Cost Effectiveness of Imaging Utilization - Bibliography

In the last decade, the imaging department has become the nucleus for diagnosis in most medical centers. This is certainly related to continued technologic advances and improvements in the quality of imaging. Faster processing and rapid on-site interpretations by local well-trained experts have further enhanced the feasibility of performing such examinations, both from the emergency room and in outpatient settings. As a result, primary care physicians have tended to rely ever more heavily on these interpretations, with the art of the physical exam being de-emphasized, particularly by younger physicians. Consequently, referring physicians are requesting diagnostic imaging exams more frequently. One might expect a negative financial impact, but increasing the utilization of diagnostic exams can often result in significant economic benefit.

The following is a synopsis of published literature that demonstrates how more frequent imaging or the utilization of imaging-guided procedures can produce significant cost savings compared to more standard methods of patient care. The ACR Managed Care Committee hopes you find this information useful when discussing the utilization of imaging with colleagues and payers.

Literature Search: Value of Increasing Radiology Utilization in Certain Clinical Situations

1. Arguedas MR, Chen VK, Eloubeidi MA, et al. Screening for Hepatocellular Carcinoma in Patients with Hepatitis C Cirrhosis: A Cost-Utility Analysis. AJG 2003; 98(3):679-690. Prior studies showed that screening for HCC with ultrasound and alpha-fetal protein (AFP) determination was cost-effective and resulted in improved survival as compared to unscreened controls, because it allows for earlier treatment (i.e. surgical resection, chemoembolization, local ablation, liver transplantation). A hypothetical cohort of 50-year-old patients with cirrhosis caused by chronic HCV infection was categorized according to the stage of liver disease prior to developing HCC. Five strategies for HCC screening were compared: no screening, AFP determination alone, AFP and US, AFP and three-phase abdominal CT, AFP and abdominal MRI. The following treatment algorithm was used: positive AFP would be imaged by three-phase CT or MRI; positive imaging study would undergo biopsy; positive biopsy of small tumors (unifocal, <5 cm) would undergo resection, chemoembolization or ablation; recurrence of small tumors would go to OLT for patients up to 70 years of age. Large tumors (multifocal, >5 cm, vascular invasion or extrahepatic spread) were treated with palliative measures. Cost-effectiveness of the strategies evaluated increased for higher incidence of HCC, tumors with slower growths, and lower cost, higher sensitivity and higher specificity of the diagnostic test. Three-phase CT scan alternating at 6-months intervals with AFP determination was shown to be the most cost-effective strategy, comparable with other acceptable screening strategies such as mammography and colonoscopy.

2. Baba Y, Takahashi M, Korogi Y. Decision analysis of cost-effectiveness of magnetic resonance angiography for mass screening for intracranial aneurysms. Academic Radiology. 1998; 5 (Suppl 2) S297-299. In an analysis of a large group of patients at two different facilities, the authors evaluated the sensitivity and specificity of MRA for detection of intracranial aneurysms, and indicate specificity was on the order of 80% and sensitivity was approximately 87%. When factored in with the incidence of intracranial aneurysms, estimated to be approximately 2% in the general population, and the rupture rate of 2% per year, it would require that 50 patients with aneurysms undergo treatment to save one patient with an aneurysm before it ruptures. The author emphasizes that these results are for the general population and that screening may in fact be practical for patients at high risk for aneurysms such as those with family members having had previous subarachnoid hemorrhage, as well as patients with polycystic kidney disease, fibromuscular dysplasia, and severe atherosclerotic disease of other vessels.

(1) Is imaging necessary? (a) The NEXUS study in the US was an observational study on prospectively enrolled 34,000 patients who underwent C-spine radiography following blunt trauma. It validated a predefined set of criteria in the absence of subsequent patient follow-up. There was a low prevalence of injury (2.4%), and the NEXUS selection criteria had a 12.9% specificity for injury. (b) The Canadian C-spine study developed a prediction rule for acute C-spine injury on a prospective cohort of 8,924 patients. Three clinical criteria were used to determine whether imaging was indicated or not. The Canadian prediction rule had 100% sensitivity and 42.5% specificity which would lower the current rate of ordering C-spine radiographs by 58.2%.

