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Improvement in Mammography Interpretation Skills in a Community Radiology Practice after Dedicated Teaching Courses: 2-Year Medical Audit of 38,633 Cases[1]

The authors conducted a complete audit of results of 38,633 mammographic examinations performed by 12 general radiologists during a 2-year period with a computerized reporting system. During this period, 11 group members attended 17 dedicated mammography courses. Audit results were analyzed for each radiologist and the entire group. In the 2nd year, the number of breast cancers diagnosed increased 50% (from 121 to 181), with a 6.5% increase in patient volume. Sensitivity increased from 80% to 87%, and there was no change in the positive predictive value of 32%. Median tumor size and node positivity decreased. Most major variables of population and technical factors were unchanged. Diagnostic approach was altered during the 2nd year, as shown by a 50% increase in the use of spot compression, magnification views, and sonography. Analysis of each radiologist's performance before and after attending mammography courses showed similar changes. These data suggest that dedicated mammography courses can help improve radiologists' performance and alter their interpretive approach.

Index terms: Breast neoplasms, diagnosis, 00.32 • Breast radiography, quality assurance, 00.11 • Cancer screening • Diagnostic radiology, observer performance

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THE success of mammography in the early detection of breast cancer and the resultant decrease in mortality (1–3) have presented radiologists with both a responsibility and a challenge. In 1987, our group of 12 general radiologists, aware of the need for improving the overall quality and efficiency of mammography in our practice, used several recommended methods (4–8) to meet that challenge; we obtained training in current mammographic image production and interpretation, improved the efficiency of image production and reporting systems, and evaluated our on-going performance by performing medical audits of mammography results.

The following is a summary of our implementation of the above methods and of the performance changes documented during the 2-year period after their introduction.

MATERIALS AND METHODS

Equipment

In February 1988, the beginning of the audit period, there were eight dedicated mammography machines (six screen-film units, two xeromamography units) in our four outpatient offices. Among the six screen-film units, three were LoRad MII units (LoRad Medical Systems, Danbury, Conn) and three were Mamex DC units (Technomed USA, Bay Shore, NY). All screen-film units were manufactured between 1986 and 1988. We used Xerox model 125 units (Xerox Medical Systems, Monrovia, Calif) for dedicated xeromammography. Both xeromammography machines were replaced with screen-film units (LoRad MII) in 1988, when 8% of examinations (1,562 of 18,706) were performed with the xeromammography units; no xeromammograms were obtained in 1989.

Dedicated processors that used an extended (3-minute) processing cycle (Kodak M-6 [Eastman Kodak, Rochester, NY] and Fuji 4200 [Fuji Medical Systems USA, Burbank, Calif]) were installed at the two busiest sites in 1987. Approximately 90% of all examinations were performed with dedicated extended processing; the remainder were performed with standard 90-second processing in shared processors. Processing was performed with standard chemistry at 95°F (35°C); no substantial change in film processing occurred after 1987.

Commercial single-emulsion mammography films (Kodak S0-177; Microvision, Dupont, Wilmington, Del) were used during the study period. Standard screens and cassettes (Kodak MinR) were used.

Quality Assurance Standards

We followed American College of Radiology (ACR) quality assurance recommendations for film processing, phantom-image evaluation, and equipment testing (9,10). ACR accreditation was applied for in May 1989 and was received in February 1990.

Personnel and Training

Our practice is a multispecialty radiology group of 12 board-certified radiologists who work at three general hospitals and four outpatient offices. Before initiation of the study, the average individual experience in diagnostic radiology and mammography was 9.0 years and 7.8 years, respectively.

During the audit period, all radiologists attended at least one dedicated 3- or 4-day basic mammography course given by Laszlo Tabar, MD, or Wende Logan-Young, MD; some attended as many as four courses. Courses were 20–24 continuing medical education hours each. The month

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See also the editorial by Monsees (pp 30–31) in this issue.

Abbreviations: ACR = American College of Radiology, NMTR = New Mexico Tumor Registry.

