference, and assesses barriers to moving the concept of less test ordering to reality.

ACADEMIC EMERGENCY MEDICINE 2015;22:1484–1492

Over the past decade, a spotlight has been shone on the prevalence of overtesting,[1,2] overdiagnosing,[3] and overtreating[4] in modern medicine. This intellectual and ethical revolution has challenged physicians and health care entities to develop more efficient methods for the application of diagnostic technology to derive greater patient-centric value. Economic drivers play a major role in fueling this revolution. Former Centers for Medicare and Medicaid Services (CMS) director Donald Berwick estimated that between $158 and $226 billion were wasted in 2011 on unnecessary treatment in the United States.[5] Increasingly, research indicates that *more* (more testing or more treatment) is not linked to *better* (improved outcomes, longer life, or faster recovery). In fact, higher spending and increased testing are often linked to *worse* outcomes.[6] The concept that less is more represents a paradigm shift in medical decision-making, especially since traditional grand rounds conferences and published case studies often chide clinicians for the elusive test that was not ordered, while celebrating those who cast wide nets with scattered test ordering.[7,8]

Surveys of emergency physicians (EPs) demonstrate evidence of unnecessary testing in emergency departments (EDs), since 85% of respondents identify such test ordering in their own EDs, and 97% report that at least "some" advanced imaging that they personally order is medically unnecessary.[9] The roots of overtesting are complex and multifactorial, including perceived malpractice risk, lack of awareness or adoption of clinical decision instruments, competing financial incentives, consultant physician preferences, and increasing complexity of emergency care.[9] Some of these influences reside outside the direct control of emergency medicine (EM), while others mandate better understanding of the potential benefits and harms associated with evidence-based test ordering. The most compelling and challenging barrier to begin reducing overtesting is a prevailing

From the Division of Emergency Medicine, Washington University in St. Louis School of Medicine (CRC), St. Louis, MO; the Department of Emergency Medicine, Brigham & Women's Hospital (ASR), Boston, MA; and Emergency Medicine, Michigan State University College of Medicine (MDB), Grand Rapids, MI.

Received April 6, 2015; revisions received July 3 and July 6, 2015; accepted July 7, 2015.

Dr. Carpenter, an associate editor at this journal, had no role in the peer-review process or publication decision for this paper. The authors have no relevant financial information or potential conflicts to disclose.

Supervising Editor: Jesse Pines, MD, MBA, MSCE.

Address for correspondence: Christopher R. Carpenter, MD, MS; e-mail: carpenterc@wusm.wustl.edu. Reprints will not be available.

ISSN 1069-6563
PII ISSN 1069-6563583

doi: 10.1111/acem.12820

culture of perfection, which seeks diagnostic certainty. Despite the survey data reflecting an introspective awareness of overtesting in EM, debate persists about whether this is an actual problem.[10] Accordingly, there is a need for an organized, cross-disciplinary, and sustained venue to initiate and maintain exchange of ideas about overtesting.

The annual "Preventing Overdiagnosis" conference (http://www.preventingoverdiagnosis.net/) was born from this paradigm shift and debuted in 2013 by bringing together diverse stakeholders, including the *British Medical Journal*, the Dartmouth Institute, and *Consumer Reports*. The objectives of this article are to 1) evaluate the relevance of the concept of "preventing overdiagnosis" to the specialty of EM; 2) provide brief first-hand summaries from EM providers who attended the first two "Preventing Overdiagnosis" conferences; and 3) contemplate barriers to reducing "wasteful" diagnostic testing in EM within the contexts of "Choosing Wisely" and the 2015 (diagnostic imaging in the emergency department) and 2016 (shared decision-making) *Academic Emergency Medicine* (*AEM*) consensus conferences.

RELEVANCE OF "PREVENTING OVERDIAGNOSIS" FOR EMERGENCY MEDICINE

The average cost for an ED visit in the United States increased from $560 in 2003 to $1,354 in 2011[11,12] and represented 5% to 10% of national health expenditures.[13] Up to 42% of ED patients have at least one blood test, often ordered as "routine" or as part of a protocol-based pathway from triage.[14] Test ordering, specifically computed tomography (CT), also increases ED lengths of stay and crowding.[15,16] However, despite the financial effects of test ordering in the ED and the decision-dense nature of our practice, the study of the cognitive psychology of diagnostics and clinical intuition in EM is a young and evolving science.[17]

Early leaders in ED clinical decision-making listed numerous forms of cognitive biases that increase the risk of diagnostic errors of omission or commission, including anchoring bias and availability bias.[17–19] Anchoring bias occurs when the clinician fixates on certain features of a presentation early in the diagnostic decision-making process and fails to adjust disease likelihood as additional information becomes available.[17,18] Availability bias describes a cognitive phenomenon in which perceived disease prevalence is erroneously associated with how readily the diagnosis comes to mind.[18,19] One method recommended to reduce diagnostic error is to understand "cognitive dispositions to respond," whereby clinicians contemplate their most susceptible or common analytical flaws and deconstruct decision-making when faced with similar scenarios.[20] Unfortunately, encouraging slower, more contemplative approaches does not consistently reduce errors in simulated settings.[21] Similarly, cognitive forcing strategies do not reduce diagnostic error in novice clinicians.[22] However, experienced clinicians are both faster and more accurate decision-makers than residents, and this effect is not significantly attenuated by interruptions.[23] Based on these data, educational strategies to prevent diagnostic error are still being developed.[24]

