3 .
Chest X-Ray

3. Chest X-Ray

UTILIZATION, COSTS, AND CONTROVERSIES

In 1970, approximately 48 million radiographic X-ray examinations of the chest were performed, accounting for almost one-half of the total volume of X-ray examinations in the United States. About 64 percent of these chest X-ray examinations were performed in hospitals; the rest were performed in private offices or groups, or in health agencies (31). Though there are no available data listing indications for chest X-rays in various settings, the common practice of routine chest X-ray on admission to hospitals or prior to surgery is likely to contribute substantially to the use of chest X-ray, (In 1977, there were approximately 34 million admissions to short-term hospitals in the United States.) In many hospital emergency rooms and outpatient departments, chest X-rays are performed routinely if a complaint refers to the chest in any way (10,76),

Although the volume of procedures is high, chest X-rays accounted for less than one-third of the total films used in 1970, owing to a below-average number of films per examination. The mean number of films used per chest examination was 1.7, whereas the average for all body areas is 2.4 films per examination. As with all procedures using ionizing radiation, the chest X-ray subjects the patient to radiation exposure.

The biological effect of radiation is expressed in "rads," i.e., the amount of energy absorbed at particular points in the body, such as the bone marrow, thyroid, and gonads. All of these points are associated with different effects, such as leukemia, malignant tumors, possible impairment of fertility, or genetic effects (28). The median gonad dose to males and females from diagnostic chest radiographs is very small, less than 0.5 millirad per exam. Photofluorographic chest exams to females have a median gonadal dose of 1 millirad per exam, also a low dosage, The bone marrow dose produced by chest radiographs is relatively low too, at about 10 millirads per exam (28). The radiation exposure on each chest film is also relatively low. On average, the radiograph exposed the patient to 47 millirads compared to an average exposure of 310 millirads for skull films and 70 millirads for forearm films. Thus, although the volume of chest examinations is high relative to other X-ray procedures, the total dose to which the population was exposed represented a much lower proportion of the total dose exposure from all medical X-rays.

Chest X-rays are also inexpensive relative to other diagnostic X-ray procedures. In a 1975 sample of physician charges for X-ray procedures in California, the average bill for a two-view chest X-ray was $25.15, compared, for example, to $47.40 for a complete skull examination (121).

Information on the setting in which chest X-rays are performed is scanty, but some limited evidence based on California medicaid claims data is available. All medicaid claims submitted by physicians in the first quarter of 1978 were compiled for specific chest X-ray procedures. The claims indicate the location of service and specialty of the physician performing the service. Tables 3 and 4 show the distribution of chest X-ray claims submitted by physicians and radiologists in California, Although these data do not include all such procedures performed (i. e, X-ray procedures performed in hospitals which bill directly for both technical and professional charges are not included), they do show the relative importance of simple v. more complicated chest X-ray procedures. Notice that two-view chest X-rays are much more common relative to single-view examinations in the ambulatory care setting than in the inpatient setting (table 3). This may result from the frequent use of portable X-ray equipment on critically ill patients in hospitals where it is technically infeasible to obtain more than one view.

Table 3.—Medicaid Chest X-Ray Claims in California Submitted by Physicians in First Quarter of 1978, by Location of Service

	Inpatient[a]	Outpatient[a]	Office	Other	Total
71010 Chest: single view.	12,605 (38.4°/0)	3,183 (1 2.4%)	13,230 (12,1 0/~)	3,456 (22.900/.)	*32,474 (17.8%)*
71020 Chest: two views.	19,753 (60.20/.)	22,295 (86.6%)	95,037 (86.90/.)	11,639 (77.10°/0)	*148,724 (81 .7°/0)*
71021 Chest: three views.	207 (00.6%)	129 (00.5°/0)	262 (00.2%)	2 (00.01%)	*600 (00.3%)*
71030 Chest: complete (minimum of four views).	255 (00.8°/0)	123 (00.5°/0)	789 (00.7°/0)	—	151 (00.1 °/0)
Total	32,820	25,730	109,318	15,097	181,949

[a]Recorded only when hospital and physician bill separately for the service (split billing arrangement)

SOURCE Urban Institute sample of 5,000 solo practitioners, including 177 radiologists

Table 4.—Medicaid Chest X-Ray Claims in California Submitted by Radiologists in First Quarter of 1978, by Location of Service

	Inpatient[a]	Out patienta	Office	Other	Total
71010 Chest: single view.	11,836 (39.5°/0)	3,127 (12.4°/0)	1,371 (04.20/o)	34 (03.70%)	16,503 (18.30/o)
71020 Chest: two views.	17,695 (59.O%)	21,944 (86.7%)	31,005 (94.4°/0)	878 (95.00°/0)	72,594 (80.4%)
71021 Chest: three views.	204 (00.7%)	126 (00.5%)	168 (00.5%)	1 (00.01 °/0)	499 (00.6%)
71030 Chest: complete (minimum of four views).	249 (00.8°/0)	121 (00.50/0)	288 (00.970)	11 (01.2070)	675 (00.7°/0)
Total	29,984	25,318	32,832	924	90,271