Table 1
Examinations and Patient Population

Patient Characteristics	1988 No. of Examinations (n = 18,706)	1988 Percentage of Group	1988 Percentage of Total	1989 No. of Examinations (n = 19,927)	1989 Percentage of Group	1989 Percentage of Total
Asymptomatic	16,067	...	85.9	17,627	...	88.5
Had not previously undergone mammography	6,185	38.5	33.1	5,059	28.7	25.4
Had previously undergone mammography	9,882	61.5	52.8	12,568	71.3	63.1
Symptomatic	2,639	...	14.1	2,300	...	11.5
Had not previously undergone mammography	1,024	38.8	5.5	677	29.4	3.4
Had previously undergone mammography	1,615	61.2	8.6	1,623	70.6	8.1
Positive family history*	2,540	...	13.6	2,860	...	14.4
Personal breast cancer history	506	...	2.7	610	...	3.1

* Mother, sister, or daughter had breast cancer.

of attendance was recorded, as well as course level (eg, 1st, 2nd, 3rd, or 4th).

Thirteen mammography technologists were employed by the group during this time; all were registered by the American Registry of Radiology Technologists. One technologist attended a basic mammography course given by Wende Logan-Young, MD. All technologists received training in mammography from two of the authors (M.N.L., S.B.P.). Much of this training was performed in the 12 months preceding the audit. All technologists attended one afternoon training session about positioning with Laszlo Tabar, MD, in May 1988. Ten technologists performed mammography half-time, and three performed mammography full-time. No substantial changes in personnel occurred during the audit.

Computer System

We instituted a dedicated mammography computer system at the beginning of the audit on February 6, 1988. Each audit lasted 12 months, and the audit period concluded January 31, 1990. We designed the computer system by using models developed by Heilbrunn and Graves (11) and Sickles (5). The system utilizes a data sheet for patient, technologist, and radiologist input. These data are entered, and a computerized report is generated. Routine patient demographic information and risk factors are included. Symptomatic patients are defined as any patient with a breast symptom, which includes many patients with symptoms that have a very low cancer association, such as breast pain. A mammography interpretation score for each breast and the final overall recommendation are recorded by the radiologist.

We determined the number of total cases read, initial (baseline) and follow-up mammograms obtained, asymptomatic patients, symptomatic patients, patients with family history of breast cancer, patients with personal history of breast cancer, surgical consultations requested, magnification views requested, sonograms requested, 6-month follow-ups requested, cancers found, node-positive cancers, benign lesions found at surgery, and cancers missed for each radiologist and for the group. The distribution of the size of cancers found was also determined for the group.

Pathology Data

Follow-up of the patients for whom surgical consultations were recommended was obtained through the pathology reports from most of the major hospitals in the Albuquerque area, by direct follow-up with the referring physicians, or, occasionally, from the patients themselves. In addition, our computer-generated list of all mammography patients was matched with the New Mexico Tumor Registry (NMTR) list of patients with breast cancer by using patient name and birth date. All matches were manually checked for accuracy. The NMTR is a statewide population-based cancer registry that is a participant in the National Institutes of Health Surveillance Epidemiology End Results program. Cancer data are collected by NMTR personnel from all pathology laboratories in the state and then coded and stored in a computer data base. No follow-up was performed in patients with negative mammograms.

Tumor size and lymph node status were obtained from the pathology report or from data reported to the NMTR. These data were not available in approximately 15 cases; size was obtained in these cases by measuring the tumor on the mammogram.

Statistical Methods

Data from both years were compared by using tests for the difference between two binomial proportions. Changes in the mammography work-up patterns were assessed with the χ^2 test for homogeneity and the Cochran-Armitage test for trend.

All statistical computations were performed with programs of the Statistical Analysis System (SAS Institute, Cary, NC). Definitions of statistical terms used during the audit are as follows.

In a true-positive case, a breast cancer is diagnosed within 12 months after surgical consultation is recommended on the basis of abnormal mammographic findings in that breast.

In a true-negative case, the mammogram is interpreted as normal, and there is no known cancer diagnosis through the NMTR or other source within 12 months of mammography.

In a false-negative case, a breast cancer is diagnosed within 12 months after a negative mammogram (ie, one in which no surgical consultation was recommended).

In a false-positive case, benign disease is found at biopsy within 12 months after recommendation for surgical consultation on the basis of abnormal mammographic findings in that breast.

Sensitivity is the probability of detecting a breast cancer when a cancer exists. Only cancers found within 12 months of mammography were included in this evaluation. Because follow-up with the NMTR data and access through physicians and local pathology laboratories were virtually complete, sensitivity was not otherwise corrected, and was calculated as $TP/(TP + FN)$, where TP is the number of true-positive cases and FP is the number of false-positive cases.