Much of the initial work on strategies to prevent diagnostic error has been focused on the use of high-cost imaging. The numbers of CT and magnetic resonance imaging (MRI) studies ordered in the ED increased three- and ninefold, respectively, between 2001 and 2010,[25] although that trend may be slowing.[26] However, the benefits of this increased use of advanced imaging are unclear and difficult to measure. For example, despite the increased use of CT to diagnose pulmonary embolism (PE),[27–29] and the greater number of PEs diagnosed, mortality from PE remains unchanged.[30,31] Increases in CT ordering for PE cannot be attributed to testing a higher proportion of high-risk patients, and there is substantial variability between hospital CT-ordering patterns.[32] PE CTs are only one imaging test; head, face, neck, and abdominal CT order rates are also increasing,[33] and high-cost imaging across the United States demonstrates substantial variability.[34]

Although CT ordering rates are rising faster in the United States than elsewhere, increases are being observed internationally as well.[35] The United States has easier CT access with a higher density of CTs than Canada, and this availability may be a factor in the increasing utilization.[36] Potential reasons for this rise and substantial variability in the use of advanced imaging by ED providers include the complex and atypical presentations of ED patients, many of whom have limited access to reliable follow-up,[37] the fact that some ED providers may lack confidence in validated clinical decision instruments related to imaging (e.g., those for minor traumatic head injury or PE),[38,39] and the lack of an acceptable "miss rate" threshold given variable physician risk tolerances,[40,41] leading to the erroneous assumption that all potentially serious diagnoses must be made all of the time. An aging population with a high burden of comorbid diseases and atypical presentations will further threaten financial resources, if current diagnostic test-ordering trends continue.[42]

In addition to CT, ED utilization rates are also increasing for diagnostic tests. As previously noted, MRI ordering increased ninefold between 2001 and 2010, a trend noted inconsistently across academic ED settings.[25,26,43,44] Increased MRI utilization is associated with increased availability and is observed in supervised residents.[45,46] MRI utilization rates do not differ in observation versus admitted patients.[47] Some MRI use does not meet appropriateness criteria.[48] Cardiac stress testing is another non-CT example of increasing overtesting. Contemporary practice is to evaluate patients who are extremely low risk of suspected acute coronary syndrome for coronary artery disease, despite 6-month myocardial infarction–related hospitalization rates of 0.33%.[49,50] The small therapeutic benefit of identifying coronary artery disease in a few is offset by significant numbers of false-positive stress test results necessitating expensive, invasive, confirmatory testing.[51] Although inpatient stress testing may decrease ED revisits,[52] opponents argue whether stress testing should occur at all for most ED chest pain patients.[53]

Overtesting with advanced imaging increases the probability of harm via intrinsic test risk (contrast dye, medical radiation exposure). Since the central issue of overdiagnosis is that nobody recognizes the overdiagnosed individual at the point of care, another harm is overtreatment.[4,54] In EM, an example of overtreatment is subsegmental PEs diagnosed by CT more often than with ventilation-perfusion (V/Q) scans. If all subsegmental PEs were equally likely to increase the risk of bad outcomes like ED returns, admission, or death, then the PEs missed by V/Q would be evident, but one randomized controlled trial demonstrated no measurable outcome difference between CT and V/Q.[55] However, an additional 5% of CT patients receive months of anticoagulation[55] and carry the medical diagnosis of PE for the rest of their lives, increasing insurance costs and probably individual patient anxiety. Incidental findings such as pulmonary nodules or adrenal masses are common with advanced imaging,[56] particularly in older individuals.[57] These "incidentalomas" can lead to significant additional downstream testing.[58] Incidental findings also occur with bedside ultrasound,[59] and common laboratory tests like troponin.[60]

In response to a growing tide of pressure from organized medicine, patient advocacy groups, and payers, the American College of Emergency Physicians (ACEP) identified five low-value clinical actions as part of the American Board of Internal Medicine Foundation's Choosing Wisely campaign in October 2013 and another five in October 2014. Half of these 10 ACEP Choosing Wisely items are diagnostic, and all relate to CT imaging of low-risk patients. Although Choosing Wisely priorities were largely driven by ACEP leadership, pilot projects have demonstrated that more objective methods can also be used to identify low-yield ED tests to target for reduction.[61,62]

SYNOPSIS OF THE PREVENTING OVERDIAGNOSIS CONFERENCES

The first "Preventing Overdiagnosis" conference was held in Hannover, New Hampshire, in September 2013 and was attended by two of the authors (CRC and ASR). The objective of the first "Preventing Overdiagnosis" conference was to bring together researchers, policymakers, and health care providers from around the world, including epidemiologists, journalists, and public health experts. The 2-day conference included over 400 attendees from around the world and from a variety of specialties, including approximately eight EPs. The majority of attendees were in internal medicine subspecialty fields, and their focus was overtesting in the scenario of longitudinal cancer or other chronic illness care. Research abstracts were presented, and one didactic session (delivered by the two authors above) addressed ED overtesting using PE as an example. The conference concluded by splitting the attendees into four groups to prioritize next steps in research, education, communication, and policy (Tables 1–4). The conference was intended to be the first of many annual gatherings, so no formal effort to record the process or disseminate the results occurred. Nonetheless, increasing interest about the concept of "Preventing Overdiagnosis" is being expressed, including by Office of Emergency Care Research Director Jeremy Brown, who encouraged 2015 *AEM* consensus conference attendees to learn more about optimizing ED test ordering from the "Preventing Overdiagnosis" conference.

Table 1
2013 "Preventing Overdiagnosis" Conference: Top Five Research Priorities

Standardize taxonomy and research methods.
Define population indicators of overuse.
Obtain meaningful clinical decision thresholds via systematic reviews and/or reanalysis of prior study data.
Prioritize comparative effectiveness trials of alternative diagnostic strategies and less aggressive treatment options.
Engage patients to derive patient-centric informed decision analyses.

