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The Economic Burden of Incidentally Detected Findings

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INTRODUCTION

Practitioners in all medical disciplines recognize the high frequency of incidentally detected findings – that is, findings that do not have associated clinical symptoms. While some are discovered on physical examination, an increasing majority are detected at imaging performed for another indication. In addition to their medical implications, incidental findings can be associated with substantial downstream costs.^{1–16} Their economic burden, however, has been sparsely studied in the published literature to date. With increasing federal scrutiny upon the net value of imaging services, the costs and benefits of incidental findings will need to be more rigorously quantified. Here, we examine current related work, and provide a framework for future investigations that will efficiently and substantially advance our knowledge in this field.

Due to unprecedented advances in imaging technology in recent years, there has been a remarkable increase in the demand for imaging. From 1995–2005, the number of CT scans obtained for Medicare beneficiaries more than doubled, and the number of MRI scans more than tripled,¹⁷ a trend substantiated in the private sector as well.¹⁸ As practitioners increasingly rely on cross-sectional imaging, they are faced with a rising burden of incidental findings. In a retrospectively identified, contemporary cohort of patients who underwent 1426 imaging studies in the setting of clinical research, 567 (39.8%) had a minimum of one incidental finding.¹⁹ Further work-up definitively benefitted patients in 6 cases (1.1%) in which significant infections or neoplasms were identified.¹⁹ While incidental findings occasionally present an opportunity to cure or halt an otherwise lethal disease, many downstream consequences are negative. For patients, they can create anxiety and additional work-up for findings which are ultimately benign or unlikely to affect their life expectancy. For busy practitioners, the recommended follow-up can be difficult to

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organize, and can detract care from more important medical issues. Furthermore, these consequences can translate into substantial downstream expenditures.

In this era of national, federally mandated healthcare reform, when making reimbursement decisions about imaging in a variety of healthcare paradigms, policymakers will want to know not only the true costs of incidental findings, but more specifically, how such costs affect the net value of a given imaging strategy. Moving forward, investigators should consider incidental findings explicitly when evaluating the value or cost-effectiveness of an imaging strategy. This approach is important because a high frequency of incidental findings (and associated expenditures) may be acceptable, for example, in a situation where an imaging study appropriately and uniquely detects a disease in question. In contrast, an imaging study that already has marginal value for detecting a given disease may be of even lesser value if a disproportionate number of incidental findings are detected.

At this point in time, much work remains to be done in this field. Some relevant studies have investigated the short-term costs associated with incidental findings at imaging, particularly when performed in a screening context.¹⁻¹⁶ However, estimates of comprehensive, long-term, societal costs consequent to imaging-detected incidental findings are largely absent. Furthermore, there is not yet a consistent precedent, within the imaging literature, for estimating the long-term health and economic outcomes of incidental findings alongside primary, long-term outcomes that are relevant to original study indications. In this review, we will: (1) provide an overview of the existing literature on imaging-detected incidental findings and their economic burden, focusing on three examination types - abdominal/pelvic CT, chest CT, and cardiac CT - that have been the subject of most relevant studies to date¹⁻¹⁶; and (2) provide insight as to how to fill critical research gaps in order to better quantify the true economic burden of imaging-detected incidental findings in our healthcare system.

ABDOMINAL IMAGING

CT Colonoscopy (CTC)

Concerns about the economic impact of incidental, extracolonic findings at CT colonography (CTC) have had a greater impact at the policy level than any other context of incidental findings.²⁰⁻²² While robust data that quantify the long-term costs of extracolonic findings are not yet available, concerns about the magnitude of this burden have contributed to skepticism among policymakers about the net value of CTC for population-level screening.^{21, 22} Of particular importance, these concerns weighed into the Centers for Medicare and Medicaid Services' decision in 2009 to decline reimbursement for CTC.²³ In this section, we provide an overview of published data on the costs of extracolonic findings, including studies done within and outside of the U.S.¹⁻¹⁰ Of note, from an economic perspective, these reported costs are considered to be short-term in horizon; the longest reported mean follow-up period among studies was 3.6 years.¹⁰ We also examine the potential benefits of a proposed classification system for extracolonic CTC findings, for improving future efforts to quantify the economic burden of extracolonic findings.^{2, 4, 24}