(2) If imaging is necessary, what is the optimal strategy? Radiography misses as many as 23-57% of C-spine fractures as compared with CT, but the clinical relevance of these missed fractures remains uncertain. CT has 99% sensitivity and 93% specificity for fractures in adults. A retrospectively derived clinical prediction rule was validated prospectively and showed CT to be cost effective for C-spine imaging in high risk patients, but not in low risk patients. The moderate risk group showed CT to cost slightly more than radiography.

4. Bosch JL, Kaufman JA, Beinfeld MT, Adriaensen ME, Brewster DC, Gazelle GS. Abdominal Aortic Aneurysms: Cost-effectiveness of Elective Endovascular and Open Surgical Repair. *Radiology*. 2002; 225:337-344. The purpose of this article was to evaluate the cost effectiveness of performing newer endovascular treatments for infrarenal aortic aneurysm repair and comparing those with the standard surgical repair of this entity. Both long term and short term costs were considered, accounting for additional long term costs impacted by various associated complications. A complex mathematical model was utilized to quantify quality-adjusted life expectancy, lifetime costs and cost-effectiveness ratio. When accounting for complication rate, long term failure rate and rupture rate, the results suggest that endovascular repair is clinically and cost effective when compared to open surgery for the elective repair of AAA.


6. Carlos RC, Axelrod DA, Ellis JH, et al. Incorporating Patient-Centered Outcomes in the Analysis of Cost-Effectiveness: Imaging Strategies for Renovascular Hypertension. *AJR* 2003; 181:1653-1661. Renovascular disease is present in 1-5% of the general hypertensive population. The clinical outcomes, quality of life and treatment costs of a hypothetical patient with medication-resistant hypertension were analyzed. Case scenarios ranging from “do nothing”, to medical treatment only, to employing various imaging strategies with subsequent intravascular interventions were compared. All alternatives were cost-effective compared with the “do nothing” case scenario. Looking at direct costs, the diagnostic use of MR angiography or CT angiography resulted in longer life expectancy and was cost-effective compared with medical therapy alone, with MR angiography dominating CT angiography. Looking at direct and indirect costs (i.e. total cost of the illness), conventional angiography dominated all other treatment and imaging strategies. MR angiography screening for renal artery stenosis in targeted hypertensive populations appears to be feasible. Other diagnostic imaging studies like US and renal scintigraphy were not included in this study.

8. Doubilet P, Weinstein MC, McNeil BJ. Use and misuse of the term "cost effective" in medicine. *NEJM*. 1986;314(4):253-256. This article had to do with the correct usage of the term "cost effective," commenting on the need to have numerical data supporting the economic benefits, which are rarely seen in both advertisements and research. The concluding paragraph, however, adds some helpful insight to our position and is as follows: ... attempting to base medical decisions on both health and monetary considerations is a difficult task that raises serious ethical issues. The data required to determine the benefits and costs of competing strategies are often unavailable or unreliable. Many medical decisions are influenced by factors that cannot be easily quantified or assigned a dollar value—for example, pain relief, the "bonding" effect of an obstetrical sonogram and the reassurance provided by a negative test.

9. Frank JB, Lim CK, Flynn JM, et al. The Efficacy of Magnetic Resonance Imaging in Pediatric Cervical Spine Clearance. *Spine* 2002; 27:1176-1179. Radiographs are less sensitive than CT for C-spine injuries, which in turn is less sensitive than MRI for detecting soft tissue and ligamentous injuries. The study compares two groups of 51 pediatric patients that were hospitalized following trauma, before and after an MRI protocol was incorporated into clinical practice for early imaging of the C-spine. The following inclusion criteria were used: 1) intubation by the time of hospital admission; 2) at least 3 days of continuous ICU stay; 3) mechanism of injury consistent with potential cervical spine injury. Early MRI imaging decreased the time to cervical spine clearance from 5.1 to 3.2 days, the ICU stay from 9.2 to 7.3 days, and the average hospital stay from 20.1 to 15.5 days, with an overall savings of $7,700 per patient.