Table 2
2013 "Preventing Overdiagnosis" Conference Top Five Education Priorities

Identify and engage key stakeholders (American Association of Medical Colleges, American College of Graduate Medical Education, professional societies).
Develop assessment methods and outcome measures.
Develop effective decision support.
Collate existing educational resources, stratified by learner level, context, and access to resources.
Integrate education across undergraduate, graduate, and postgraduate medical education.

Table 3
2013 "Preventing Overdiagnosis" Conference Top Five Communication Priorities

Collate evidence of and tools for overdiagnosis within the context of overtreatment.
Carefully balance messaging to convey potential harms and uncertainties around overtesting/overdiagnosis weighing risks of underdiagnosis and undertreatment.
Develop communication strategies and resources for consumers and journalists, perhaps including narrative medicine approach.
Produce freely accessible primer to overdiagnosis using short, evidence-based synopses, condition by condition (example *BMJ*'s "Too Much Medicine" series), perhaps using Wikipedia.
Provide mechanism for ongoing discussions to sustain momentum using social media and Internet conferencing.

Because the "Preventing Overdiagnosis" conference organizers were oncologists and primary care providers, almost all of the published proceedings have focused on cancer screening tests, which have limited applicability to EM.[63,64] One sponsor of the conference is *British Medical Journal*, which launched the ongoing series "Too Much Medicine" (www.bmj.com/too-much-medicine) as one consequence of the problems with

Table 4
2013 "Preventing Overdiagnosis" Conference Top Five Policy Priorities

Review and revise all specialist-directed guidelines using a broader constituency, using Grading of Recommendations Assessment Development and Evaluation (GRADE) to explicitly recognize, describe, and quantify the potential harms of overdiagnosis and consequential overtreatment.
Derive mutually agreeable measures of overuse, overtesting, overdiagnosis, and overtreatment.
Dissociate physician payments from test ordering.
Provide incentives for "appropriate" testing.
Regulate direct-to-consumer advertising.

overtesting. Again, almost all of the articles in this new series focus on screening (abdominal aortic aneurysm, breast cancer, bone fragility). In EM, diagnostic testing is more applicable so our current article contrasts the first "Preventing Overdiagnosis" conference's top five recommendations with the 2015 *AEM* consensus conference.

The main goal of the 2015 *AEM* consensus conference was to derive research priorities for diagnostic imaging in the ED.[65] Interestingly, many of the research priorities identified by the "Preventing Overdiagnosis" attendees aligned with those of the 2015 consensus conference, including prioritizing comparative effectiveness trials[66] and engaging in shared decision-making.[67] Additional research priorities identified by the "Preventing Overdiagnosis" attendees (Table 1) that were not reviewed by the 2015 consensus conference were defining overuse and overdiagnosis, as well as deriving meaningful test and treatment thresholds from diagnostic systematic reviews, which the *Academic Emergency Medicine* Evidence-Based Diagnostics series has been doing since 2011.[68]

The "Preventing Overdiagnosis" education research priorities (Table 2) included developing effective methods to assess diagnostic efficiency and using nonobtrusive real-time computer decision support systems, both of which were also 2015 consensus conference priorities.[69] In addition, "Preventing Overdiagnosis" attendees recognized a need to formulate learner-level appropriate educational resources and then integrate these resources across the continuum of medical education. To engage the larger community of patients, one "Preventing Overdiagnosis" workshop focused on using Wikipedia to shape widely acceptable definitions responsive to an evolving health care landscape.

Since one sponsor of "Preventing Overdiagnosis" is *Consumer Reports,* and a portion of attendees represented mass media, one group focused on messaging (Table 3), which was not a focus of the 2015 *AEM* consensus conference. One messaging strategy was to provide a one-stop resource for consumers interested in learning more about overdiagnosis. In EM there are academic textbooks[70] and journal series[71] devoted to diagnostics, but nothing at the level of the patient consumer, and nothing focused on overtesting, overdiagnosis, or overtreatment like the *BMJ* "Too Much Medicine" series. The "Preventing Overdiagnosis" communication group recognized the need to carefully balance messaging for overuse and underuse of diagnostic technology, perhaps using the narrative medicine approach.[72] The journalists in the audience recognized the potential value of social media to magnify messaging and accelerate dissemination, a priority not considered in the 2015 *AEM* consensus conference.[73]

The last "Preventing Overdiagnosis" group prioritized policy initiatives (Table 4) and tangentially considered one strategy outlined at the 2015 *AEM* consensus conference: provide incentives for "appropriate" testing. Other "Preventing Overdiagnosis" policy priorities not contemplated by the 2015 *AEM* consensus conference included developing widely accepted measures across specialties and stakeholders for phenomena like "overtesting," stringently regulating direct-to-consumer advertising, and ensuring that guideline developers include a representative voice and standardized terms.

As a follow-up to the successful first conference, a second "Preventing Overdiagnosis" conference took place at the University of Oxford over 3 days in September 2014. The themes were similar to the first conference, with increased emphasis on developing a definition for "overdiagnosis."[74] On the surface, "diagnosis" is simply a label for a condition; however, determining when a continuous human condition becomes a "disease" is challenging, which brings the arbitrary threshold problem to the forefront. For example, is a PE identified on CT only considered a disease among patients presenting to the ED with symptoms such as shortness of breath? Or does someone identified as having subsegmental PE on CT ordered in the setting of a major trauma also have the "disease"? The threshold may also depend on perspective—physicians may base the threshold for "abnormal" on management decisions, whereas the patient may prefer to label the condition as "disease" only when it impairs quality of life or affects longevity.[75] Therefore, each condition is likely to have different diagnostic thresholds depending on perspective, which in turn may drive overdiagnosis. There was also recognition that each medical specialty will need to respond to the overdiagnosis problem condition by condition. These and other issues related to overdiagnosis will be further explored at the third "Preventing Overdiagnosis" conference, scheduled for September 2015 in Washington, DC.