Several U.S. studies have investigated the scope of incidental findings detected at CTC and their associated short-term costs.^{2-7, 10} Cumulatively, in seven primary series, incidental findings were reported in 41-98% of cases - clinically significant in 7-18% of cases - resulting in added work-up costs of \$13-\$248 per scan (Table 1).^{2-7, 10} Importantly, these studies varied significantly in the types of costs included. Five studies reported only added costs due to medical imaging or other diagnostic tests.^{2-5, 10} Hara et al, in a prospective study of 264 patients, found that 30/264 (11.4%) scans had clinically significant extracolonic findings, generating a mean additional cost of \$28 per scan over the entire

screening cohort.⁵ Glueker et al³ confirmed the results in a larger cohort from the same institution, finding additional costs of \$34 per patient screened. Yee et al¹⁰ subsequently published their results in a large, prospectively followed screening cohort, and found that extracolonic findings resulted in additional work-up costs of \$28 per patient screened. Flicker et al² and Veerapan et al⁴ reported added costs due to imaging alone,² and due to imaging plus other diagnostic tests,⁴ respectively; these two studies are discussed in greater detail below, in the context of a classification system for extracolonic findings.²⁴

Two studies instead reported total work-up costs, including treatment.^{6, 7} Pickhardt et al, in a retrospective study of 2195 patients, found that clinically significant extracolonic findings were detected in 157 (7.2%) CTC scans.⁷ Relevant new diagnoses were made in 2.5% of patients, including 9 previously unknown malignancies.⁷ For the work-up of extracolonic findings, the mean cost per patient screened was \$99, with \$31 attributed to non-surgical costs (including further imaging), and \$68 attributed to surgical and inpatient hospital costs.⁷ In 136 asymptomatic patients, Kimberly et al found that 134 (98.5%) had at least one extracolonic finding, and that 25 (17.5%) patients had clinically significant extracolonic findings.⁶ The average cost for evaluating the extracolonic findings was \$248 per patient screened: \$185 for additional imaging, \$8 for laboratory studies, and \$38 for procedures.⁶ The authors noted that their higher reported costs, relative to prior studies, may have been due to their practice of reporting all extracolonic findings to primary care physicians without further specific guidance regarding work-up.⁶

Analogous studies from the United Kingdom^{8, 9} and Australia¹ have yielded comparable results (Table 1). In a prospective Australian study of 432 asymptomatic patients, 146 (27.3%) patients had extracolonic findings, of which 32 (7.4%) were deemed clinically significant.¹ Added work-up costs of clinic visits, further imaging, and laboratory tests amounted to an extra \$24 (USD) per scan when averaged over the entire cohort.¹ In a prospective study of 225 symptomatic patients in the UK, 116 (51.6%) CTC scans performed had extracolonic findings; 24 (10.7%) generated further work-up.⁹ Additional costs generated by CTC were £153 (US\$282)²⁵ per scan when averaged over the entire cohort, the majority of which were from surgical procedures.⁹ In a retrospective UK study of 400 symptomatic patients, 268 (67%) scans performed were associated with extracolonic findings; 116 (29%) scans had clinically significant findings.⁸ Among this population, 45 patients underwent further work-up, and 22 were diagnosed with new extracolonic malignancies.⁸ The total cost of work-up for extracolonic findings was £34 (US\$67) per scan when averaged over the entire cohort.⁸

An important limitation to consider when comparing the costs of extracolonic CTC findings across investigations is the wide variation in the classification of these findings. This variability is substantiated by a wide reported range in the prevalence of extracolonic findings (41–98%) (Table 1).^{1–3, 5–10} To address this variability, Zalis et al²⁴ developed a classification system for extracolonic findings, with the goal of improving both clinical care and research relevant to CTC findings. Flicker et al² subsequently reported their findings when applying this classification system to a retrospective group of 376 patients who underwent CTC. They found that 272 (72.3%) scans had extracolonic findings; 51 (13.6%) had *E3* findings (likely unimportant, but incompletely characterized, and work-up may be indicated) and 16 (4.3%) had *E4* findings (potentially important, and should be communicated to the referring physician).² The extra cost of working up these lesions amounted to \$13 per screening scan when averaged over the entire cohort.² Veerappan et al⁴ also applied the classification system to a retrospectively identified screening cohort. In their study of 2277 patients, they reported extracolonic findings in 1037 patients (45.5%), including 211 (9.3%) patients with *E3* findings, and 39 (1.7%) with *E4* findings.⁴ Costs resulting from the work-up of these findings totaled \$50 per patient, when averaged over the

entire cohort.⁴ This system, if universally adopted, could help to ensure that referrals for evaluation of extracolonic lesions are done more consistently. Ultimately, consistent reporting will be critical for understanding the true economic burden of incidental, extracolonic findings at CTC. As noted above, the magnitude of this burden may substantially influence the viability of CTC for colorectal cancer screening in the future.