Positive predictive value is the percentage of biopsies that were positive for cancer when performed within 12 months of obtaining an abnormal mammogram (request for surgical consultation). Positive predictive value was calculated as $TP/$(number of biopsies) or $TP/(TP + FP)$. We included only patients who underwent biopsy in our analysis of positive predictive value.

All cases (true-positive and false-negative) were found by means of the NMTR match. Cases without biopsy results were not included in the above calculations.

Table 2
Biopsy Results

	No. of Examinations			
	1988 (n = 18,706)	1989 (n = 19,927)	Increase (%)	*P* Value*
Surgical consultations recommended	461 (2.46)	668 (3.35)	36	<.001
Biopsy performed	368 (1.97)	570 (2.86)	45	<.001
Cancers found at biopsy	121 (0.65)	181 (0.91)	40	.004

Note.—Numbers in parentheses are percentages.
* Determined with two-sided test for difference between the percentages for both years.

Table 3
Comparison of Tumor Size, Nodal Status, Sensitivity, and Positive Predictive Value

Parameter	1988	1989	Change (%)	*P* Value*
Average tumor size (cm)	1.72	1.57	−9	...
Median tumor size (cm)	1.5	1.2	−20	.1802
Minimal cancers (%)†	36	41	+14	...
Node-positive cancers (%)	26	18.5	−29	.131
No. of true-positive cases	121	181	+50	...
No. of false-negative cases	30	27	−10	...
Sensitivity (%)	80	87	+9	.053
Positive predictive value (%)	33	32	...	...

* Determined with two-sided test for difference between medians or percentages for both years.
† Cancer is less than 1 cm in diameter or is in situ.

Table 4
Biopsy Rates for Asymptomatic and Symptomatic Patients

	No. of Patients		
Patient Characteristics	1988	1989	Increase (%)
Symptomatic	16,067	17,627	
Surgical consultations recommended	282 (1.76)	433 (2.46)	40
Cancer found at biopsy	77 (0.48)	110 (0.62)	30
Asymptomatic	2,639	2,300	
Surgical consultations recommended	179 (6.78)	235 (10.22)	51
Cancer found at biopsy	44 (1.67)	71 (3.09)	85

Note.—Numbers in parentheses are percentages.

RESULTS

The number of mammograms obtained increased 6.5% between 1988 and 1989, from 18,706 to 19,927 (Table 1). The proportion of asymptomatic versus symptomatic patients (Table 1) and the distribution of patient ages at mammography were very similar for both years. Mean patient ages were 52.4 years and 52.6 years (standard deviation, 13.2 and 13.1 years) for 1988 and 1989, respectively.

The percentage of asymptomatic patients who had previously undergone mammography increased from 62% to 71% between the 1st and the 2nd year. The percentage of symptomatic patients who had previously undergone mammography increased similarly, from 61% to 71%. The percentage of patients with a positive family or personal history of breast cancer showed little difference between 1988 and 1989 (Table 1).

There were no important changes in the distribution of individual radiologist's share of the mammography work load during the time studied. In both years, the same two radiologists shared 38% of the work load, and the other 10 shared the remaining 62%, with none of the others exceeding 12% of the total work load.

With the follow-up methods described earlier, we obtained biopsy results in 938 of the 1,129 patients (83%) in whom surgical consultation was recommended (Table 2). Of the remaining 191 patients, 128 elected to undergo follow-up or refused biopsy and did not have a known diagnosis of cancer made within the next 12 months. The remaining 63 patients were lost to follow-up. Given the role of the NMTR, it is unlikely that many cancers were excluded because cancers would be missed with the audit only if the biopsy was performed out of state or if the patient's name changed.

Although the number of patients was comparable for both years, the number of surgical consultations recommended increased significantly ($P < .001$) and the proportion of patients found to have cancer increased 40% ($P = .004$) in the 2nd year (Table 2). Additionally, tumor size and the percentage of tumors with positive nodes decreased, with median tumor size for all cases decreasing from 1.5 cm in 1988 to 1.2 cm in 1989 ($P = .18$). The number of minimal tumors (in situ cancers and those smaller than 1 cm) increased over this time by 14% (Table 3).

The radiologists' sensitivity improved as well, increasing from 80% in 1988 to 87% in 1989 ($P = .053$) (Table 3), while positive predictive value changed very little, remaining around 33% (Table 3). The number of false-negative cases decreased 10%, from 30 to 27. All false-negative cases were identified from the NMTR match; in most cases, this was the only source of false-negative information. The median tumor size in false-negative cases was 1.5 cm in both 1988 and 1989. This was slightly larger than the median size in the true-positive group (1.2 cm) in 1989 and the same as that of the true-positive group in 1988.