CHALLENGES TO REDUCING TESTING IN EM

While the "Preventing Overdiagnosis" conferences are beginning to outline a series of steps that may turn the tide of overdiagnosis, realistic expectations of reduced testing in the ED must be tempered against an understanding of factors driving increased reliance on tests.[76] Replacing readily available imaging with more detailed clinical evaluation necessitates more time at the bedside, which may negatively affect ED operational flow. Ordering a test is often faster and less intellectually taxing than contemplating and discussing imaging appropriateness and conveying these concepts to the patient to facilitate shared decision-making,[77] although this perspective has been assessed in primary care settings, not the ED.[78] Multiple ED studies demonstrate that ordering CTs prolongs ED length of stay so "faster" might be

more accurately described as faster decision-making. There are also measurable benefits of advanced imaging. For example, utilizing CTs for some ED conditions is also associated with lower ED returns,[79] and CT use has been associated with lower negative appendectomy rates.[80] Measuring and rewarding diagnostic efficiency might incentivize more rational test ordering, but defining "diagnostic efficiency" is an unmet challenge.

Many other factors also drive ED provider decisions to order advanced imaging that may be of limited utility for low-risk patients, including physician risk aversion;[41] lack of safe harbors;[81] slow and uncertain tort reform;[82] patient expectations (real or imagined);[83] and insufficient physician awareness of radiation risks,[84–86] alternative diagnostic strategies, or applicable clinical decision instruments.[87] Tort reform, in particular, has been highlighted as an essential ingredient to reducing the overtesting of "defensive medicine." While early research in states with aggressive tort reform seems to suggest that such reforms do not reduce CT or MRI order rates, these studies neglected current implementation science principles of delays in best practice adoption.[88,89]

Historically, the U.S. health care reimbursement model used a volume-based process: more tests or services equaled more fees paid. This model failed to incentivize societal cost containment via limited testing directed at those patients most likely to benefit. Value-based purchasing is the model adopted in the most recent health care reform efforts, but achieving the dual objectives of reduced cost and improved quality requires overcoming barriers such as incomplete information systems, nontransparent billing, and competing stakeholder priorities. For example, trauma centers often place excessive value on the "pan-scan"[90] and often reimage transferred patients.[91] Using a vertically integrated health care system in which images can be shared across hospitals would likely reduce repeat imaging, but such a system is lacking in most health care systems.[92]

Clinical policy guidelines with specific imaging recommendations exist for many EM scenarios, including nontraumatic thoracic aortic dissection,[93] headache,[19] blunt abdominal trauma,[94] and acute traumatic brain injury.[95] Clinical policies for other conditions with highly variable interphysician and interhospital diagnostic work-up decisions like seizure[96] and syncope[97] do not include recommendations for imaging. In addition, many common ED scenarios like cough, sore throat, toothache, flank pain, hematuria, and dizziness have no EM-specific clinical policies to guide imaging decisions or protocol development. Deriving high-quality clinical policy guidelines is time-consuming, expensive, and reliant on the volunteer efforts of panel development groups to derive key questions, find and appraise relevant evidence, and construct recommendations that encompass widely diverse situations and resource accessibility.

Developing performance measures from guidelines is equally complex.[98] Examples of well-intentioned but poorly designed performance measures (e.g., antibiotic timing for pneumonia) abound and have consumed valuable time and resources without demonstrable patient benefit.[99] Because poorly conceived performance measures can lead to unintended consequences and waste, the key question for diagnostic efficiency (lab or imaging) measures is whether to base measures on appropriateness or utilization.[98] If the choice is appropriateness, who defines this term, based on what evidence, and in what scenarios? In addition, how is "appropriateness" defined when two different organizations render different recommendations with respect to the same clinical scenario? For example, a head CT for an 80-year-old on warfarin with an acute headache might be classified as *appropriate* by one quality measure using the ACEP Clinical Policy, but *inappropriate* using a proposed CMS measure aimed at determining appropriateness based on administrative data.[100] If the choice to measure appropriateness is utilization, which thresholds define overuse and how are these thresholds adjusted for illness severity, patient priorities, and access to care?

Unfortunately, definitive diagnostic research is lacking for many ED scenarios,[70] and the existing research suffers from many forms of bias.[101] Funding for diagnostic research is lacking, particularly in comparison with interventional trials for new drugs or medical devices. A hierarchy of diagnostic evidence increases the confidence that a new test will offer benefit; this hierarchy begins with technical efficacy to measure a molecule or obtain an image, then expands to assess diagnostic accuracy, then measurable benefit for subsets of individuals identified by the new test who were previously missed, and culminates with measurable patient-centric benefits and ultimately societal benefit.[102] Most diagnostic research does not extend beyond traditional accuracy studies, largely because the Food and Drug Administration regulations do not mandate the same level of efficacy or safety as with a new pharmaceutical agent. In cases where the new diagnostic test is safer, cheaper, faster, and more available than the old test, randomized controlled trials are unnecessary.[103] Unfortunately, most new diagnostic tests fail to meet these criteria, but are nonetheless incorporated into practice after accuracy studies without effectiveness trials. For example, brain natriuretic peptic (BNP) is an accurate test to distinguish acute decompensated congestive heart failure from other causes of dyspnea, but five ED-based randomized controlled trials reported inconsistent results in terms of reducing length of stay, return visits, or health care costs when the EP had knowledge of the BNP level.[104] To improve the quality of ED diagnostic decision-making, the quantity and quality of research for new diagnostic tests needs to improve, which will require collaboration and cooperation between industry, nonindustry funders, and investigators.