Abdominal CT – Non-CTC Indications

While CTC represents a setting where the economic burden of incidental findings is of foremost concern from a policy perspective, abdominal CT performed for other indications accounts for the vast majority of incidental findings in abdominal imaging.^{11, 12, 26} However, as in the case of CTC, published data informing attendant costs are limited. In a prospective study of 344 patients undergoing CT urography for evaluation of hematuria, Liu and colleagues¹¹ found that 259 (75.3%) had extraurinary incidental findings; 62 (18.0%) had incidental findings deemed of high clinical significance. Among the 344 patients, 8.4% underwent further diagnostic imaging, at an added cost of \$41 when averaged over all scans initially performed.¹¹ In a retrospective study of 175 CT angiography studies performed on renal donor candidates, Maizlin and colleagues¹² reported 71 (40.6%) patients to have extrarenal incidental findings; 18 (10.3%) had findings of high clinical significance. The further recommended follow-up studies added an estimated \$35 per scan, when averaged over all scans performed.¹² Further research is needed to better understand the economic burden of incidental findings across the wide spectrum of common clinical indications for abdominal CT.

THORACIC IMAGING

Among chest CT indications, lung cancer screening, if widely adopted for high-risk patients such as smokers, may generate the highest burden of incidental findings.^{14, 27} However, in smokers, factors such as high competing risks of mortality, and a high prevalence of non-malignant lung nodules (requiring substantial consequent work-up) have rendered the value of a CT screening approach questionable.^{14, 27–29} Even so, investigators have attempted to quantify the magnitude of incidental findings at screening chest CT and their short-term costs. MacRedmond et al²⁷ reported a 62% prevalence of incidental findings at screening chest CT, most commonly emphysema and coronary artery disease. In a retrospective Canadian study of 4073 patients who received screening chest CT scans, Kucharczyk et al¹⁴ found that 782 (19.2%) patients had incidental findings; 486 (11.9%) patients required imaging follow-up. Seven biopsy-proven cancers were ultimately diagnosed: four breast cancers, two rib plasmacytomas, and one thyroid cancer.¹⁴ Per screening chest CT examination performed, the added costs of further diagnostic work-up were estimated to be C\$12.¹⁴ Of specific note, these studies did not include lung nodules as incidental findings - although a large percentage of detected lung nodules are benign at CT, their detection and work-up is related to the clinical indication of lung cancer screening, and thus they are not considered incidental. In the setting of most other chest CT indications - for example, cardiac CT, as discussed below - incidental lung nodules contribute substantively to short- and long-term costs of incidental findings.

Importantly, thyroid abnormalities are also commonly incidentally detected at chest CT during imaging of the lower neck. More than 50% of asymptomatic patients have thyroid nodules at autopsy;³⁰ therefore, the likelihood of encountering a thyroid nodule on a CT or MRI study that includes a portion of the thyroid gland is high. Yousem et al¹³ retrospectively analyzed 231 CT and MRI studies of the neck, and found 36 (15.6%) to demonstrate incidental thyroid nodules. Of all cases, 2.6% underwent further work-up. The cost of further work-up and treatment was \$31 when averaged over all patients scanned.¹³

CARDIAC IMAGING

A well-known debate in the field of cardiac CT is whether or not to limit the field-of-view to the heart, an issue driven largely by the burden of extracardiac incidental findings. Many argue that a major, salient limitation of cardiac CT is the high rate of pulmonary nodule detection and the extent to which this causes low-yield, unanticipated follow-up and interventions, as well as increased costs.¹⁶

Early investigations have begun to quantify the extent of extracardiac incidental findings, and their attendant short-term costs. A literature review by Sosnouski et al³¹ noted that incidental extracardiac findings were present on coronary CT angiography (CTA) in 25–61% of studies. Lee et al retrospectively studied 151 patients who underwent full-field cardiac CT, and found that 65 (43.0%) patients had incidental findings; in 47 patients (31.1%), findings were deemed potentially clinically significant.¹⁶ Despite recommendations for work-up for 19 findings, only 6 patients received further work-up, one in whom a malignancy was detected and treated.¹⁶ Of note, a high prevalence of incidental pulmonary nodules was observed - 55% of patients (26/47) with potentially significant incidental findings had pulmonary nodules >4-mm.¹⁶ The direct costs of additional work-up were \$17.42 per patient, when averaged over the entire cohort studied.¹⁶ MacHaalany et al¹⁵ prospectively studied 966 Canadian patients evaluated with full field-of-view cardiac CT, and found that 401 (41.5%) patients exhibited extracardiac findings. These findings were classified into clinically significant (12/966, 1.2%), indeterminate (68/966, 7.0%), and clinically non-significant (321/966, 33.2%) categories.¹⁵ A total of 164 additional imaging studies and procedures were performed for the 80 patients with clinically significant or indeterminate findings; 6 patients were ultimately diagnosed and treated for malignancy.¹⁵ Direct costs of investigating all incidental findings were C\$60 (US\$86) per scanned patient.¹⁵