[a]Recorded only when hospital and physician bill separately for the service (split billing arrangement)

SOURCE Urban Institute sample of 177 solo radiologists (326 percent of solo radiologists in Call fornia)

Virtually all medicaid chest X-ray examinations in California hospitals in 1978 were performed by radiologists. Other kinds of physicians played a more important role in performing chest X-rays in physicians' offices. About 70 percent of all medicaid chest X-rays in physicians' offices were performed by nonradiologists.

As expected, radiologists tend to perform more intensive chest X-ray examinations than do other kinds of physicians. Only 4 percent of chest X-rays performed by radiologists in their offices were for single-film examinations, while 15 percent of chest X-rays performed by other physicians were single-film procedures.

The high volume of chest X-ray procedures is due in large part to its importance as a screening test. Chest X-rays have been used to screen for cardiopulmonary disease in the general population and in selected high-risk groups. They have also been advocated for use in healthly populations as a baseline measure for evaluation of future radiographs (14,42). Chest X-ray screening has most frequently been advocated for detection of tuberculosis (TB), lung cancer, and cardiovascular disease. Its use has been encouraged by hospital and nursing home policies which have dictated routine admission or preoperative chest radiographs, by laws or regulations which have required chest X-rays of workers in high-risk occupations, by colleges and summer camps which have required prematriculation chest X-rays, and by public health agencies which have made chest X-ray examinations available to selected high-risk groups and sometimes to the public at large. These screening uses have had pervasive effects on the American public. Over 80 percent of all noninstitutionalized Americans over 17 years of age in 1973 had had at least one chest X-ray procedure. Thirty-one percent had received the examination in the previous year (29). There is no source of data, recent or old, on the proportion of chest X-ray examinations performed for screening purposes. However, the Bureau of Radiological Health reported that in 1.970, about 20 percent of all radiologic examinations of the thorax were conducted at health agencies. * It may be assumed

*About 9 percent of these chest X-ray examinations were photofluorograms, a procedure whose appropriateness relative to the radiograph has been questioned (31).

that the vast majority of these examinations were performed for screening purposes. Since a large but unknown proportion of the chest X-rays performed at other locations such as hospitals and physicians' offices are also for screening purposes, the contribution of screening to total chest X-ray volume in 1970 is likely to have been well above 20 percent.

The popularity of chest X-ray as a screening procedure has declined in the past decade, partly in response to the secular decline in the prevalence of TB, one major target of chest X-ray screening programs (102, 115). The change in attitudes about the appropriate place of chest X-rays is also a result of the myriad research studies documenting low diagnostic yield and high case-finding costs of many chest X-ray screening programs, even those targeted at high-risk groups. In the 1970's, public and quasi-public bodies issued recommendations reversing policies toward chest X-ray screening programs; these recommendations have rested on the studies of diagnostic yield in various populations (27,94), Today, the literature on chest X-ray screening for TB appears to be focused on workers in foodhandling occupations (18,108) and on high-prevalence groups, such as refugees from Southeast Asia, where a very high proportion would be expected to react positively to the tuberculin skin test due to high levels of exposure to the tuberclin bacillus **(31,67).** Nevertheless, selective screening programs using chest X-rays still exist. For example, all immigrants are required to have chest X-rays, and in many States, teachers', hairdressers', nurses', and other health professionals' X-ray screening programs continue. Currently, there is much debate over whether the X-ray should be used to screen high-risk groups for lung cancer (4,44).

Although most of the controversy over the chest X-ray examination has centered on its use on asymptomatic people, there has been some concern about the use of chest X-ray in diagnostic contexts. In particular, the frequency of radiographic followup of patients with cardiopulmonary disease has been raised as an issue in the evaluative literature. How often, for example, should a patient hospitalized for pneumonia be subjected to a chest X-ray, both during the hospital stay and after discharge? Hospital policy or medical practice may dictate too frequent followup examinations, * thus subjecting the patient to unnecessary radiation and medical costs.

There is also substantial question about appropriate radiological methods, Some of these issues are the number of views (hence, films) needed, the appropriateness of photofluorography radiography, the necessary level of expertise or credentials of the reader, and the optimal number of readers. Clinical studies have compared the additional diagnostic yield obtained from the two-view chest examination with that obtained from the single-view procedure (105). Other studies have assessed the diagnostic efficiency of alternative reader and equipment configurations (60).

Aside from these questions of appropriate radiological method, evaluation of the usefulness of the chest X-ray in symptomatic patients has been limited. To our knowledge, there have been no attempts to evaluate diagnostic efficiency or outcomes of chest X-rays in patients with particular kinds of signs or symptoms; only one study of high-yield criteria for ordering chest films has been attempted to date (10).