Recent research suggests that EPs recognize wasteful testing[9] and accept shared decision-making as necessary and realistic.[105] The 2015 *AEM* consensus conference identified and prioritized the highest-yield research areas needed to more effectively use diagnostic imaging in the ED, and the resultant publications elsewhere in this issue should inform a 5- to 10-year research agenda on this issue.[106] Next year, the 2016 *AEM* consensus conference will similarly seek to define

research priorities and appropriate applications for shared decision-making in the ED. Shared decision-making is likely to be an essential component of a multipronged approach to reducing unnecessary laboratory and imaging testing in the coming years. Obstacles to efficient and effective ED shared decision-making include uncertainty regarding the appropriate scenarios in which to employ shared decision-making,[107] variable patient health literacy,[108] and the lack of validated educational tools to facilitate these discussions. Fortunately, patients often support shared decision-making to reduce low-yield test ordering—this has been demonstrated in the setting of PE,[109] chest pain,[110] and trauma.[111]

CONCLUSIONS

The "Preventing Overdiagnosis" conferences have represented an opportunity for EM researchers, educators, clinicians, and guideline developers to network with diagnostic experts from other specialties, nations, and non–health care consumer-based settings. The barriers to safely reducing overtesting in the contemporary ED are unique and therefore will require the sustained efforts of emergency physicians to develop solutions and quality parameters. Understanding both the barriers and the opportunities to reduce overtesting and downstream overtreatment within EM necessitates a balanced research agenda, including increased attention of funding agencies and guideline developers, to formulate and answer key diagnostic questions.

References

1. Moynihan R, Doust J, Henry D. Preventing overdiagnosis: how to stop harming the healthy. BMJ 2012;344:e3502.
2. Hoffman JR, Cooper RJ. Overdiagnosis of disease: a modern epidemic. Arch Intern Med 2012;172:1123–4.
3. Welch HG, Schwartz L, Woloshin S. Overdiagnosed: Making People Sick in the Pursuit of Health. Boston, MA: Beacon Press, 2011.
4. Brownlee S. Overtreated: Why Too Much Medicine Is Making Us Sicker and Poorer. New York, NY: Bloomsbury Publishing, 2007.
5. Berwick DM, Hackbarth AD. Eliminating waste in US health care. JAMA 2012;307:1513–6.
6. Hussey PS, Wertheimer S, Mehrotra A. The association between health care quality and cost: a systematic review. Ann Intern Med 2013;158:27–34.
7. Prasad V. Reclaiming the morbidity and mortality conference: between Codman and Kundera. Med Humanit 2010;36:108–11.
8. Siegel TA, McGillicuddy DC, Barkin AZ, Rosen CL. Morbidity and Mortality conference in emergency medicine. J Emerg Med 2010;38:507–11.
9. Kanzaria HK, Hoffman JR, Probst MA, Caloveras JP, Berry SH, Brook RH. Emergency physician perceptions of medically unnecessary advanced diagnostic imaging. Acad Emerg Med 2015;22:390–8.
10. Sullivan W, Hoffman JR, Kanzaria HK, Tintinalli J. Who defines "Unnecessary"? Emerg Phys Monthly 2015. Available at: http://epmonthly.com/article/pro-con-unnecessary-testing/. Accessed Sep 9, 2015.
11. Machlin SR. Expenses for a Hospital Emergency Room Visit, 2003. Medical Expenditure Panel Survey. Available at: http://meps.ahrq.gov/mepsweb/data_files/publications/st111/stat111.shtml. Accessed Sep 12, 2015.
12. Gonzalez JM. National Health Care Expenses in the U.S. Civilian Noninstitutionalized Population, 2011. Medical Expenditure Panel Survey. Available at: http://meps.ahrq.gov/mepsweb/data_files/publications/st425/stat425.shtml. Accessed Sep 12, 2015.
13. Lee MH, Schuur JD, Zink BJ. Owning the cost of emergency medicine: beyond 2%. Ann Emerg Med 2013;62:498–505.
14. Centers for Disease Control and Prevention. National Hospital Ambulatory Medical Care Survey: 2010 Emergency Department Summary Tables. Available at: http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2010_ed_web_tables.pdf. Accessed Sep 12, 2015.
15. Kanzaria HK, Probst MA, Ponce NA, Hsia RY. The association between advanced diagnostic imaging and ED length of stay. Am J Emerg Med 2014;32:1253–8.
16. Kawano T, Nishiyama K, Hayashi H. Execution of diagnostic testing has a stronger effect on emergency department crowding than other common factors: a cross-sectional study. PLoS One 2014;9:e108447.
17. Sandhu H, Carpenter C. Clinical decisionmaking: opening the black box of cognitive reasoning. Ann Emerg Med 2006;48:713–22.
18. Croskerry P. Achieving quality in clinical decision making: cognitive strategies and detection of bias. Acad Emerg Med 2002;9:1184–204.
19. Edlow JA, Panagos PD, Godwin SA, Thomas TL, Decker WW. Clinical policy: critical issues in the evaluation and management of adult patients presenting to the emergency department with acute headache. Ann Emerg Med 2008;52:407–36.
20. Croskerry P. Cognitive forcing strategies in clinical decisionmaking. Ann Emerg Med 2003;41:110–20.
21. Norman G, Sherbino J, Dore K, et al. The etiology of diagnostic errors: a controlled trial of system 1 versus system 2 reasoning. Acad Med 2014;89:277–84.
22. Sherbino J, Kulasegaram K, Howey E, Norman G. Ineffectiveness of cognitive forcing strategies to reduce biases in diagnostic reasoning: a controlled trial. Can J Emerg Med 2014;16:34–40.
23. Monteiro SD, Sherbino JD, Ilgen JS, et al. Disrupting diagnostic reasoning: do interruptions, instructions, and experience affect the diagnostic accuracy and response time of residents and emergency physicians? Acad Med 2015;90:511–7.