PRIMARY LIMITATIONS OF ECONOMIC INVESTIGATIONS TO DATE

To date, most published literature on the economic burden of incidental findings is centered in CT of the chest and abdomen in adults.^{1–3, 5–16} Cost analyses of incidental findings seen during neurological, musculoskeletal, or pediatric imaging are sparse or absent. In addition, most studies address screening scenarios. When performing imaging for symptoms, or for a known disease process, the short-term costs of incidental findings may differ. For example, in a patient with a large hepatocellular carcinoma at CT, a questionable small renal lesion will not merit further work-up in most cases, due to the poor prognosis of the hepatic malignancy. However, in an asymptomatic patient without known morbidities, the renal finding may result in substantial further work-up and attendant costs.

Furthermore, to date, reported added costs associated with incidental findings and their consequent work-up have been modest, with the majority of studies reporting added costs of under \$100 per scan performed.^{1–16} However, these estimates may be artificially low. As noted, the types of costs included across investigations (e.g. diagnostic work-up costs, treatment costs) are variable.^{1–16} A related limitation is that the time horizons of most analyses - the period from detection of an incidental finding to the termination of patient follow-up and cost analysis - have been short, and have not explicitly addressed life expectancy consequences (benefits or harms) of incidental findings.^{1–16} These short follow-up periods constitute one of the largest limitations of this body of research. That being said, the resource requirements for tracking the long-term downstream costs and health consequences of incidental findings, particularly for large patient cohorts, are preclusive in many research settings.

In order to better understand the economic burden of incidental findings in imaging, there remains a significant amount of research to be done. Salient methods and issues to be investigated, particularly those that will efficiently and effectively advance this field, are discussed in detail below.

FUTURE RESEARCH DIRECTIONS

A Call for Economic Models

Economic models integrate multiple data sources – including costs, life expectancy, and quality-of-life – to predict the long-term, downstream consequences and value of a given imaging test or procedure.^{32–35} When considering methods for evaluating the economic burden of incidental findings, such models carry three primary advantages: (1) long-term downstream costs, benefits, and harms can be estimated, accounting for the costs of added procedures and complications, as well as potential life expectancy gains or losses; (2) competing risks of morbidity and mortality, such as may be relevant with advanced age or concurrent disease processes, can be explicitly considered; and (3) a societal perspective can be achieved, making the results more generalizable than would be the case for a single-institution study.³⁵ Thus, economic models can provide a more realistic and comprehensive view of the economic burden of incidental findings than is typically possible through primary data collection. However, in order to develop robust economic models in this field, more primary data collection relevant to incidental findings is first needed. Below, we describe what types of data will be important to collect, and how such data can be integrated to develop efficient models for economic analyses.

Classifying Incidental Findings During Primary Data Collection

In order to build robust economic models, more information is needed about the scope of incidental findings in each imaging subspecialty. Moreover, as investigators collect these data, there will be a critical need to classify these findings in a uniform fashion. Consider, for example, two investigative groups that are studying the same group of patients, all of whom received abdominal CT scans. One group may designate a renal cyst as an incidental finding, whereas the other group may not. If each group reports added costs per incidental finding, the results of their analyses will be different, even though they are studying the same group. A recently published consensus paper on the management of incidental findings at abdominal CT generated by the American College of Radiology (ACR) Incidental Findings Committee,³⁶ and the previously mentioned classification system for extracolonic findings proposed by Zalis and colleagues for CTC,²⁴ represent important steps towards more uniform classification of incidental findings, but much more work is needed in this area.