*It is possible that medical practices dictate too few followup examinations and thereby subject the patient to poorer expected health outcomes. Problems in the direction of too few radiographs do not appear to hold much attention in the literature.

CHEST X-RAY EVALUATIONS

This section summarizes the most prominent evaluation studies of the chest X-ray in the last 10 years, The purpose of this review is not only to document the evidence available to support

decisions about the use of chest X-rays, but also to identify and assess the importance of methodological problems inherent in the literature.

The review is organized into these general categories: 1) studies of chest X-ray as a screening device, 2) studies of diagnostic uses of chest X-ray, and 3) studies of radiological method. Because the screening literature is large, it has been further divided into studies of community-based chest X-ray screening for TB, community-based screening for lung cancer, and X-ray screening for cardiopulmonary problems in selected patient populations.

Studies of Community-Based TB Screening Programs

The use of the chest X-ray as a mass screening tool for the detection of tuberculosis was common in public health departments in the 1940's and 1950's. As information accumulated on the low diagnostic yield of chest X-rays, however, the cost effectiveness of these programs was increasingly questioned (62,73,113). Table 5 summarizes the findings of studies published in the early 1970's on the usefulness of chest X-ray screening for TB. Virtually all of these studies used diagnostic yield as the principal evaluative criterion. The diagnostic yield of TB cases is calculated from a series of chest X-rays on large numbers of individuals. In those with neither symptoms nor high-risk factors such as alcohol abuse, the TB yield was found to be universally below 0.5 percent. Targeting screening programs to high-risk locales did not raise the yield.

The observed diagnostic yield of a test varies directly with the prevalence of the disease in the population studied. As disease prevalence decreases, diagnostic yield will decrease and case-finding costs will rise. After definitive antibiotic therapy for TB became available in the United States, the mass chest X-ray programs experienced rapidly decreasing yields.

The use of diagnostic yield or case-finding cost as a criterion for evaluating a screening program requires an implicit assumption about the implications of finding a case. If, for example, it is concluded that a screening program with a diagnostic yield of 1 percent is unjustified, one must assume that the benefits to the 1 percent of cases found do not outweigh the cost of the screening program. In the case of TB screening, the rarely expressed assumption is that TB discovered in its early symptomatic stages is curable and that the risks of disease communication by undetected active cases do not warrant the cost and radiological risk of the screening pro-

Table 5.—Screening for Tuberculosis

Study[a]	Year(s) of data collection	Population description	Number of cases	Sample	TB yield	Case-finding cost	Comments
Lewis (73)	1969	Ghetto population	109,000	Cleveland mobile X-ray mass screening program for TB	0.01%		This O .01% was 5% of the new cases reported that year
Swallow and Sbarbaro (113)	1965-70	General urban population (Denver)	—	All TB screening and case- finding pro. grams in Denver for 5 years are retro. spectively analyzed	a) Detected O 010, of new active disease b) Inactive TB detected in O.3% of people X-rayed c) Other abnormal conditions found at rate of 3 3° ,	$8,115 $ 372 $ 35	Only 13.5% of new active cases is found by screening
Retchman (102)	1970	General urban population (New York City)	283,000	–	0 02",		
Felngold (39)	1972-75	Primarily elderly and chronically Ill outpatients	48,000	Over 3 years, cases taken from the general medical out patient Clinic of an urban hospital	0.05%	$4091	50% of the new cases were in alcohol abusers
Horwttz and Darrow (62)	1972	Danish adults	677,800	Those appearing in Danish chest clinic for mass screening	o 02" o		Symptomatic patients examined by chest X ray in same clinic had TB yield of O 3° ,

[a]Numbersin parentheses refer to references in the list that appears at the end of this background paper

gram. If TB were incurable once it reached the clinical stage but completely curable in the preclinical stage, a different consensus might be reached about the minimum level of diagnostic yield required to justify a screening program,

The reliance on diagnostic yield as a criterion for evaluating chest X-ray screening programs is curious, especially in light of the exampIes of good outcome-oriented evaluations of other screening and preventive technologies that are available in the literature (23,96,109). The development of a cost-benefit evacuative framework for analyzing the value of chest X-ray screening programs in populations with varying TB prevalence rates would be useful in resolving issues that are likely to continue to arise as new high-risk groups are identified.

Public health agencies and professional societies and associations have been influenced by the studies of diagnostic yield. In 1972, the Department of Health, Education, and Welfare issued a policy statement recommending against chest X-ray screening programs in the general population and in favor of limiting its use as a screening tool to adults in selected high prevalence populations. In other groups, the chest X-ray would be a followup procedure to positive reactions on tuberculin skin tests (27). This statement superseded a department policy dating back to 1958, which endorsed community-based chest X-ray screening programs, particularly when targeted to high-risk groups. Prior to the **1972 statement,** the **National** Tuberculosis and Respiratory Disease Association, the American College of Chest Physicians, and the American College of Radiology had issued similar statements against mass chest X-ray screening programs.

