Chest Radiography in Patients With Early Stage Prostatic Carcinoma*

Effect on Treatment Planning and Cost Analysis

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Study objective: An evaluation of the impact of routine preoperative chest radiographs was retrospectively undertaken in a pilot group of 292 patients with prostatic carcinoma who were part of a prospective study of prostate specific antigen screening for prostate carcinoma.

Design: Retrospective.

Setting: Hospital-based outpatients.

Patients and participants: A cost-effectiveness model was used to assess the value of routine chest radiography in this patient population. Chest radiography findings were categorized into four groups based on follow-up and impact.

Measurements and results: Forty-three patients (15 percent) had a total of 45 positive findings on their chest radiographs. No patient had intrathoracic metastases from prostatic carcinoma. Only two patients (both with unsuspected second neoplasms) had findings that impacted on their treatment and one avoided retropubic radical prostatectomy. Total cost was $2,000 (based on Medicare reimbursement), or $14,000 (based on physician and hospital charges).

Conclusion: Although benefit is small in terms of number of patients affected, clinical impact, in the two patients with significant findings, was great. Although cost-effectiveness cannot be confirmed on the basis of this series, further evaluation of its utility for this application should be undertaken.

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Key words: cancer screening; clinical efficacy; cost analysis; prostatic neoplasms; thoracic radiography

The utility of "routine" chest radiographs, including those for hospital admission and preoperative evaluation, has been examined for several decades in many different settings.1-22 No consensus yet exists as to its effectiveness. In 1955, Loder1 reviewed 1,000 consecutive preoperative chest radiographs and concluded that the examination was valuable. He did not address cost concerns but quantified outcome in terms of frequency of findings significant to the anesthesiologist. Beginning in 1973, more frequent reports were published demonstrating that in certain patient populations the preoperative chest radiograph had limited or no utility and should be discontinued. Such recommendations have been made for pediatric patients,2-4 younger (less than 60 years of age), otherwise healthy, nonsmokers,5-6 and women undergoing preoperative assessment for gynecologic surgery for benign disease.7

Early studies of the value of chest radiography focused on risk-benefit, implying that the small risk of radiation must be balanced by a significant benefit.8,9 Many studies in the past 15 years have addressed related cost concerns,5,10-15 including the expenses related to false-positive observations.16

Results, nevertheless, differ depending on what parameters are being evaluated (quantification of findings vs significant findings vs changes in outcome), who is evaluating the findings (anesthesiologists, surgeons, internists, or radiologists), and the setting (including patient populations with high vs low prior test probability of disease.17

In 1985, Hubbell et al18 evaluated the clinical impact of "routine" admission chest examinations in a Veteran's Administration medical population and concluded that outcome was not improved. This was in contradistinction to a smaller study performed in the same institution 4 years earlier.17 The main difference between the two studies was that the study of Hubbell et al18 was limited to the evaluation of outcome change in patients with no complaints referable to the chest. Since that time, additional publications add support to their conclusion of nonutility in preoperative patient populations.19-22

Although cost concerns are raised in many of these papers, no cost-benefit or cost-effectiveness analysis was undertaken. Reasons for this include the inher-
While difficulty in assessing the impact on patient management of outcome based solely on findings from a diagnostic imaging study.

Most of these prior investigations have assessed fairly heterogeneous patient populations, and conclusions often cannot be applied to specific groups or individuals. We have undertaken a pilot evaluation of the role of “routine” preoperative chest radiographs in a population of patients with prostatic carcinoma detected in a screening program. Our intention was not merely to quantify the incidence of abnormal findings, but to attempt to ascertain their impact. In addition, a cost-effectiveness model was used to assess the value of “routine” chest radiography in this specific patient population.

Patients and Methods

Patient Population

From June 1989 through April 1992, 497 patients were diagnosed with prostatic carcinoma as part of a prospective study of prostate specific antigen (PSA) screening for prostatic carcinoma. Early results from this study already have been published. As part of their postdiagnosis/preoperative evaluation, all patients were referred for CT of the abdomen and pelvis, radionuclide bone scintigraphy, and standard chest radiography. Two hundred ninety-two patients had retrievable charts with original chest radiographs and formed the basis for our evaluation. Almost all of the remaining 205 patients had follow-up evaluations at a different institution or, much less commonly, unretrievable or incomplete charts. All patients did not have acute chest symptoms.