Furthermore, the clinical and economic importance of most incidental findings depends upon patient-specific factors. When investigators collect and classify data on incidental findings, patient-specific factors that could influence management decisions should be concurrently tracked and reported. Consider a small simple pancreatic cyst, detected incidentally on an abdominal CT. The patient's age at detection will likely direct the management of this finding, including follow-up imaging and cost requirements. This relationship between patient status and the burden of incidental findings merits specific consideration - investigators must be careful not to over- or underestimate the economic burden of incidental findings in one population by erroneously extrapolating cost data to another.

Addressing Cost Differences Related to Practice Heterogeneity

Estimating costs that are incurred as a consequence of incidental findings similarly requires a systematized, transparent approach. The clinical course and outcomes of patients who have had incidental findings are defined by heterogeneous practitioner recommendations and patient adherence patterns – this spectrum of patient experience must be collected in detail. As described below, economic modeling techniques, in turn, allow this type of heterogeneity to be explicitly considered. For example, the economic impact of different levels of adherence to recommended follow-up imaging can be evaluated, ranging from 0% (no adherence) to 100% adherence. Heterogeneity in work-up practices (e.g. imaging-guided biopsy versus direct surgery for a solid, incidental renal mass), can also be explicitly considered in a model, to determine the economic consequences of different approaches.³⁴

Developing Economic Models that Incorporate Incidental Findings

In economic analyses, when evaluating a diagnostic strategy for disease detection, long-term, comprehensive costs are ideally estimated alongside consequent life expectancy – this method enables not just costs, but the underlying value of the strategy to be estimated. Long-term cost and life expectancy projections can be concurrently estimated using a variety of biostatistical, Markov modeling, or Monte Carlo simulation techniques.^{29, 32, 34, 37} Importantly, these long-term projections are made not only for the diagnostic strategy under consideration, but also for relevant alternative strategies. Recent relevant examples include cost-effectiveness analyses of CTC for colorectal cancer screening (relative to current standards, including optical colonoscopy),³² MRI for breast cancer screening in *BRCA1* mutation carriers (relative to mammography),³³ and imaging-guided biopsy in patients with small renal masses (relative to empiric surgery).³⁴ Moving forward, incidental findings should ideally be incorporated within economic models that aim to evaluate the overall value of a given diagnostic imaging strategy. In this way, the attendant long-term costs and life expectancy implications of incidental findings can be integrated with other costs, risks and benefits inherent to the imaging strategy under consideration for a given clinical indication. Thus, the impact of incidental findings on a strategy's underlying value can be evaluated explicitly.

Importantly, quality-of-life (QOL) is an integral component of economic analyses in medicine, but has been sparsely studied to date in imaging practices.^{38–41} The rationale for incorporating QOL into economic analyses in medicine, and for adjusting life expectancy estimates to incorporate QOL (e.g. quality-adjusted life years QALYs), is that in order to estimate how a society values health care services, the value that a society places upon time spent in different states of health must be considered.³⁵ In the context of incidental findings, many would argue that patient stress and inconvenience incurred during any additional recommended work-up must be considered. However, equally important to consider is the anxiety that can result from forgoing the work-up of a lesion with a low, but nonzero likelihood of malignancy. These competing QOL forces merit further investigation. Ultimately, if practitioners only recommend further work-up for incidental findings when they are highly likely to have clinical consequences, the economic burden of incidental findings could be reduced enormously. However, QOL influences must be considered when making related policy decisions, to ensure that they are well-aligned with societal preferences.

Cost-Effectiveness Analysis

When a model is developed to generate long-term cost and effectiveness data for competing healthcare strategies, a cost-effectiveness analysis can be performed to compare the relative value of the strategies under consideration.³⁵ Importantly, this type of analysis is structured to address a specific clinical scenario – e.g. the cost-effectiveness of CTC relative to optical

colonoscopy for colorectal cancer screening – not a single diagnostic test in isolation. In a standard cost-effectiveness analysis, lifetime costs and quality-adjusted life expectancy are estimated for each diagnostic strategy under consideration, and are simultaneously compared in an incremental cost-effectiveness analysis.³⁵ Within this type of analysis, as noted above, the extent to which incidental findings affect the cost and effectiveness of an imaging strategy under consideration can be explicitly evaluated. Importantly, this approach to estimating the economic burden of incidental findings is likely to yield more clinically meaningful results than isolated analyses of the costs of incidental findings, because it critically accounts for the original value of the imaging strategy under consideration for addressing the clinical question at hand.