24. Sherbino J, Norman GR. Reframing diagnostic error: maybe it's content, and not process, that leads to error. Acad Emerg Med 2014;21:931–3.
25. Ahn S, Kim WY, Lim KS, et al. Advanced radiology utilization in a tertiary care emergency department from 2001 to 2010. PLoS One 2014;9: e112650.
26. Raja AS, Ip IK, Sodickson AD, et al. Radiology utilization in the emergency department: trends of the past 2 decades. Am J Roentgenol 2014;203:355–60.
27. Crichlow A, Cuker A, Mills AM. Overuse of computed tomography pulmonary angiography in the evaluation of patients with suspected pulmonary embolism in the emergency department. Acad Emerg Med 2012;19:1219–26.
28. Coco AS, O'Gurek DT. Increased emergency department computed tomography use for common chest symptoms without clear patient benefits. J Am Board Fam Med 2012;25:33–41.
29. Feng LB, Pines JM, Yusuf HR, Grosse SD. U.S. trends in computed tomography use and diagnoses in emergency department visits by patients with symptoms suggestive of pulmonary embolism, 2001-2009. Acad Emerg Med 2013;20:1033–40.
30. Wiener RS, Schwartz LM, Woloshin S. Time trends in pulmonary embolism in the United States: evidence of overdiagnosis. Arch Intern Med 2011;171:831–7.
31. Segard T, Macdonald WB. Changing trends in venous thromboembolism-related imaging in Western Australian teaching hospitals, 2002-2010. Med J Aust 2013;198:100–3.
32. Kindermann DR, McCarthy ML, Ding R, et al. Emergency department variation in utilization and diagnostic yield of advanced radiography in diagnosis of pulmonary embolus. J Emerg Med 2014;46:791–9.
33. Lee J, Kirschner J, Pawa S, Wiener DE, Newman DH, Shah K. Computed tomography use in the adult emergency department of an academic urban hospital from 2001 to 2007. Ann Emerg Med 2010;56:591–6.
34. Ip IK, Raja AS, Seltzer SE, Gawande AA, Joynt KE, Khorasani R. Use of public data to target variation in providers' use of CT and MR imaging among Medicare beneficiaries. Radiology 2015;275:718–24.
35. Berdahl CT, Vermeulen MJ, Larson DB, Schull MJ. Emergency department computed tomography utilization in the United States and Canada. Ann Emerg Med 2013;62:486–94.
36. Runde D, Shah K, Naraghi L, et al. Computed tomography utilization rates after the placement of a scanner in an emergency department: a single-center experience. Emerg Radiol 2014;21:473–8.
37. Probst MA, Kanzaria HK, Schriger DL. A conceptual model of emergency physician decision making for head computed tomography in mild head injury. Am J Emerg Med 2014;32:645–50.
38. Quaas J, Derrick B, Mitrani L, et al. Survey of patient and physician influences and decision-making regarding CT utilization for minor head injury. Injury 2014;45:1503–8.
39. Hennessey A, Setyono DA, Lau WB, Fields JM. A patient with a large pulmonary saddle embolus eluding both clinical gestalt and validated decision rules. Ann Emerg Med 2012;59:521–3.
40. Pines JM, Lessler AL, Ward MJ, Courtney MD. The mortality benefit threshold for patients with suspected pulmonary embolism. Acad Emerg Med 2012;19:1109–13.
41. Pines JM, Isserman JA, Szyld D, Dean AJ, McCuskery CM, Hollander JE. The effect of physician risk tolerance and the presence of an observation unit on decision making for ED patients with chest pain. Am J Emerg Med 2010;28:771–9.
42. Pines JM, Mullins PM, Cooper JK, Feng LB, Roth KE. National trends in emergency department use, care patterns, and quality of care of older adults in the United States. J Am Geriatr Soc 2013;61:12–7.
43. Korley FK, Pham JC, Kirsch TD. Use of advanced radiology during visits to US emergency departments for injury-related conditions, 1998-2007. JAMA 2010;304:1465–71.
44. Quaday KA, Salzman JG, Gordon BD. Magnetic resonance imaging and computed tomography utilization trends in an academic ED. Am J Emerg Med 2014;32:524–8.
45. Redd V, Levin S, Toerper M, Creel A, Peterson S. Effects of fully accessible magnetic resonance imaging in the emergency department. Acad Emerg Med 2015;22:741–9.
46. Pitts SR, Morgan SR, Schrager JD, Berger TJ. Emergency department resource use by supervised residents vs attending physicians alone. JAMA 2014;312:2394–400.
47. Prabhakar AM, Misono AS, Harvey HB, Yun BJ, Saini S, Oklu R. Imaging utilization from the ED: no difference between observation and admitted patients. Am J Emerg Med 2015;33:1076–9.
48. Schlemmer E, Mitchiner JC, Brown M, Wasilevich E. Imaging during low back pain ED visits: a claims-based descriptive analysis. Am J Emerg Med 2015;33:414–8.
49. Prasad V, Cheung M, Cifu A. Chest pain in the emergency department: the case against our current practice of routine noninvasive testing. Arch Intern Med 2012;172:1506–9.
50. Foy AJ, Liu G, Davidson WR, Sciamanna C, Leslie DL. Comparative effectiveness of diagnostic testing strategies in emergency department patients with chest pain: an analysis of downstream testing, interventions, and outcomes. JAMA Intern Med 2015;175:428–36.
51. Hermann LK, Newman DH, Pleasant WA, et al. Yield of routine provocative cardiac testing among patients in an emergency department-based chest pain unit. JAMA Intern Med 2013;173:1128–33.
52. Mallidi J, Penumetsa S, Friderici JL, Saab F, Rothberg MB. The effect of inpatient stress testing on subsequent emergency department visits, readmissions, and costs. J Hosp Med 2013;8:564–8.
53. Redberg RF. Stress testing in the emergency department: not which test but whether any test