Radiologic Report Review

All original chest radiographic interpretations were classified into five groups. All reports were generated by board-certified radiologists. The studies, themselves, were not reviewed again, since our purpose was to investigate outcome changes and not technical efficacy. If no significant abnormality was detected, the examination was labeled as normal for purposes of this study. Reports of abnormal findings were further classified into groups as follows:

Group A. Finding with documented follow-up indicating a change in management.

Group B. Finding without follow-up which might affect management if follow-up were obtained, i.e., a possible A finding without follow-up.

Group C. Finding, which, after chart review, appeared unlikely to have affected clinical management.

Group D. Finding, which, with follow-up (including discovery of old films or other correlative studies) has proven to be benign or normal. (This group might be considered as representing false-positive results.)

Chart Review

All patients with abnormal chest radiographic reports had chart review to determine if management was altered because of such a report. When necessary and possible, a follow-up telephone call to the patient’s personal physician was used as a further source of verifying data.

Cost-Effectiveness Analysis

We used a model based on a standard definition of cost-effectiveness: measuring costs as the net input of money into a healthcare program. In our group, this was measured as follows:

\[
\text{Costs} = \text{Cost of 292 chest radiographs} + \text{Cost of follow-up imaging/analysis} - \text{Savings accrued because of diversion from planned surgery}
\]

This methodology reduces overall costs when a patient has been diverted from surgery by the costs of that surgery (minus the cost from any alternative treatment option). Effectiveness, in contradistinction, is much more difficult to quantify. We have implied effectiveness when a true-positive was identified and a definite impact on outcome was perceived.

There are four assumptions inherent in this approach: (1) Cost accounting (appendix A). (2) Patients with a life expectancy of less than 10 years are not candidates for surgery and are believed to benefit similarly or better from a nonsurgical approach (hormonal therapy, radiation therapy, or observation). This assumption, while not universally accepted, is the general consensus among physicians dealing with prostatic carcinoma. (3) Avoidance of surgery in those with limited life expectancy maintains or increases the total number of quality-adjusted life-years remaining. (4) The detection of unsuspected disease is beneficial.

When necessary and appropriate, statistical comparisons were performed with the \( x^2 \) test and Student’s \( t \) test unless otherwise indicated.

Results

Demographics and Clinical Information

The age range of the 292 patients was from 50 to 84 years, with a median and mean of 67 years. The mean PSA level for all patients was 12 ng/ml, with a SD of 15 and a median of 7 ng/ml, with a range of 2.9 to 152 ng/ml. Pathologic staging in those patients undergoing surgery or with a radionuclide scangram compatible with metastatic disease revealed 34 patients with stage A (11.6 percent), 125 patients with stage B (42.5 percent), 59 patients with stage C (20.2 percent), and 16 patients with stage D (5.5 percent). Fifty-eight patients (20 percent) have either not yet had surgery or have chosen a nonsurgical approach. Two hundred seventeen patients had a retropubic radical prostatectomy (RP) with an additional five patients having only a pelvic lymph node dissection for staging. Forty-one patients had radiation therapy and 13 patients had hormonal therapy. Ten patients have selected observation alone, and six have not yet decided on therapy.

Chest Radiographic Findings

Two hundred forty-nine (85 percent) patients had chest radiographic reports indicating no significant disease. Forty-three patients (15 percent) had positive chest radiographic interpretations with a total of 45 abnormal findings (two patients had findings fitting into two groups each). As shown in Table 1, three patients (1 percent) had group A findings. Five patients (2 percent) had group B findings. Twenty-six patients (9 percent) had group C findings. Eleven patients (4 percent) had group D findings.
Table 1—Chest Radiographic Findings*