Lung Cancer Screening

The question of whether periodic chest X-ray screening for lung cancer is useful in high-risk groups (generally comprising smokers over **40** years of age) has been analyzed by evaluative criteria that differ markedly from those used to analyze TB screening. Research on lung cancer screening has gone beyond calculation of diagnostic yield to consider the net effect of periodic screening on 2-, 3-, and 5-year survival rates and in some cases mortality rates from lung cancer,

This emphasis on final outcomes of the disease process results from the lack of a viable therapy for almost all but the earliest localized lung cancers. For these, resection (removal) of the diseased lung offers the only hope of cure. To be effective, then, a screening strategy must be able to detect cancers while they are still localized. To the extent that periodic screening does, indeed, uncover localized lung cancers, it is a life-saving measure, At present, however, the evacuation and staging of lung cancers is imprecise, and the ultimate proof of cure comes only with time. Thus, diagnostic yield, or even the yield of apparently respectable cancers, is inadequate. Most investigators have compared 5-year lung cancer survival rates in screened and unscreened populations,

Lung cancer screening programs vary in their particulars, The testing protocols of some programs have involved a chest X-ray only, while others have included sputum. The frequency of screening has also varied. Annual, semiannual, and even more frequent examinations have been offered to participants,

Table 6 summarizes the results of the principal studies of lung cancer screening in the past 15 years. Randomized lung cancer screening studies are ongoing in three institutions— the Mayo Clinic, Memorial Sloan Kettering, and The Johns Hopkins University–as part of an evaluation of lung cancer detection methods sponsored by the National Cancer Institute (see table 6). The final results of these studies are not yet available.

The studies of lung cancer screening presented in table 6 are difficult to compare because of the different time periods covered, screening protocols undertaken, and biases inherent in their design. Most studies have not been randomized, leaving open the possibility that participant self-selection may have distorted the results. It is also difficult to interpret the 2- or 5-year survival rate when survival is **counted** from the time of disease detection. Screened groups may be expected to have higher survival rates simply because their disease is detected earlier, independent of the effect of surgery. Although the measured

Table 6.—Screening for Lung Cancer

Study[a]	Year(s) of data collection	Patient description	Number of cases	Patient sample selection	Yield	Screening cost per cure	Outcome/overall mortality
Boucot (15)	1951-61	Men, 45 years and older	6,136	Prospective study of asymptomatic male volunteers in biannual screening over 1O-year period.	**2%** (excluding results of Initial tests)	$83,000	80/0 of detected cases survived 5 years
Gilbertsen and Lillehei (50}	1950-69	Adults, 45 years and older	13,000	Prospective study of asymptomatic adults in routine annual screening program at University Medical Center	0 080/0	—	10% of detected cases had 5-year survival
Brett (16)	1965-68	Men, 40 years and older, in British factories	29,723	Over 3 years. Test group was given semiannual X-rays	0.3% (excluding results of Initial tests)		15% had a 5-year survival rate
				Control group radio. graphed at beginning and end of study	O.3% (excluding results of Initial tests)		**6%** had a 5-year survival rate
Gryzbowski and Coy (53)	1969	Men-over 40, smokers, and one additional risk factor	2,112	Screening in Vancouver by X-ray and sputum cytology	0. 47% (found by X-ray)	—	
Lilienfeld (74)	1958-61	Residents of Veterans Adminis. tration Domicil. iaries, who were at high risk of developing lung cancer	14,607	Residents were screened approximately every 6 months for 3 years, by chest X-ray and/or sputum cytology	0.01%	$1.000 for-a workup on a SUSPICIOUS X-ray	**12%** 3-year survival rate in respectable cases. 13°/0 of the diagnosed cases were respectable
Borrie (14)	1976			Tokyo Health Control Center One year	11 per 100,000 (0 01 %) for patients over 60 105 per 100,000 (1%)		
Stitik and Tockman (1 12)	1973-78	Men, ever 65 years old, smoke a pack of cigarettes per day or more	10,362	'Randomized clinical trial, volunteers selected from Maryland records Control group IS given annual chest X-rays (4 views). Study group IS given annual chest X-rays and sputum cytology every 4 months	1.1'/. "suspected cancer. 0.3% confirmed cancer (results of Initial screening)		
Fontana (43) (and as reported by American Cancer Society)	1971-76	Men, 45 years and older, who smoked one or more packs of cigarettes a day	11,000	Randomized clinical trial—control group is offered an annual chest X-ray. Study group IS screened with sputum cytology and chest X-rays every 4 months	—	—	
Melamed, et al (88)	1971-76	Men, over 40 cigarette smokers, at a high risk	6,612	Randomized clinical trial—control group 3,387 men given annual chest X-ray	O.03% early cancer	—	
				Study group 3,325 men given annual chest X-ray and sputum cytology every 4 months	0.03% early cancer found by X ray		
Dales, et al (22)	1964-75	Men and women aged 35 to 54 at beginning of study, residents of San Francisco Bay Area and members for > 2 years of Kaiser Foundation Health Plan	10,713	Study group of 5,156 members urged to take annual multiphasic health checkups (including chest X-ray) Control group of 5,557 members not so urged	–	Savings of over $2,100 per study group, men 45 to 54 years of age No net savings associated with younger men or women	Death rate per 1,000 for 11 year study period due to cancer of bronchus and lung, Control 47 Study 49