CONCLUSION

The use of medical imaging, particularly CT and MRI, has soared in the last several decades.^{17, 18} Over the same time period, the cost of medical care in the United States has been increasing at rates that are not economically sustainable. With increased scrutiny of the costs of medical care, imaging has been highlighted as an area of particular growth and cost.¹⁸ Increased imaging utilization among practitioners results in an unavoidable rise in incidentally detected findings. These findings, generated primarily by cross-sectional imaging studies, have significant downstream cost implications. Furthermore, concerns over the economic burden of incidental findings can influence policy decisions to either approve or decline reimbursement for new imaging technologies and applications, as in the case of CTC for colorectal cancer screening.^{21, 42}

Published cost data relevant to imaging-detected incidental findings are sparse, and do not yet enable accurate estimation of the economic burden of imaging-detected incidental findings in our current healthcare system.¹⁸ Substantial further work is needed in this field. While further primary data collection will be critical for better defining the scope of incidental findings and understanding current practice patterns related to their work-up, the resource requirements for identifying the long-term costs, risks, and benefits of incidental findings are preclusively high in most settings. As detailed in our review, economic modeling techniques can be used to more efficiently estimate the long-term, downstream costs and patient outcomes that result from incidental findings, and to understand the effects of incidental findings upon the value of widely used diagnostic imaging strategies. This combined approach of primary data collection and economic modeling has the potential to yield high-quality evidence regarding the burden of imaging-detected incidental findings in a wide spectrum of clinical and patient scenarios. Equipped with such information, clinicians and policy-makers alike will be able to make better decisions about the appropriateness of imaging procedures in future healthcare practices.

References

1. Chin M, Mendelson R, Edwards J, Foster N, Forbes G. Computed tomographic colonography: prevalence, nature, and clinical significance of extracolonic findings in a community screening program. *Am J Gastroenterol*. 2005; 100(12):2771–6. [PubMed: 16393234]
2. Flicker MS, Tsoukas AT, Hazra A, Dachman AH. Economic impact of extracolonic findings at computed tomographic colonography. *J Comput Assist Tomogr*. 2008; 32(4):497–503. [PubMed: 18664832]
3. Gluecker TM, Johnson CD, Wilson LA, et al. Extracolonic findings at CT colonography: evaluation of prevalence and cost in a screening population. *Gastroenterology*. 2003; 124(4):911–6. [PubMed: 12671887]
4. Veerappan GR, Ally MR, Choi JH, Pak JS, Maydonovitch C, Wong RK. Extracolonic findings on CT colonography increases yield of colorectal cancer screening. *AJR Am J Roentgenol*. 2010; 195(3):677–86. [PubMed: 20729446]