The data for asymptomatic patients showed similar trends. The rate of cancers detected in the asymptomatic patients increased 30%, from 0.48% to 0.62% (Table 4). This increase occurred both in patients who had and had not previously undergone mammography (Table 5).

The median tumor size in asymptomatic patients decreased from 1.20 cm in 1988 to 0.90 cm in 1989 ($P = .01$), and the percentage of node-positive cancers decreased from 12.5% in 1988 to 5.7% in 1989 ($P = .09$) (Table 6). Minimal cancers constituted 62% of all cancers in asymptomatic patients in 1989, a 24% increase from 1988.

Attendance records from mammography courses showed that before the audit began, four radiologists had attended one basic course and one had attended a more advanced course. By October 1989, 21 months into the audit, all 12 radiologists had attended a basic course; six had attended a second, more advanced course; and two had attended at least two, more advanced courses. Radiologists attended a total of 22 courses by the end of the audit.

The composite of the number of cancers found per 1,000 cases read by all radiologists before any mammography course was attended was compared with the number of cancers found after attending one course, two courses, and three or more courses. The results showed a steady upward trend, from 7.35 cancers found per 1,000 cases read before attendance at any mammography course to 11.26 cancers found per 1,000 cases read after attendance at three or more mammography courses ($P = .04$). This last group consisted of only two radiologists.

Diagnostic work-up patterns for the entire group also changed between the 1st and 2nd years, with the number of special views requested increasing 57% (from 3.6% to 5.6%), the number of sonograms obtained increasing 51% (from 5.1% to 7.7%), and the number of 6-month follow-up examinations requested decreasing by 17% (from 3.5% to 2.9%) (Table 7).

Additionally, individual changes in the diagnostic work-up patterns of each radiologist were quantified before and after attendance at each mammography course. Six of the 11 radiologists for whom there was sufficient data for evaluation demonstrated a statistically significant change in their work-up pattern (P values ranged from $< .001$ to .034), with increases in the numbers of spot magnifications, other views, and sonograms requested. The group as a whole also showed substantial changes after course attendance: recommendations for further work-up increased from 2.8% of all cases before course attendance to 8.7% after attendance of two or more courses ($P < .001$).

Table 5
Cancers Found at Initial and Follow-up Mammography in Asymptomatic Patients

	No. of Patients			
	1988	1989	Increase (%)	*P* Value*
Initial examination	6,185	5,059		
No. of cancers found	36 (0.58)	36 (0.71)	22	.41
Follow-up examination†	9,882	12,568		
No. of cancers found	41 (0.41)	74 (0.59)	42	.07

Note.—Numbers in parentheses are percentages.
* Difference between the percentages for both years, as determined with a two-sided test.
† Previous examinations had been performed, but not necessarily 1 year earlier.

Table 6
Comparison of Tumor Size and Nodal Status for Asymptomatic Patients

Parameter	1988	1989	Change (%)
Average tumor size (cm)	1.32	0.95	−28
Median tumor size (cm)	1.20	0.90	−25*
Minimal cancers (%)†	50	62	+24
Carcinoma in situ (%)	23	25	+9
Node-positive cancers (%)	12.5	5.7	−54‡

* $P = .011$, two-sided test.
† Cancer is less than 1 cm in diameter or is in situ.
‡ $P = .086$, two-sided test.

Table 7
Changes in Approach to Mammography Interpretation: Options Utilized

	No. of Cases		
	1988 ($n = 18{,}706$)	1989 ($n = 19{,}927$)	Change (%)
Extra views requested	668 (3.6)	1,120 (5.6)	+57
Sonograms requested	961 (5.1)	1,552 (7.7)	+51
6-mo follow-up requested	664 (3.5)	580 (2.9)	−17
Surgical consultations requested	461 (2.5)	668 (3.3)	+45

Note.—Numbers in parentheses are percentages.

DISCUSSION

The possible explanations for these documented changes can be divided into five primary areas: better images, changes in screening population, random chance, factitious changes, and improved interpretation skills of radiologists. No substantial technical changes affecting image quality were instituted during this period that would account for the observed difference. Although technologists undoubtedly improved their positioning skills during this period, the major training period for the technologists preceded the audit period. The distributions of patient age and major risk factors (Table 1) were unchanged as well. Random chance seems unlikely, given the magnitude, consistency, and statistical significance of the changes observed.