[a]Numbers in parentheses refer to references in the list that appear at the end of this background PaPer

survival rates can be corrected for this "leadtime bias" (125), the lung cancer mortality rate is a more appropriate outcome measure. The ongoing randomized studies are expected to measure the impact of their screening protocols on lung cancer mortality.

Recognizing these limitations, the findings to date do not support the notion that X-ray screening programs have a favorable impact on lung cancer survival. In a recent study of the issue, the American Cancer Society (ACS) reached the same conclusion (4). In addition to the results reported in table 6, the authors of that study had access to some preliminary results of the Mayo Clinic lung cancer study which showed no difference in mortality rates between screened and unscreened populations. The ACS study emphasized the long and costly search for cancer sometimes initiated by cost, morbidity, and time needed to localize a tumor when the sputum cytology is positive or suspicious and the chest X-ray is negative. In the absence of evidence suggesting beneficial effects on mortality, these problems of followup and the cost of screening led ACS to recommend against periodic screening.

The ACS action has been controversial. The principal investigators of the Mayo Clinic study have argued that the recommendation was premature because it used preliminary results (44), More recent data may indeed show improvement in mortality rates (90), Moreover, according to the investigators in the lung cancer detection study, the need for long and costly followup is a relatively rare event. *

While all parties to the debate agree that mass lung cancer screening programs are not justified by the evidence available at this time, there is sharp disagreement as to how the physician should advise the individual patient seeking a physical examination. The ACS board believes that physicians should discourage periodic lung cancer detection procedures, because their benefits have not been demonstrated, while their costs are high. Other-s believe that since screening is the only possibility for detecting lung cancer early, cost should not be considered in the individual decision (44).

To some extent, the issue can be resolved by considering who pays for the screening examination. If the patient is fully and fairly informed about the evidence on benefits and risks and is prepared to pay for the procedure out-of-pocket, then by definition the procedure is worth its costs to that patient. If, however, the screening test is covered by third-party payers such as public or private insurers, the issue of physician responsibility is, or at least should be, more complex. Since the patient is subsidized, the patient may demand a test for which he or she would not otherwise be willing to pay. To the extent that the ACS interpretation of the benefits, risks, and costs of lung cancer screening is accurate, promulgation of this information and its recommendations is a valuable service to both patients and third-party payers.

Studies of Chest X-Ray Screening of Selected Patient Populations

The use of chest X-ray as a routine screening test for cardiopulmonary abnormalities in patients with unrelated complaints has been studied many times. Table 7 presents summaries of the most important studes. Diagnostic yield and case-finding cost appear to be the most widely used criteria for evaluating these uses of the chest X-ray, but *many* studies differentiate between the total yield and the yield of clinically significant findings.

In studies of routine hospital admission and preoperative X-rays, the diagnostic yield differed widely with age of patient (105), but, even within particular age groups, the variation in diagnostic yield from study to study is high. For example, one study of admission chest X-ray yield from study to study is high. For example, one study of admission chest X-ray yield in a geriatric hospital reported 2 percent abnormalities (56), while another detected abnormalities in 16 percent of patients over 40 years of age (105). Such variation may be due to differences in patient case mix, reader definition of abnormality, radiological method, or reader competence.

*It is estimated by Robert Fontana M.D., of the Mayo Clinic, that only 15 percent of positive sputum findings are accompanied by negative chest X-rays (personal communication).