5. Hara AK, Johnson CD, MacCarty RL, Welch TJ. Incidental extracolonic findings at CT colonography. *Radiology*. 2000; 215(2):353–7. [PubMed: 10796907]
6. Kimberly JR, Phillips KC, Santago P, et al. Extracolonic findings at virtual colonoscopy: an important consideration in asymptomatic colorectal cancer screening. *J Gen Intern Med*. 2009; 24(1):69–73. [PubMed: 18958531]
7. Pickhardt PJ, Hanson ME, Vanness DJ, et al. Unsuspected extracolonic findings at screening CT colonography: clinical and economic impact. *Radiology*. 2008; 249(1):151–9. [PubMed: 18796673]
8. Tolan DJ, Armstrong EM, Chapman AH. Replacing barium enema with CT colonography in patients older than 70 years: the importance of detecting extracolonic abnormalities. *AJR Am J Roentgenol*. 2007; 189(5):1104–11. [PubMed: 17954647]
9. Xiong T, McEvoy K, Morton DG, Halligan S, Lilford RJ. Resources and costs associated with incidental extracolonic findings from CT colonography: a study in a symptomatic population. *Br J Radiol*. 2006; 79(948):948–61. [PubMed: 16822798]
10. Yee J, Kumar NN, Godara S, et al. Extracolonic abnormalities discovered incidentally at CT colonography in a male population. *Radiology*. 2005; 236(2):519–26. [PubMed: 16040909]
11. Liu W, Mortelet KJ, Silverman SG. Incidental extraurinary findings at MDCT urography in patients with hematuria: prevalence and impact on imaging costs. *AJR Am J Roentgenol*. 2005; 185(4):1051–6. [PubMed: 16177432]
12. Maizlin ZV, Barnard SA, Gourlay WA, Brown JA. Economic and ethical impact of extrarenal findings on potential living kidney donor assessment with computed tomography angiography. *Transpl Int*. 2007; 20(4):338–42. [PubMed: 17326774]
13. Yousem DM, Huang T, Loevner LA, Langlotz CP. Clinical and economic impact of incidental thyroid lesions found with CT and MR. *AJNR Am J Neuroradiol*. 1997; 18(8):1423–8. [PubMed: 9296181]
14. Kucharczyk MJ, Menezes RJ, McGregor A, Paul NS, Roberts HC. Assessing the Impact of Incidental Findings in a Lung Cancer Screening Study by Using Low-dose Computed Tomography. *Can Assoc Radiol J*. 2010
15. Machaalany J, Yam Y, Ruddy TD, et al. Potential clinical and economic consequences of noncardiac incidental findings on cardiac computed tomography. *J Am Coll Cardiol*. 2009; 54(16):1533–41. [PubMed: 19815125]
16. Lee CI, Tsai EB, Sigal BM, Plevritis SK, Garber AM, Rubin GD. Incidental extracardiac findings at coronary CT: clinical and economic impact. *AJR Am J Roentgenol*. 2010; 194(6):1531–8. [PubMed: 20489093]
17. Baker LC, Atlas SW, Afendulis CC. Expanded use of imaging technology and the challenge of measuring value. *Health Aff (Millwood)*. 2008; 27(6):1467–78. [PubMed: 18997202]
18. Smith-Bindman R, Miglioretti DL, Larson EB. Rising use of diagnostic medical imaging in a large integrated health system. *Health Aff (Millwood)*. 2008; 27(6):1491–502. [PubMed: 18997204]
19. Orme NM, Fletcher JG, Siddiki HA, et al. Incidental findings in imaging research: evaluating incidence, benefit, and burden. *Arch Intern Med*. 2010; 170(17):1525–32. [PubMed: 20876402]
20. Pearson SD, Knudsen AB, Scherer RW, Weissberg J, Gazelle GS. Assessing the comparative effectiveness of a diagnostic technology: CT colonography. *Health Aff (Millwood)*. 2008; 27(6):1503–14. [PubMed: 18997205]
21. Zuber, AGKA.; Rutter, CM., et al. Cost-effectiveness of CT Colonography to Screen for Colorectal Cancer: Technology Assessment Report. Published Jan 22, 2009
22. Screening for colorectal cancer: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med*. 2008; 149(9):627–37. [PubMed: 18838716]
23. Decision Memo for Screening Computed Tomography (CTC) for Colorectal Cancer (CAG-00396N). Updated May 12, 2009, Retrieved Oct 20, 2010, from <http://www.cms.gov/mcd/viewdecisionmemo.asp?from2=viewdecisionmemo.asp&id=220&>
24. Zalis ME, Barish MA, Choi JR, et al. CT colonography reporting and data system: a consensus proposal. *Radiology*. 2005; 236(1):3–9. [PubMed: 15987959]
25. Central Intelligence Agency. The World Factbook; Updated Oct 1, 2010, Retrieved Oct 20, 2010, from <https://www.cia.gov/library/publications/the-world-factbook/fields/2076.html>