<table>
<thead>
<tr>
<th>Group</th>
<th>Finding</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (3 patients, 1%)</td>
<td>Bronchoalveolar carcinoma</td>
<td>1</td>
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<tr>
<td></td>
<td>Lymphoma</td>
<td>1</td>
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<tr>
<td></td>
<td>Rib metastasis</td>
<td>1</td>
</tr>
<tr>
<td>B (5 patients, 1.7%)</td>
<td>Solitary pulmonary nodules</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Mediastinal widening</td>
<td>1</td>
</tr>
<tr>
<td>C (26 patients, 8.9%)</td>
<td>Cardiomegaly</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Intertstitial lung disease</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Pleural effusion or thickening</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Emphysema</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Asbestos-related pleural disease</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Coronary artery calcification</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Large left pulmonary artery</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Mediastinal adenopathy</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(known sarcoïdosis)</td>
<td></td>
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<tr>
<td>D (11 patients, 3.8%)</td>
<td>Artifactual or benign pulmonary nodules</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Lung mass (nonneoplastic)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Benign rib lesion</td>
<td>5</td>
</tr>
</tbody>
</table>

*Group A and D findings have some form of follow-up indicating their present diagnostic group. At the time of the initial radiologic report, however, primary or metastatic disease was suspected in all Group C findings add up to more than 26, since some patients had more than one finding in this category.

The mean age for all patients with abnormal (groups A through D) chest radiographs was 69.6 years, with a SD of 5.5 years. This was a statistically significant difference when compared with normal subjects, with a mean age of 66.6 years and a SD of 5.5 years (p<0.01).

Studies Required for Follow-up

These included five CT examinations of the thorax. Three patients had repeat standard chest radiographs, one with nipple markers. One patient had rib detail radiographs.

In addition to these radiologic procedures, two patients had a surgical biopsy of the ribs, and metastatic neoplasm was the suspected finding.

Follow-up

Group A Patients: The patient with bronchoalveolar cell carcinoma underwent successful lobectomy. He subsequently underwent RRP and has done well. The patient with lymphoma, asymptomatic at the time of diagnosis, was originally scheduled for RRP. He subsequently was treated with chemotherapy but expired. One patient with a presumed rib metastasis had several other abnormal areas, evidenced by radionuclide bone scintigraphy and underwent orchiectomy.

Group B Patients: Of the four patients with solitary pulmonary nodules on initial chest examination, one patient had a nodule measuring 5 mm, which was subsequently reinterpreted to be partially calcified and likely due to old granulomatous disease. The remaining three patients were older (71, 77, and 79 years of age) and had high PSA levels (10.5, 11, and 24.8 ng/ml). These patients all opted for radiation therapy. However, this decision was not influenced by the chest radiographic findings. A patient with mediastinal widening has not had radiographic follow-up, but has done well after RRP.

Group C Patients: While no finding apparently affected clinical management, it is notable that patients in this category underwent RRP 61.5 percent of the time compared with all other patients who underwent RRP 75.6 percent of the time. This difference is not statistically significant (X^2=2.4; p>0.1).

Group D Patients: Suspected pulmonary nodules in five patients were shown in comparison with old chest radiographs, CT, or follow-up to be aartificial (n=4) or stable (n=1). One patient had a suspicious-looking mass shown on chest examination which was considered a postinflammatory lesion on the chest CT. Of the five patients with rib findings suggestive of abnormality, one was found to be an osteoid osteoma after biopsy; in another, biopsy revealed no evidence of malignancy. In another, a final radiographic diagnosis of fibrous dysplasia was rendered after correlation with the radionuclide bone scintigram. Two patients had prior radiographs, indicating stability and a benign condition.

Economic Evaluation

By our estimation (Appendix A), the reimbursement for RRP including copayment from Medicare is $8,543.13. The total reimbursement (including copayment) for 292 chest radiographs would be $9,043.24 based on $30.97 per examination. The total reimbursement from Medicare associated with imaging follow-up was $1,588.92 (for five CT studies, three repeat chest radiographs, and one rib detail study). The cost incurred for the surgical biopsy of the two benign bone lesions was not included since this procedure is considered an outcome from a similarly positive bone scintigram and not the chest radiograph. The economic benefit associated with routine chest radiography in this population can be assessed as $8,543.13 based on Medicare reimbursement. This is the savings associated with avoiding RRP in the patient subsequently proven to have lymphoma. Thus, the routine use of chest radiographs preoperatively in prostatic carcinoma would cost $2,089.03. As per Appendix B, based on charges this figure would be $13,954.