should be done [comment]. JAMA Intern Med 2015;175:436.
54. Welch HG. Overdiagnosed: Making People Sick in the Pursuit of Health. Boston, MA: Beacon Press, 2011.
55. Anderson DR, Kahn SR, Rodger MA, et al. Computed tomographic pulmonary angiography vs ventilation-perfusion lung scanning in patients with suspected pulmonary embolism: a randomized controlled trial. JAMA 2007;298:2743–53.
56. Perelas A, Dimou A, Saenz A, et al. Incidental findings on computed tomography angiography in patients evaluated for pulmonary embolism. Ann Am Thorac Soc 2015;12:689–95.
57. Samim M, Goss S, Luty S, Weinreb J, Moore C. Incidental findings on CT for suspected renal colic in emergency department patients: prevalence and types in 5,383 consecutive examinations. J Am Coll Radiol 2015;12:63–9.
58. Kelly ME, Heeney A, Redmond CE, et al. Incidental findings detected on emergency abdominal CT scans: a 1-year review. Abdom Imaging 2015;40:1853–7.
59. Tewari A, Shuaib W, Maddu KK, et al. Incidental findings on bedside ultrasonography: detection rate and accuracy of resident-performed examinations in the acute setting. Can Assoc Radiol J 2015;66:153–7.
60. Talebi S, Ferra RM, Tedla S, et al. Hazards with ordering troponin in patients with low pretest probability of acute coronary syndrome. Am J Emerg Med 2015;33:1258–60.
61. Venkatesh AK, Schuur JD. A "Top Five" list for emergency medicine: a policy and research agenda for stewardship to improve the value of emergency care. Am J Emerg Med 2013;31:1520–4.
62. Schuur JD, Carney DP, Lyn ET, et al. A top-five list for emergency medicine: a pilot project to improve the value of emergency care. JAMA Intern Med 2014;174:509–15.
63. Moynihan R, Nickel B, Hersch J, et al. Public opinions about overdiagnosis: a national community survey. PLoS One 2015;10:e0125165.
64. Moynihan R. Preventing overdiagnosis: the myth, the music, and the medical meeting. BMJ 2015;350:h1370.
65. Marin J, Mills A. Developing a research agenda to optimize diagnostic imaging in the emergency department: an executive summary of the 2015 Academic Emergency Medicine consensus conference. Acad Emerg Med 2015;22:1363–71.
66. Moore CL, Broder J, Gunn M, et al. Comparative effectiveness research: alternatives to traditional computed tomography use in the acute care setting. Acad Emerg Med 2015;22:1465–73.
67. Kanzaria HK, McCabe A, Meisel Z, et al. Advancing patient-centered outcomes in emergency diagnostic imaging: a research agenda. Acad Emerg Med 2015;22:1435–46.
68. Carpenter CR, Schuur JD, Everett WW, Pines JM. Evidence-based diagnostics: adult septic arthritis. Acad Emerg Med 2011;18:781–96.
69. Probst MA, Dayan PS, Raja AS, et al. Knowledge translation and barriers to imaging optimization in the emergency department: a research agenda. Acad Emerg Med 2015;22:1455–64.
70. Pines JM, Carpenter CR, Raja A, Schuur J. Evidence-Based Emergency Care: Diagnostic Testing and Clinical Decision Rules, 2nd ed. Oxford, UK: Wiley-Blackwell Publishing, 2013.
71. Lang ES, Worster A. Getting the evidence straight in emergency diagnostics. Acad Emerg Med 2011;18:797–9.
72. Carpenter CR, Neta G, Glasgow RE, Rabin BA, Brownson RC. Storytelling to enhance the value of research. Am J Public Health 2015;105:e1–2.
73. Weingart SD, Thoma B. The online hierarchy of needs: a beginner's guide to medical social media and FOAM. Emerg Med Australas 2015;27:5.
74. Carter SM, Rogers W, Heath I, Degeling C, Doust J, Barratt A. The challenge of overdiagnosis begins with its definition. BMJ 2015;350:h869.
75. Tikkinen KA, Leinonen JS, Guyatt GH, Ebrahim S, Jarvinen TL. What is a disease? Perspectives of the public, health professionals and legislators. BMJ Open 2012;2:pii: e001632.
76. Pines JM, Newman DH, Pilgrim R, Schuur JD. Strategies for integrating cost-consciousness into acute care should focus on rewarding high-value care. Health Aff (Millwood) 2013;32:2157–65.
77. Newman-Toker DE, McDonald KM, Meltzer DO. How much diagnostic safety can we afford, and how should we decide? A health economics perspective. BMJ Qual Saf 2013;22(Suppl 2):ii11–20.
78. Sarkar U, Bonacum D, Strull W, et al. Challenges of making a diagnosis in the outpatient setting: a multi-site survey of primary care physicians. BMJ Qual Saf 2012;21:641–8.
79. Patterson BW, Vendkatesh AK, AlKhawam L, Pang PS. Abdominal computed tomography utilization and 30-day revisitation in emergency department patients presenting with abdominal pain. Acad Emerg Med 2015;22:803–10.
80. Raja AS, Wright C, Sodickson AD, et al. Negative appendectomy rate in the era of CT: an 18-year perspective. Radiology 2010;256:460–5.
81. Mehlman MJ. Medical practice guidelines as malpractice safe harbors: illusion or deceit? J Law Med Ethics 2012;40:286–300.
82. Hoffman JR, Kanzaria HK. Intolerance of error and culture of blame drive medical excess. BMJ 2014;349:g5702.
83. Baumann BM, Chen EH, Mills AM, et al. Patient perceptions of computed tomographic imaging and their understanding of radiation risk and exposure. Ann Emerg Med 2011;58:1–7.
84. Griffey RT, Jeffe DB, Bailey T. Emergency physicians' attitudes and preferences regarding computed tomography, radiation exposure, and imaging decision support. Acad Emerg Med 2014;21:768–77.
85. Robey TE, Edwards K, Murphy MK. Barriers to computed tomography radiation risk communication in the emergency department: a qualitative