Table 7.—Chest X-Rays for Selected Patient Populations

Study[a]	Year(s) of data collection	Population description	Number of cases	Patient sample selection	Yield (as a percent of N)	Other measures of efficacy effectiveness: Case finding cost	Other measures of efficacy effectiveness: Effect on patient management	Comments
Feingold (39)	1972	Routine hospital admission chest X-ray	39,017	Hospital admissions for the year	2 cases (insignificant percentage)			
Sagel. et al (105)	October 1973 to March 1974	Hospital admis sions and preoperative pa tients	10,597 a) 6,063 521 3,689 b) 1,996 C) 2,538	Prospective study of chest X-ray taken over a 6-month period, in three categories, a) Routine under 20 years over 40 years b) Possible chest abnormality c) Suspected chest abnor mantles	(For serious" abnormalities) a) 16% 0" o 26° O b) 34° o C) 69%		Effect not measured — Four surgical cases were postponed but the effect 'on the ma jority of cases IS unknown	
Hammar (56)	1954-69	Hospital admissions in a predominantly geriatric hospital population	36,475	A retrospective review of hospital admission records at a Minnesota hospital	2% abnormalities detected O 08°, new cases TB		Delayed surgery (in 0.04%	
Bartha and Nugent (8)	1974	Adults with hypertension	102	All patients entering clinic over a year's time with hypertension and having a roentgenogram	24%	$106 (estimated at $25 per examination)	No Influence on hypertension management	
Steel, et al (111)	1974	Gertatric patients	195	Seen in clinic for placement and evaluation	Abnormalities of aorta 11 20/0 Of heart and lungs 61%		–	
Pollen, et al (20)	1969	Members of a San Francisco health maintenance organization	44,663	These multiphasic examinations were performed during a 12 month period	7.4% under 40 21 "o, over 60 19 2"o	$ 6.20b $21.90 $2.40	–	b
Sane, et al (106)	November 1974 to June 1975.	Children (to 19 years), preoperative	1,500	A prospective study Of 1,500 consecutive pre operative children	7 4°, with abnormalities: 4.7% unsuspected significant abnormalities	**$316** per Significant finding (estimated at $15 per examination}	3 8°. postponed or changed surgical strategy	–
Brill, et al (17)	—	Children up to 18 years old in low income area	1,000	Consecutive inpatients and outpatients in pediatric clinic as part of screening program—excludes patients with positive TB tests or known chest abnormal {ties	6%: 4% were minor skeletal abnormalities	–	No medical or surgical treatment rendered	
Farnsworth, et al (38)	–	Children 15 months to 14 years, entering elective surgery	350	Routine preoperative chest roentgenograms reviewed retrospectively Chosen chronologically, they ex eluded cases of thoracic surgery, chest disorders and major trauma	880,0		Surgery never cancel led, preoperative diagnosis never changed	—
Royal College of Radiologists (103)	1977	Patients in nonacute, noncardiopulmonary surgery	10,619	8 British hospitals participated in the prospective study of chest X-ray	NA		No effect on patient management	—
Loder (75)	1977	British inpatients.	1,000	Over a 2 month period, preoperative patients	Over 30 11. 5% Under 30 1 .14%	–	Frequent changes in management of older patients	—

Table 7.—Chest X-Rays for Selected Patient Populations—Continued

Study[a]	Year(s) of data collection	Population description	Number of cases	Patient sample selection	Yield (as a percent of N)	Other measures of efficacy effectiveness: Case finding cost	Other measures of efficacy effectiveness: Effect on patient management	Comments
Petterson and Janouver (98)	1976	Middle class hospital population	1 530	All preoperative patients	—	$15,000 per postponed surgery	Postponed surgery in 2 cases	—
Rees, et al. (101)	1976	Preoperative patients electing non cardiopulmonary surgery in males	667	Radiography performed on consecutive preoperative noncardiopulmonary surgery	<30 years of age number appreciable abnormality	–	–	38% had chest X ray in previous year
Bone brake et al. (1 1)	1966-75	Pregnant women given prenatal chest roentgenograms	11,725	Retrospective review of all available delivery records at Mayo Clinic	O .6%	$.2,773 (estimated at $1750 per examination)	No beneficial change In patient management	–
Mattox (87)	1972	Pregnant women given prenatal chest X ray	1,239	Retrospective review of patient records at Unversity Medical Center	1 3°, (significant abnormal findings)	$1,176 (approximately)	–	All findings would have been discovered without X rays except 1 benign nonin fectious case of T B — case cost approximately **$20000** to find
Schneider and Dykan (108)	1977	Sample of job candidates in New York City hospital	3500	Chest X-rays were given to 14% of this sample— those over 40 with a positive TB skin test	O	–	–	
Brubaker (18)	1971	Job applicants in food manufacturing plants were given routine physicals	29	During the year 842 applicants were given physical examinations 29 chest X rays resulted	14°, (4 findings out of 29 examinations)	$72		–

aNumbers in parentheses refer to references in the list that appears at the end of this background paper
bCost of X-ray examination did not include overhead

Frequently, the studies of chest X-rays in hospital medical or surgical inpatients have reported on the proportion of cases in which the chest X-ray changed patient management. With the exception of two studies, one on chest X-rays in children prior to surgery **(106)** and one on inpatients in a British hospital (7.5), the chest X-ray appears to have negligible effects on plans for surgery *or* other aspects of patient management.