10. Garcia Pena BM, Taylor GA, Lund DP, Mandl KD. Effect of computed tomography on patient management and costs in children with suspected appendicitis. *Pediatrics*. 1999;104:440-446. CT was obtained with three strategies: 1) obtain on all patients and discharge if normal, 2) obtain on all patients and admit all, 3) selectively obtain CT if white blood cell count>10,000. All strategies decreased the number of hospital days, negative laparotomies and the per patient cost. Savings for strategy 1 was $2018/patient, for strategy 2 $554/patient, and for strategy 3 $691/patient.

11. Gould MK, Sanders GD, Barnett PG, et al. Cost-Effectiveness of Alternative Management Strategies for Patients with Solitary Pulmonary Nodules. *Ann Intern Med* 2003; 138:724-735. This study outlines an algorithm to diagnose and manage non-calcified solitary pulmonary nodules discovered incidentally by chest radiography in adult patients with no known extrathoracic malignancy (detection of regional lymph node metastases was not included). It analyzes the diagnostic impact and cost-effectiveness of FDG-PET when added to CT, transthoracic needle biopsy, surgery and/or observation in clinically plausible sequences (i.e. CT and FDG-PET never followed needle biopsy or surgery; needle biopsy and observation never followed surgery). Meta-analysis of prior studies showed sensitivity and specificity for FDG-PET and CT to be 94.2% and 83.3%, and 96.5% and 55.8% respectively. The authors concluded that: (1) clinical and cost effectiveness of any strategy depended critically on the pretest probability of malignancy and the risk for surgical complications; (2) CT was recommended as the initial test in nearly all circumstances; (3) use of FDG-PET was most cost-effective when pretest probability and CT results were discordant; (4) aggressive use of needle biopsy and surgery was most cost-effective once the results of imaging tests were known, with FDG-PET replacing needle biopsy in specific cases.

12. Hollenbeak CS, Lowe VJ, Stack BC. The Cost-Effectiveness of Fluorodeoxyglucose 18-F Positron Emission Tomography (FDG-PET) in the N0 Neck. *Cancer* 2001; 92:2341-2348. Traditionally, two options are available for the management of head and neck squamous cell carcinoma (HNSCC) following a negative CT: observation with serial physical examinations, or treatment with modified radical neck dissection (MRND) or radiation therapy (XRT). The third viable option is additional diagnostic imaging (i.e. PET with 87% sensitivity and 95% specificity) prior to observation or treatment. If the PET is negative, observation or treatment (MRND, XRT) can be used. If the PET is positive, only treatment (MRND, XRT) remains a viable option. This study analyzes the cost-effectiveness of including PET in the diagnostic and treatment protocol
for HNSCC. Life expectancy is 5.9 yrs with and 11.5 yrs without lymph node involvement. The PET-inclusive strategy is more expensive but has improved outcomes resulting in higher cost-effectiveness ($8,718 per year of life saved, $2,505 per quality-adjusted life-years). The PET strategy remains cost-effective as long as the prevalence of nodal disease following a negative CT is between 16-36% (a literature review shows the prevalence in clinical practice to be 28.6%).

13. Hricak H, Yu KK, Powell CB, Subak LL, Stem J. Comparison of diagnostic studies in the pretreatment evaluation of stage 1b carcinoma of the cervix. *Academic Radiology*. 1996; 3(Suppl 1):S44-46. This study evaluated patients with carcinoma of cervix with primary lesion greater than 2cm size. The size of the mass limits the clinician's ability to accurately stage extent of disease beyond the uterus. They showed a high correlation of both abnormal and normal MRI scans with respect to demonstration of parametrial invasion at surgery. When MR was utilized in the diagnostic work-up, there was a significant decrease in use of other diagnostic exams, both invasive and noninvasive. Using the national average Medicare global fee schedule, the total cost of these test were $887 in the MR group, in comparison to $1336 in those without MR. No significant differences in staging accuracy occurred between the two groups. The authors recommend that diagnostic exams such as excretory urography, barium enema, cystoscopy, and sigmoidoscopy be eliminated from routine use and that MR be utilized in all patients with primary lesions greater than 2 cm.

14. Jordan JE, Donaldson SS, Enzmann DR. Cost effectiveness and outcome assessment of magnetic resonance imaging in diagnosing cord compression. *Cancer*. 1998;75(10):2579-2586. This article is both a retrospective review and literature review. The authors found that with the use of MR in imaging patients with diagnosed cord compression, costs were reduced by 65 percent. Imaging studies utilized prior to MRI for diagnosis included myelography, CT, plain film and nuclear medicine. The average cost for diagnosis in these groups dropped from $3664/patient to $2283/patient. The lack of hospitalization costs with myelography contributed significantly to the reduced cost with MRI diagnosis.