26. Messersmith WA, Brown DF, Barry MJ. The prevalence and implications of incidental findings on ED abdominal CT scans. *Am J Emerg Med*. 2001; 19(6):479–81. [PubMed: 11593466]
27. MacRedmond R, Logan PM, Lee M, Kenny D, Foley C, Costello RW. Screening for lung cancer using low dose CT scanning. *Thorax*. 2004; 59(3):237–41. [PubMed: 14985561]
28. Black C, Bagust A, Boland A, et al. The clinical effectiveness and cost-effectiveness of computed tomography screening for lung cancer: systematic reviews. *Health Technol Assess*. 2006; 10(3):iii–iv. ix–x, 1–90.
29. McMahon PM, Kong CY, Johnson BE, et al. Estimating long-term effectiveness of lung cancer screening in the Mayo CT screening study. *Radiology*. 2008; 248(1):278–87. [PubMed: 18458247]
30. Mortensen JD, Woolner LB, Bennett WA. Gross and microscopic findings in clinically normal thyroid glands. *J Clin Endocrinol Metab*. 1955; 15(10):1270–80. [PubMed: 13263417]
31. Sosnouski D, Bonsall RP, Mayer FB, Ravenel JG. Extracardiac findings at cardiac CT: a practical approach. *J Thorac Imaging*. 2007; 22(1):77–85. [PubMed: 17325579]
32. Knudsen AB, Lansdorp-Vogelaar I, Rutter CM, et al. Cost-effectiveness of computed tomographic colonography screening for colorectal cancer in the medicare population. *J Natl Cancer Inst*. 2010; 102(16):1238–52. [PubMed: 20664028]
33. Lee JM, McMahon PM, Kong CY, et al. Cost-effectiveness of breast MR imaging and screen-film mammography for screening BRCA1 gene mutation carriers. *Radiology*. 2010; 254(3):793–800. [PubMed: 20177093]
34. Pandharipande PV, Gervais DA, Hartman RI, et al. Renal mass biopsy to guide treatment decisions for small incidental renal tumors: a cost-effectiveness analysis. *Radiology*. 2010; 256(3):836–46. [PubMed: 20720070]
35. Weinstein MC, Siegel JE, Gold MR, Kamlet MS, Russell LB. Recommendations of the Panel on Cost-effectiveness in Health and Medicine. *JAMA*. 1996; 276(15):1253–8. [PubMed: 8849754]
36. Berland LL, Silverman SG, Gore RM, et al. Managing Incidental Findings on Abdominal CT: White Paper of the ACR Incidental Findings Committee. *J Am Coll Radiol*. 2010; 7(10):754–73. [PubMed: 20889105]
37. Lee JM, Kopans DB, McMahon PM, et al. Breast cancer screening in BRCA1 mutation carriers: effectiveness of MR imaging--Markov Monte Carlo decision analysis. *Radiology*. 2008; 246(3):763–71. [PubMed: 18309013]
38. Hsung JM, Langlotz CP, Orel SG, Fox KR, Schnall MD, Schwartz JS. Cost-effectiveness of MR imaging and core-needle biopsy in the preoperative work-up of suspicious breast lesions. *Radiology*. 1999; 213(1):39–49. [PubMed: 10540638]
39. Swan JS, Fryback DG, Lawrence WF, et al. MR and conventional angiography: work in progress toward assessing utility in radiology. *Acad Radiol*. 1997; 4(7):475–82. [PubMed: 9232166]
40. Swan JS, Sainfort F, Lawrence WF, Kuruchittham V, Kongnakorn T, Heisey DM. Process utility for imaging in cerebrovascular disease. *Acad Radiol*. 2003; 10(3):266–74. [PubMed: 12643553]
41. Swan JS, Ying J, Stahl J, et al. Initial development of the Temporary Utilities Index: a multiattribute system for classifying the functional health impact of diagnostic testing. *Qual Life Res*. 2010; 19(3):401–12. [PubMed: 20084464]
42. Screening for colorectal cancer: recommendation and rationale. *Ann Intern Med*. 2002; 137(2):129–31. [PubMed: 12118971]

Table 1

CT Colonography Studies Reporting Added Costs of Incidental Findings

Authors	Journal	Year	Location	Study Type	Population	Cohort Mean Age	Number of Cases	% Incidental Findings	% Clinically Significant	Average Added Cost Per Scan
Hara et al ⁵	Radiology	2000	US	Prospective	Asymptomatic	64	264	41%	11%	\$28 [#]
Gluecker et al ³	Gastroenterology	2003	US	Prospective	Asymptomatic	64 [*]	681	69%	10%	\$34 [#]
Yee et al ¹⁰	Radiology	2005	US	Prospective	Mixed	63	500	63%	9%	\$28 [#]
Chin et al ¹	Am J Gastroent	2005	AUS	Prospective	Asymptomatic	59	432	27%	7%	\$24 [†]
Xiong et al ⁹	Br J Radiol	2006	UK	Prospective	Symptomatic	74 [*]	225	52%	N/A	\$282 ^{‡§}
Tolan et al ⁸	AJR	2007	UK	Retrospective	Symptomatic	80	400	67%	29%	\$67 [†]
Flicker et al ²	JCAT	2008	US	Retrospective	Mixed	61	376	72%	18%	\$13 [#]
Pickhardt et al ⁷	Radiology	2008	US	Retrospective	Asymptomatic	58	2195	N/A	7%	\$99 [‡]
Kimberly et al ⁶	J Gen Intern Med	2008	US	Prospective	Mixed	57 [*]	136	98%	18%	\$248 [‡]
Veerappan et al ⁴	AJR	2010	US	Retrospective	Asymptomatic	59	2277	46%	11%	\$50 [†]

US= United States, AUS= Australia, UK= United Kingdom, N/A= Not Specifically Addressed

* median reported instead of mean

§ converted based on 2006 rates²⁵

includes imaging-related costs

† includes imaging-related costs and other diagnostic costs

‡ includes imaging-related costs, as well as other diagnostic costs and treatment costs