A study by Sane, et al. (106) of preoperative chest X-rays in children highlights the difficulty of drawing conclusions for medical practice from studies of diagnostic yield. In the study, 4.7 percent of all chest X-ray examinations showed previously unsuspected, clinically significant abnormalities. The cost of detecting each abnormality was estimated at $316. * The authors concluded that this "low" case-finding cost justifies the use of the preoperative chest X-ray. In a comment on the study, Neuhauser laid out the kinds of information on subsequent benefits and costs that would be needed to make such a judgment with confidence (95). One would need to know how the detection of abnormalities translates not only into changes in patient management but also into ultimate patient outcomes. Even when the yield is so low as to be negligible, the diagnostic yield alone is insufficient. For example, in a recent smaller study of pediatric preoperative chest *X-rays, only* 1 *of*

● The cost of each chest X-ray examination was assumed to be $15,

350 X-ray examinations revealed a clinically consequential finding which could not have been anticipated on the basis of the clinical history and examination (38). To make sense of these results, one would need to know whether the clinically significant finding had an impact on mortality or morbidity,

In summary, the studies of chest X-ray screening in selected patient populations reveal wide interinstitution variation in diagnostic yield for similar types of patients and general use of an informative but incomplete evaluative measure—the diagnostic yield—as the basis for inferences about the appropriate place of chest X-ray in medical practice. It is no wonder, then, that this literature has had relatively little impact on routine X-ray policies of hospitals.

Studies of Patient Management and Followup

How often should a patient with a cardiopulmonary disease be X-rayed for purposes of monitoring patient progress? To our knowledge, this question has been addressed only in the case of tuberculosis and pneumonia.

The issue for tuberculosis has been framed in terms of the need for periodic radiographic and sputum examination in TB patients who have completed a program of modern chemotherapy. The diagnostic yield of TB on recalled patients was found to be negligible in three studies (2,6,33), leading the Center for Disease Control and the American Thoracic Society in 1974 to recommend against such a policy (5,25).

The annual number of hospital discharges for pneumococcal pnemonia in the United States has been estimated at approximately 382,000 (31). If all such pneumonia patients were X-rayed one more time than is necessary over the course of the disease, **382,000** unneeded X-ray examinations would be conducted. Thus, the question of optimal frequency of X-ray followup has major cost implications.

Jay and his colleagues prospectively followed 80 consecutive patients admitted to a teaching hospital for acute bacterial pneumonia (65). Typically, these patients were subjected to chest X-ray examinations every 1 to 3 days in the hospital and every 2 weeks after discharge until radiographic abnormalities disappeared. In the 72 surviving patients, the standard radiographic signs of pneumonia had disappeared in all patients by the eighth week from admission, but after 4 weeks, 36 percent of radiographs were still positive for pneumonia, At 4 weeks, almost 50 percent of the radiographs showed some form of abnormality related to pneumonia, thus necessitating continued followup. The authors concluded that the appropriate interval for radiographic followup after diagnosis is once at the time of discharge from the hospital and subsequently at 6-week intervals.

A more recent study of radiographic followup of pneumonia in children up to 15 years of age showed that after 4 weeks 80 percent of the radiographs were normal, whereas complete resolution of radiographic findings occurred in all patients after 6 weeks. These authors also concluded that in the absence of persistent signs or symptoms, the interval between radiographs should be 6 weeks (52).

Studies of changes in diagnostic yield over time in followup examinations are productive in identifying areas where significant savings can occur. But as in other contexts, diagnostic yield must be interpreted cautiously. In the instance of pneumonia, evidence from the chest X-ray is not generally used to alter therapy except when symptoms persist over a long period of time. In other conditions, the chest X-ray may be critical for therapeutic decisions, and changes in the radiograph, while occurring in few patients, may be important signals for therapeutic strategy. Thus, in any study of chest X-ray as a followup test, the implications of normal or abnormal findings for therapy and outcomes must be understood and accounted for.

Studies of the Diagnostic Uses of Chest X= Ray

Under the auspices of the American College of Radiology, Lusted conducted a study of the information content of chest roentgenograms (and other X-ray procedures) in hospital emergency rooms (76). Information content was measured

by an index of the change in physicians' assessments of the probability of disease due to the chest X-ray. A large change in these subjective probability estimates would mean that the X-ray provided valuable diagnostic information. While the value of such information can only be assessed in terms of its impact on therapy and outcomes, its existence is a necessary condition for these ultimate results.

Before each chest X-ray procedure was performed, the ordering physician was asked to estimate the probability of the most significant disease and the most likely condition. After the physician had reviewed the chest X-ray, these probabilities were estimated again. Using a logarithmic index, the authors concluded that in about 90 percent of all chest examinations, these probabilities changed sufficiently to infer high information content. *

The study contained some serious design flaws. The selection of participating institutions and physicians was not random and may well have been seriously biased. When the ordering physician was asked to revise his initial probability estimates after the X-ray, he was reminded of his early assessment, thus probably strengthening an already existing bias toward large changes in probability assessments. The index of probability change used in the study is also difficult to interpret in terms of real gains in information.