"Effectiveness" Evaluation

The definable health benefit for our population
applies to two patients: one with lymphoma and one with bronchoalveolar cell carcinoma. We excluded the patient with a group A finding who had a bone metastasis detected on the chest radiograph, since this finding also was detected on a radionuclide bone scintigraph. One of the two patients avoided RRP. Since he was asymptomatic at presentation, it is assumed that had widening of the mediastinum (subsequently proven to be due to lymphoma) not been detected this patient would have undergone a RRP and potentially suffered unnecessary morbidity and mortality. The other benefit to these patients is in the earlier detection of potentially (and proven in one patient) lethal disease processes.

In analyzing the remaining abnormal chest radiographic interpretations from our series, no direct benefit could be ascertained.

**Economic “Cost” of Work-up of False-Positive**

If studies performed for true-positive findings are excluded, then radiologic follow-up included three thoracic CT examinations and three repeat chest radiographic examinations. The Medicare reimbursements associated with this false-positive workup would be $969.33, which represents 9.1 percent of the total cost of the program.

**DISCUSSION**

Medicare patients accounted for 31.3 million chest radiographs in 1990, including 17.1 million 2-view examinations. Using an average reimbursement of approximately $30/study, approximately $1 billion is spent by Medicare, alone, on this examination on an annual basis. Over 100,000 patients will be diagnosed with prostatic carcinoma during the coming year in the United States. With rare exception, most patients will have chest radiography performed either as part of staging or as a preoperative examination. Although the accepted practice in the United States is to obtain a chest radiograph before surgery in most adult patients, the literature and the health services of some countries would oppose such a practice.

Previous reports have shown “value” for the chest radiograph in the evaluation of patients with advanced prostatic carcinoma, ie, stage D. In the series by Apple et al, 35 percent of patients with stage D disease had visible intrathoracic abnormalities, but only 24 percent of patients had abnormalities attributable to intrathoracic metastases. They did not evaluate the impact of their findings but imply that the sheer prevalence indicates value. Lindell et al reported a 5.2 percent incidence of intrathoracic metastases in 1,435 patients evaluated at initial presentation. No patients had intrathoracic metastases in our series, a not unexpected result since all of our patients were part of a screening study, with even the stage D patients having only limited metastatic disease.

We have quantified findings in a relatively homogeneous patient population and have shown, like others before, that routine chest radiography has a relatively low yield in the asymptomatic patient. Only 43 of 292 patients (15 percent) had positive chest radiographic findings. Two of these patients had findings that impacted on the management of the disease and treatment. A patient with bronchoalveolar cell carcinoma underwent successful lobectomy and subsequent RRP. A patient with lymphoma was diverted from a RRP with its accompanying morbidity and cost. Although not unexpected, we have observed that abnormal chest radiographs, occur significantly more frequently with advancing age.

From a strict cost analysis, our program (the use of chest radiographs preoperatively in prostate carcinoma) would cost approximately $2,000 (based on Medicare reimbursement) to $14,000 (based on charges). We have purposely chosen low-cost numbers for the surgical costs and high-cost numbers for the radiologic studies to strengthen any potential claim to cost-effectiveness of the chest radiograph. If it were required that a program be cost-saving in order to be cost-effective, then we could not conclude from our initial assessment that the preoperative chest radiograph is cost-effective. As emphasized earlier, effectiveness is difficult to quantify. Given the morbidity (as well as cost) associated with RRP, one could argue that the impact of any positive radiograph is significant. Even in our small series, it is clear that a significant health benefit is definable, though applicable to only two patients.

In addition, it is important to recognize that not all abnormal chest radiographic findings will be followed up. Patients in our study had findings, such as pulmonary nodules, that potentially could have affected management. Referring clinicians incorporate other factors, such as age, history, and patient preference into their decision to evaluate these findings. It is impossible to assess the cost-effectiveness or even clinical impact of these radiographic findings (group B and C) because of the retrospective nature of our study. Conceivably these findings may have impacted in some way on a decision to divert a patient from surgery, and our assessment may be underestimating the impact of the chest radiograph.

Another potential benefit associated with the use of the preoperative chest radiograph is its utility as a baseline in patients who develop postoperative complications; economic impact and possibly its medical benefit is unmeasurable.

Although we have only reviewed the findings in 59 percent (292 of 497 patients) enrolled in the original
study, we do not believe this represents a significant source of bias. The vast majority of patients without follow-up were patients who chose to follow-up their prostatic carcinoma diagnosis at a different institution. There is no indication that this group should be different from our study group.