15. Knott JC, Baldey AC, Grigg LE, Cameron PA, Lichtenstein M, Better N. Impact of acute chest pain Tc-99m sestamibi myocardial perfusion imaging on clinical management. *J Nucl Cardiol*. 2002 May-Jun; 9(3):257-62. A group of 120 patients who presented with acute chest pain were evaluated. Routine diagnostic work-up was performed in addition to the injection of Tc-99m sestamibi performed during the acute event, which has been shown to be a sensitive assessment for acute myocardial ischemia. Of significance was a 34 percent reduction in the number of admissions for those patients who originally presented to the emergency room. Furthermore, for patients who presented with symptoms while already admitted for other reasons, there was a 40 percent decrease in the number of coronary angiograms that were ultimately performed. Additional patients were also identified who required angiography and who had coronary artery abnormalities detected due only to the positive sestamibi scan.

16. Levin DC, Matteucci T. Do radiologists control imaging studies? Survey results from 198 academic institutions. *Radiology*. 1989;170:879-881. In many of the potentially controversial imaging and interventional procedures, radiologists' domains were not challenged. Even areas such as OB US, IVC filter placement and urethrography, their roles were "significant."

17. Liberman L, Fahs MC, Dershaw DD et al. Impact of stereotaxic core breast biopsy on cost of diagnosis. *Radiology*. 1995;195:633-637. The cost savings for stereotactic biopsy of nonpalpable breast lesions is compared with that of wire localization and subsequent surgical excisional biopsy. The average medical reimbursement for stereotaxic biopsy was $733 compared to $1626 for surgical biopsy. Dr. Liberman does note significantly that in situations when the histopathology shows small foci of DCIS or atypical hyperplasia, an additional step before surgical biopsy is added. Since both DCIS and atypical hyperplasia tend more commonly to present as calcifications, the likelihood of needing excisional surgical biopsy following stereotaxic biopsy is more common with calcifications. As a result, the adjusted cost savings are different when comparing values for calcifications and those for masses. She found an adjusted
cost savings for calcifications of $714 versus $1007 for masses. From a socioeconomic standpoint, one can also account for additional savings on a national basis with less time off from work and savings that approach $200 million annually.

18. Liberman L, Feng TL, Dershaw DD, Morris EA, Abramson AF. US-guided core breast biopsy: use and cost effectiveness. *Radiology*. 1998;208:717-723. This study compared costs based on Medicare reimbursements between ultrasound-guided and wire localization with subsequent excisional biopsy for nonpalpable breast lesions. The authors found that the cost of ultrasound-guided biopsy was $385 versus $1332 for surgical biopsy with wire localization. When accounting for some cases in which inadequate sampling occurred, the overall savings per case was $744. Interestingly, they also calculated a potential national cost savings of $59,520,000.

19. Marcy PY, Chevallier P, Grannon C, et al. Cost-benefit analysis of percutaneous interventional radiological procedures in cancer patients. *Supportive Care in Cancer*. 1999;7(5):365-367. The authors evaluated the benefit of performing certain image guided interventional procedures in a group of oncology patients. Procedures performed included percutaneous placement of ureteral stents for obstructive uropathy, IVC filter placement, and percutaneous gastrostomy tube placement. The procedures resolved the symptoms and thus improved quality of life in at least 80% of patients. The costs of the procedures were relatively small based on the cost of hospitalization (0.85-11.3%). Overall length of hospitalization was decreased. Although the authors didn't mention it, had they also compared cost of hospitalization in patients who had not undergone such palliative procedures, perhaps their data might have shown global decreases in cost secondary to markedly shorter hospital stays.