Even with these problems corrected, the findings of the study would offer little in the way of information on the appropriate uses of chest X-rays in emergency rooms, because the results are aggregated across all presenting signs and symptoms. Whether chest X-rays overall provide much or little information is of no consequence, for the information content most likely varies widely among different kinds of patients seen in emergency rooms. The objective of evaluation is to discover which indications are justified and which are not.

This objective has been pursued in a recent study of symptomatic patients receiving chest X-rays in an emergency room (10). Over 1,100 consecutive patients presenting at an emergency ward with complaints related to the chest were followed prospectively. Their clinical signs, symptoms, and some risk factors were recorded, and the relationship between these findings and the X-ray results was studied. In patients over 40 years of age, 37 percent of X-rays taken in those with normal physical examinations showed acute radiographic findings such as enlarged heart, pneumonia, plural effusion, and congestive heart failure. In younger patients without positive clinical signs, only 4.8 percent of all X-rays had acute findings (most frequently pneumonia). If X-rays had been withheld from younger patients (under 40) with normal physical examinations, 16 percent of the X-rays would have been avoided, while approximately 1.5 percent of acute radiographic X-ray findings would have been missed. These cases (typical pneumonia) were clinically important, however, and the authors recommended that X-rays be provided if symptoms persist in the younger group.

The high yield of abnormal chest X-ray findings in symptomatic patients may explain why the use of chest X-rays in this patient group is not controversial. The seriousness of some findings and the importance of therapy to the outcome of diseases like pneumonia justify the presumption that the benefits in lives saved or reduced morbidity outweigh the cost of X-rays, particularly in older patients with chest complaints who present at emergency rooms.

Studies of Radiological Method

Potential variations in radiological method can affect diagnostic efficiency, diagnostic yield, costs, and outcomes to differing degrees for each diagnostic or screening application of the chest X-ray. The type of equipment and film used, the number of views taken, technician competence, number and competence of readers, and access of readers to patient information are all potentially important aspects of radiological method.

Because the way jn which these elements are combined is important in assessing the validity of an X-ray evaluation study, such information should always be given in the study results. Un-

*The computed index of information content was close to zero (absolute value less than 0.25) in 95 percent of all cases.

fortunately, this is not always easy. Retrospective studies often are unable to determine these elements from the medical record. Nevertheless, inherent in any evaluation study is the question of whether the results would have differed significantly had the method varied.

The question of radiological method has been addressed directly in a few studies. Sagel and his colleagues (105) investigated the usefulness of including the lateral view in addition to the frontal view in routine hospital admission chest X-ray examinations (105). In a retrospective study of over 10,000 chest X-ray examinations, the additional information provided by the lateral view was assessed. For patients between 20 and 39 years of age without reasonable possibility of chest disease, a potentially serious abnormality was seen only on the lateral view and not on the posteroanterior film in only one case **(0.05** percent). When chest disease was considered **a possibility**, the additional diagnostic yield uniquely contributed by the lateral film was 2 percent. In older patients (40 and above) with no suspicion of chest disease, the additional yield of the lateral field was 0.9 percent. The authors concluded that chest X-ray examinations with lateral views should be limited to older patients and those with a reasonable probability of chest disease.

One cannot assess the validity of this recommendation without knowing more about the implications for outcomes of the abnormalities uncovered, It must also be assessed in light of the question of the need for a chest X-ray at all in routine hospital admissions.

The optimal number of readers of chest X-ray films has been addressed by a number of authors, particularly those interested in the screening uses of chest X-ray (60). Radiological findings are interpretive; as such, they are subject to observer error both in false positives and false negatives. A false positive will entail additional followup and possibly even inappropriate therapy, whereas a false negative can deny or delay the initiation of needed therapy, Retrospective studies of TB X-ray screening programs showed that between 20 and 30 percent of positive cases were missed by single reading (60). Adding an independent second reader, however, increases the probability of false positives.

Inherent in any dual-reader configuration is the need to resolve disagreements, Arbitration, independent third reader with majority vote, “believe positive” or “believe negative” are examples of such rules. Hessel, Herman, and Swenson (60) have analyzed the effect of alternative methods for resolving reader disagreements on the ultimate accuracy of chest radiographs with two readers. Using the results of independent readings by eight radiologists on 100 randomly selected chest radiographs, accuracy increased from 43.3 percent with an individual reader to **50** to 54,7 percent under dual-reader systems with various schemes for resolving disagreements. Specific methods for resolving disagreements had differential effects on the false-positive and false-negative rates. Consequently, the best method of resolution would depend on the implication of each of these two kinds of errors on patient outcomes and costs.