Factitious changes that could account for increased cancers identified in the 2nd year include changes in the interpretive criteria of the pathologists and detection of incidental breast cancers unrelated to mammographic findings. When surveyed, the two groups of pathologists who performed more than 90% of the pathologic examinations during the study indicated that they had not knowingly changed their interpretive criteria during the study period. Greater detection of incidental cancers could not account for the 40% increase in cancers we detected in 1989; in an autopsy series with careful mammographic and pathologic examination, the rate of incidental breast cancer detected in New Mexico women was only 2% (12).

Therefore, improved radiologist interpretation skills stand out as the primary factor responsible for the increase in cancers detected; ongoing technical improvements probably played a secondary role. The improvement in interpretation and evaluation skills was not due to different radiologists interpreting the examinations the 2nd year, since there were no global changes in either the distribution of examinations among radiologists or in the radiologists involved.

Another possible explanation for improved skills is that there were more high-quality comparison mammograms obtained in the 2nd year that enabled improved diagnosis at follow-up. This may have played a small role, as suggested by the relatively larger percentage of cancers found in the group that underwent follow-up in the 2nd year (Table 5).

Increased experience also doubtless contributed to the results, as it does for radiologists and technologists throughout all areas of radiology (13). However, the likelihood that 1 more year of experience alone could account for such changes in our group of 12 radiologists and 13 mammography technologists seems small because the radiologists had an average of 7.8 years of prior mammography experience.

Other possible factors related to courses or experience also may have contributed to the increased cancer detection rate, including intramural learning through mammogram critiques among group radiologists, individual learning from the radiology literature, and devotion of more interpretation time to each mammogram. Although difficult to quantify, each may have complemented the overall ongoing education efforts.

Although the improvement in the image quality of comparison mammograms and more experience played a role, we believe the major factor leading to the observed improvement in cancer detection rate and the decrease in median tumor size and node positivity in the 2nd year was the radiologists' attendance at mammography courses. Although it was certainly not the only factor involved, this was the only major change that occurred between 1988 and 1989. Further strong support for such a conclusion comes from the statistically significant change in mammographic work-up patterns found in the majority of radiologists after attending a course. This change documents the direct influence of the courses, in which attendees are trained in the complete diagnostic work-up approach to mammographic abnormalities. Complete mammographic work-up through additional imaging evaluation is now widely utilized in the United States and Europe (14–20).

The improvement in interpretation we observed after course attendance was not a simple lowering of threshold but a fundamental change in interpretive approach to mammography. This is evidenced by the concomitant change in work-up patterns, the overall improvement in sensitivity, and the lack of a change in positive predictive value. If we had merely lowered our threshold for abnormal conclusions, we would have expected a decrease in positive predictive value; this did not occur. Furthermore, the increase in sensitivity was associated with diagnosis of tumors at an earlier stage.

The marked increase in the number of cancers found in the 2nd year, especially smaller, earlier stage tumors, strongly suggests that there was a more complete harvesting of prevalent tumors (those tumors present in the patient population before initial screening mammography) in the 2nd year of the study, thus generating more tumors than expected. One would expect this increase in cancer detection to continue only as long as the radiologists continue to improve their interpretive skills. After that point, the rate of cancers found at follow-up should approach the true incidence rate (the rate at which interval changes appear between initial and follow-up screening mammography), assuming that the patients undergo yearly follow-up examinations. Moreover, the rate of cancers found at initial screening mammography (the prevalence rate) should remain relatively constant at that point.

Surprisingly, there was little change in the rate or number of false-negative cases between the years. The increased number of cancers found in the 2nd year apparently was not derived primarily from fewer false-negative cases. The importance of this finding is unclear, as it is based on a small number being more susceptible to random fluctuation. However, if the rate of false-negative findings is unchanged when screening skills otherwise improve, there may be a type of cancer that is not found as early with screening mammography as with clinical examination. If this is the case, the sensitivity may level off or decrease over the next several years. Careful analysis of each false-negative examination and continued assessment of future data may yield a clear answer.

In conclusion, although many factors contributed to improvement of mammography skills, we believe that attendance at dedicated mammography courses was the major factor responsible for the improvement we observed in our detection of early, node-negative, potentially curable breast cancers. ■

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