20. Morris AM, Flowers CR, Morris KT, et al. Comparing the Cost-Effectiveness of the Triple Test Score (TTS) to Traditional Methods for Evaluating Palpable Breast Masses. *Med Care* 2003; 41:962-971. The TTS (physical examination, mammography and FNA) was compared with traditional methods (physical examination, mammography, FNA, US and open biopsy) for evaluation of palpalable breast masses. The TTS was calculated by adding together component scores (each component - physical examination, mammography and FNA - received 1 for benign, 2 for suspicious/indeterminate, 3 for malignant). Previous validation showed TTS correlated with the open biopsy as follows: TTS<4 had benign histology; TTS=5 was indeterminate; TTS>6 had malignant histology. In this study, TTS and traditional methods had equal clinical effectiveness, with no missed breast cancer. Open biopsy was performed on 13% of benign masses when TTS was employed, and on 88% of benign masses when traditional methods were employed. Cost of initial work-up was more for TTS than traditional methods ($627 vs. $377), but cost per mass evaluated and cost per malignancy diagnosed were less for TTS than traditional methods ($925 vs. $1793 and $2925 vs. $5670, respectively).

21. Perone N, Bounameaux H, Perrier A. Comparison of Four Strategies for Diagnosing Deep Vein Thrombosis: A Cost-Effectiveness Analysis. *Am J Med* 2001; 110:33-40. Ultrasound (97% sensitivity, 98% specificity), plasma D-dimer level (98% sensitivity, 41% specificity), clinical probability (low, intermediate, high) and phlebography (gold standard) are used for DVT evaluation. Four clinically-validated diagnostic strategies were evaluated for their cost-effectiveness as compared with each other and the “no treatment” option. The four diagnostic strategies had similar clinical effectiveness, but significant differences in cost effectiveness: serial US was the most expensive ($1,482 per patient), followed by serial US with D-dimer ($1,425) and risk-based serial US ($1,402), and D-dimer with risk-based single US being the least expensive ($1,200, 17% incremental cost reduction compared with serial US). This cost-effectiveness order is maintained as long as US sensitivity > 90%, or D-dimer sensitivity > 91%. Overall, D-dimer with risk-based single US (i.e. D-dimer as the initial test followed by US examination only in patients with an abnormal D-dimer result; phlebography is reserved to patients with an abnormal D-dimer, normal US and high clinical probability for DVT).

22. Rao PM, Rhea JT, Novelline RA, Mostafavi AA, McCabe CJ. Effect of computed tomography of the appendix on treatment of patients and use of hospital resources. *NEJM*.
The authors evaluated 100 patients who had CT for suspected appendicitis. Fifty-three had appendicitis; 47 did not. After the cost of CT, overall savings was $447 per patient ($44,731).

23. Rhea JT, Rao PM, Novelline RA, McCabe CJ. A focused appendiceal CT technique to reduce the cost of caring for patients with clinically suspected appendicitis. AJR. 1997;169:113-118. Use of focused CT reduced both variable and total cost by $23,030 and $45,556 respectively per 100 patients. Costs were reduced through decreased number of negative laparotomies and decreased number of hospital days (cost of one negative appendectomy equals the cost of 18 appendiceal CT scans).

24. Rosen MP, Sands DZ, Longmaid HE 3rd, Reynolds KF, Wagner M, Raptopoulos V. Impact of abdominal CT on the management of patients presenting to the emergency department with acute abdominal pain. AJR. 2000;174:1391-1396. This is a review of fifty-seven patients who presented to the emergency room with acute abdominal pain of a nontraumatic origin. CT added significantly to the confidence level of the emergency room physician's diagnosis evaluated subjectively. The use of CT averted the admission of ten of 42 of these patients, approximately 24 percent. Furthermore, patient management was altered in 60 percent of patients.

25. Rosen MP, Siewert B, Sands DZ, Bromberg R, Edlow J, Raptopoulos V. Value of abdominal CT in the emergency department for patients with abdominal pain. Eur Radiol. 2003;13:418-424. Patients with abdominal pain who presented to a teaching facility were evaluated with CT when appropriate. This article demonstrated that 17% of hospitals admissions and 62% of surgeries were avoided based on the CT findings. There was also a significant benefit derived by the treating physician markedly improving their confidence level with their diagnoses.