In conclusion, we have investigated the value of the preoperative chest radiograph in patients with prostatic carcinoma diagnosed as part of a screening study, who could be expected to have a low incidence of advanced disease. Such was the case according to the final staging. In our study, the chest radiograph had no impact on final prostatic carcinoma staging, and its only potential value would be as part of preoperative planning and management. Our findings suggest that a small (in terms of number of patients) but significant benefit (detection of asymptomatic comorbid disease and avoidance of unnecessary surgery) was achieved at a cost in the range of $2,000 to $14,000. Because of the limited size of our sample and the difficulty in assessing benefit, retrospectively, we cannot conclude that the preoperative chest radiograph is cost-effective. In addition, the limited size of our sample limits the ability to determine other predictors of comorbid disease. We suggest that our results warrant a larger prospective study of the value of preoperative chest radiography in this era of health care reform.

ACKNOWLEDGMENTS: We gratefully acknowledge the Division of Urology, Washington University School of Medicine and specifically Dr. W. J. Catalona, for support and assistance in this project.

APPENDIX A

Cost Accounting: We have chosen a societal approach for this model\(^1\) to account for costs with charges and Medicare reimbursements. Although only 60 percent of our patients were eligible for Medicare reimbursement, we used this schedule, since it represents the low end of the reimbursement schedule and is nationally standardized. There are obvious limitations. Medicare reimbursement likely underestimates true cost, whereas in an attempt to recoup costs from uninsured and underinsured patients, hospital charges overestimate costs. We tested this model with both in mind and realize that the true solution lies between these extremes. For purposes of clarity, we have focused on the figures for Medicare in the text of this paper and included an evaluation with charges in Appendix B.

We have obtained all figures listed later from the various departments at Barnes Hospital. Medicare reimbursements are similarly listed and include the 20 percent copayment whenever applicable. To strengthen any claim to cost-effectiveness, we have chosen low-cost numbers for the surgical side of the equation and high-cost numbers for the radiologic side whenever ranges were submitted. Also, additional charges to the surgical side, including consultants’ fees, home nursing care, and postoperative complication management, have been disregarded for the purpose of this evaluation.

Charges and Reimbursements Associated With an RRP at Barnes Hospital, St. Louis

<table>
<thead>
<tr>
<th>Component</th>
<th>Charge</th>
<th>Medicare Reimbursement</th>
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<tbody>
<tr>
<td>Surgery</td>
<td>$4,264</td>
<td>$2,201.24</td>
</tr>
<tr>
<td>Anesthesiology</td>
<td>$990</td>
<td>$278.93</td>
</tr>
<tr>
<td>Hospital (including operating room time)</td>
<td>$19,655</td>
<td>$5,980.41</td>
</tr>
<tr>
<td>Pathology</td>
<td>$137</td>
<td>$82.55</td>
</tr>
<tr>
<td>Total</td>
<td>$19,046</td>
<td>$8,543.13</td>
</tr>
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</table>

Charges and Reimbursements Associated With Radiologic Procedures Used in This Paper

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Charge</th>
<th>Medicare Reimbursement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest radiograph (2 views)</td>
<td>$102</td>
<td>$30.97</td>
</tr>
<tr>
<td>Chest CT with intravenous injection of contrast material</td>
<td>$503</td>
<td>$292.14</td>
</tr>
<tr>
<td>Rib detail, unilateral</td>
<td>$95</td>
<td>$35.31</td>
</tr>
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APPENDIX B

Applying the same model used in our paper and applying it to charges instead of Medicare reimbursements yields the following. The cost of the imaging workup would be $33,000 as noted. The surgical savings would be $19,046. The total cost of the program, then, would be $13,954.

REFERENCES

13 Tornebrandt K, Fletcher R. Pre-operative chest x-rays in elderly patients. Anaesthesia 1982; 37:901-02
16 Tape TG, Mushlin Al. The utility of routine chest radiographs. Ann Intern Med 1986; 104:663-70
20 Tape TG, Mushlin Al. How useful are routine chest x-rays of pre-operative patients at risk for postoperative chest disease? J Gen Intern Med 1988; 3:15-20
25 Data from Part B, Medicare Annual data, 1990. Baltimore: Health Financing Administration
27 Racoveanu NT. A rational approach to diagnostic radiology. WHO Chron 1983; 37:140-42