analysis of patient and physician perspectives. Acad Emerg Med 2014;21:122–9.
86. Barbic D, Barbic S, Dankoff J. An exploration of Canadian emergency physicians' and residents' knowledge of computed tomography radiation dosing and risk. Can J Emerg Med 2014;16:27–35.
87. Eagles D, Stiell IG, Clement CM, et al. International survey of emergency physicians' awareness and use of the Canadian Cervical-Spine Rule and the Canadian Computed Tomography Head Rule. Acad Emerg Med 2008;15:1256–61.
88. Waxman DA, Greenberg MD, Ridgely MS, Kellermann AL, Heaton P. The effect of malpractice reform on emergency department care. N Engl J Med 2014;371:1518–25.
89. Neta G, Glasgow RE, Carpenter CR, et al. A framework for enhancing the value of research for dissemination and implementation. Am J Public Health 2015;105:49–57.
90. Baugh KA, Weireter LJ, Collins JN. The trauma pan scan: what else do you find? Am Surg 2014;80:855–9.
91. Gupta R, Greer SE, Martin ED. Inefficiencies in a rural trauma system: the burden of repeat imaging in interfacility transfers. J Trauma 2010;69:253–5.
92. Liepert AE, Bledsoe J, Stevens MH, Cochran A. Protecting trauma patients from duplicated computed tomography scans: the relevance of integrated care systems. Am J Surg 2014;208:511–6.
93. Diercks DB, Promes SB, Schuur JD, Shah K, Valente JH, Cantrill SV. Clinical policy: critical issues in the evaluation and management of adult patients with suspected acute nontraumatic thoracic aortic dissection. Ann Emerg Med 2015;65:32–42.
94. Diercks DB, Mehrotra A, Nazarian DJ, Promes SB, Decker WW, Fesmire FM. Clinical policy: critical issues in the evaluation of adult patients presenting to the emergency department with acute blunt abdominal trauma. Ann Emerg Med 2011;57:387–404.
95. Jagoda AS, Bazarian JJ, Bruns JJ, et al. Clinical policy: neuroimaging and decisionmaking in adult mild traumatic brain injury in the acute setting. Ann Emerg Med 2008;52:714–48.
96. Huff JS, Melnick ER, Tomaszewski CA, Thiessen ME, Jagoda AS, Fesmire FM. Clinical policy: critical issues in the evaluation and management of adult patients presenting to the emergency department with seizures. Ann Emerg Med 2014;63:437–47.
97. Huff JS, Decker WW, Quinn JV, et al. Clinical policy: critical issues in the evaluation and management of adult patients presenting to the emergency department with syncope. Ann Emerg Med 2007;49:431–44.
98. Raja AS, Walls RM, Schuur JD. Decreasing use of high-cost imaging: the danger of utilization-based performance measures. Ann Emerg Med 2010;56:597–9.
99. Quattromani E, Powell ES, Khare RK, et al. Hospital-reported data on the pneumonia quality measure "Time to First Antibiotic Dose" are not associated with inpatient mortality: results of a nationwide cross-sectional analysis. Acad Emerg Med 2011;18:496–503.
100. Schuur JD, Brown MD, Cheung DS, et al. Assessment of Medicare's imaging efficiency measure for emergency department patients with atraumatic headache. Ann Emerg Med 2012;60:230–90.
101. Kohn MA, Carpenter CR, Newman TB. Understanding the direction of bias in studies of diagnostic test accuracy. Acad Emerg Med 2013;20:1194–206.
102. Pearl WS. A hierarchical outcomes approach to test assessment. Ann Emerg Med 1999;33:77–84.
103. Lord SJ, Irwig L, Simes RJ. When is measuring sensitivity and specificity sufficient to evaluate a diagnostic test, and when do we need randomized trials? Ann Intern Med 2006;144:850–5.
104. Carpenter CR, Keim SM, Worster A, Rosen P. Brain natriuretic peptide in the evaluation of emergency department dyspnea: is there a role? J Emerg Med 2012;42:197–205.
105. Kanzaria HK, Brook RH, Probst MA, Harris D, Berry SH, Hoffman JR. Emergency physician perceptions of shared decision making. Acad Emerg Med 2015;22:399–405.
106. Hess EP, Marin J, Mills A. Medically unnecessary advanced diagnostic imaging and shared decision-making in the emergency department: opportunities for future research. Acad Emerg Med 2015;22:475–7.
107. Hess EP, Grudzen CR, Thompson R, Raja AS, Cone DC, Carpenter CR. Shared decision making in the emergency department: respecting patient autonomy when seconds count. Acad Emerg Med 2015;22:856–64.
108. Carpenter CR, Kaphingst KA, Goodman MS, Lin MJ, Melson AT, Griffey RT. Feasibility and diagnostic accuracy of brief health literacy and numeracy screening instruments in an urban emergency department. Acad Emerg Med 2014;21:137–46.
109. Geyer BC, Xu M, Kabrhel C. Patient preferences for testing for pulmonary embolism in the ED using a shared decision-making model. Am J Emerg Med 2014;32:233–6.
110. Chen JC, Cooper RJ, Lopez-O'Sullivan A, Schriger DL. Measuring patient tolerance for future adverse events in low-risk emergency department chest pain patients. Ann Emerg Med 2014;64:127–36.
111. Rodriquez RM, Henderson TM, Ritchie AM, et al. Patient preferences and acceptable risk for computed tomography in trauma. Injury 2014;45:1345–9.