26. Rosendahl K, Markestad T, Lie RT, Sudmann E, Geitung JT. Cost-effectiveness of alternative screening strategies for developmental dysplasia of the hip. Arch Pediatr Adolesc Med. 1995;149(6):643-648. Ultrasound screening shows economic benefit in the diagnosis of DDH, particularly because treatment of late DDH is considerably more expensive than early treatment. There were some increased costs related to higher treatment rate for infants subjected to ultrasound screening than those who were not. These costs were far outweighed by the savings for treatment of late DDH.

27. Ruckdeschel JC. Rapid cost-effective diagnosis of spinal cord compression due to cancer. Cancer Control. 1995; 2(4) 320-323. In a cost analysis of the radiological workup of cancer patients with back pain at risk for epidural compression, comparison is made between more conventional radiology assessments and the use of MRI. The conventional imaging evaluation would include plain films, bone scan and myelography (often followed by CT). The authors show a significant cost savings when imaging is routed directly to MRI, and particularly limited to the region of the location of the back pain.

28. von Schulthess GK, Steinert HC, Dummer R, et al. Cost effectiveness of whole body PET imaging in non-small cell lung cancer and malignant melanoma. Academic Radiology. 1998; 5(Suppl 2):S300-302. The authors have reviewed cost analysis of diagnostic and therapy with the value of FDG-PET scanning in directing therapies in two specific disease categories, specifically those with non-small cell lung cancer (NSCLC) and patients with melanoma. By demonstrating otherwise unsuspected distant metastases in 10% of patients with NSCLC, thoracic surgery was averted, thus significantly reducing unnecessary costs. In the patient groups with melanoma, the value of PET scanning was particularly emphasized in differentiating patients who would benefit from newer more costly therapies such as adjuvant immunochemotherapy. Patients without metastases were candidates, whereas those with FDG proven metastases would not be given this extremely expensive, but apparently effective treatment.
29. Wallace MB, Nietert PJ, Earle C, et al. An Analysis of Multiple Staging Management Strategies for Carcinoma of the Esophagus: Computed Tomography (CT), Endoscopic Ultrasound (EUS), Positron Emission Tomography (PET), and Thoracoscopy/Laparoscopy (TL). Ann Thorac Surg 2002; 74:1026-32. The cost and clinical effectiveness of staging options for esophageal cancer (CT, CT+EUS with FNA, CT+TL, CT+EUS with FNA+TL, PET+EUS with FNA, CT+PET+EUS with FNA) were compared. This model assumed that no surgical resection or further staging were performed if metastases were diagnosed. PET+EUS with FNA was more effective and slightly more expensive (by $4,158) as compared CT+EUS with FNA (the most cost effective strategy). Therefore, PET followed by EUS with FNA provides the most cost-effective strategy for preoperative staging and management of patients with esophageal carcinoma, and is preferred over the less expensive but also less effective CT and EUS with FNA alternative.

30. Wisnivesky JP, Mushlin AI, Sicherman N, et al. The Cost-Effectiveness of Low-Dose CT Screening for Lung Cancer: Preliminary Results of Baseline Screening. Chest 2003; 124:614-621. Under the current standard of care, >70% of lung malignancies are diagnosed in advanced stage (IIIA, IIIB, IV). Preliminary results from the Early Lung Cancer Action Project showed that >80% of non-small cell lung cancers detected during annual screening with low-dose CT were stage IA and smaller than 10mm in size. This study looked at the cost-effectiveness of screening high-risk patients (i.e. >60 years with >10 pack-years of cigarette smoking and no other malignancies). The following protocol was used for annual lung screening with low-dose CT: yearly low-dose lung CT; any lung nodules were re-evaluated with a HRCT; non-calcified nodules <5mm were re-evaluated at 3, 6, 12 and 24 months and classified as benign as long as no growth was detected; 6-10mm non-calcified nodules were assessed either by follow-up imaging at 3, 6, 12, 24 months or by FNA or biopsy; >11mm non-calcified or growing nodules were evaluated by FNA or biopsy. Low-dose CT screening was cost-effective as long as <50% lung lesions were benign.

31. Yin D, Baum RA, Carpenter JP, Langlotz CP, Pentecost MJ. Cost effectiveness of MR angiography in cases of limb-threatening peripheral vascular disease. Radiology. 1995;194:757-764. The authors calculated incremental "cost per quality-adjusted life year gained" using MRA with or without conventional angio. They determined the "cost effectiveness ratio" to be $25,895.